DESIGN AND ANALYSIS OF AIR DISTRIBUTION DUCTING SYSTEM BY Mc QUAY DUCT SIZER

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***Abstract*: Air conditioning is the process of altering the properties of air (primarily temperature and humidity) to more comfortable conditions, typically with the aim of distributing the conditioned air to an occupied space such as a building or a vehicle to improve thermal comfort and indoor air quality. In the most general sense, air conditioning can refer to any form of technology that modifies the condition of air (heating, cooling, (de-)humidification, cleaning, ventilation, or air movement).**

Air-distribution systems include air handlers, ductwork, and associated components for heating, ventilating, and air-conditioning buildings. They provide fresh air to maintain adequate indoor-air quality while providing conditioned air to offset heating or cooling loads. Their many components need to operate in unison to properly maintain desired conditions. They use relatively large amounts of energy so applying smart operational strategies and good maintenance practice can significantly reduce energy consumption.

The key components of air distribution systems are:

- **Fan Coil Units / Air Handling Units**
- **Ducting System**
- **Diffusers**

Air distribution system performance can have a big impact on overall HVAC system efficiency. Therefore, air distribution systems face a number of mandatory measures and prescriptive requirements. Duct efficiency is affected different parameters like aspect ratio, location, insulation, leakages etc. The report furnishes in detail of the effect of these parameters and provides a detailed design of Air Distribution Ducting System with the help of Mc Quay Duct Sizer. The project further works on the routing of the ducting system for maintaining the flow of air in the entire building.

Index Terms: heating, cooling, (de-)humidification, cleaning, ventilation, Air Handling Units

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I. INTRODUCTION

In the present day, as the population increases the need for comfort also increases. The human being needs more comfort because of inferior environment (like light, sound, machine which produce heat). Sound, light and heat affect human comfort a lot. They may adversely affect the human comfort positively or negatively. Researchers suggest that, human body is used to be comfortable at a temperature of 22°C to 25°C. When the temperature of room is lower or higher than this temperature, than the human body feels uncomfortable. This is because, the human body is structured in a way that, it should receive a certain amount of light, failure to which it can cause sunburns and other skin conditions. Human Comfort represents a combination of temperature and humidity levels to attain human comfort. The outdoor conditions that prevail across different places in the world are not as suitable for the well-being of human, cold and humid climates prevail across the globe. Human comfort lists the design of indoor conditions i.e., temperature and relative humidity, which are the basis of design of an HVAC system for construction industry across the world. All types of buildings like residential, commercial and hospitals have different design conditions as per their application. There are many types of air conditioning system like window air conditioners, split air conditioners etc. but these AC's system are used in small room or office where cooling load required is low. When the cooling load required is very high like multiplex building, hospital etc. central AC's system is used. In central AC's system the cooled air is directly not distributed to the rooms. The cooled air from the air conditioning equipment must be properly distributed to rooms or spaces to be cold in order to provide comfort condition. When the cooled air cannot be supplied directly from the air conditioning equipment to the spaces to be cooled, then the ducts are installed. The duct systems convey the cold air from the air conditioning equipment to the proper air distribution point and also carry the return air from the room back to the air conditioning equipment for reconditioning and recirculation.

1.1 HVAC-HEATING, VENTILATION AND AIR CONDITIONING

HVAC (Heating, Ventilating, and Air Conditioning) refers to a process used to achieve Human comfort level from outdoor humid conditions. It refers to the equipment, distribution network, and terminals that provide either collectively or individually the Heating, Ventilating, or Air-Conditioning processes to a building. HVAC system design is a major sub discipline of Mechanical Engineering based on the principles of Thermodynamics, Fluid Mechanics, and Heat Transfer.

HVAC systems provide:
• Heating

• Cooling
• Air handling, Ventilation, and Air quality

HVAC systems have a significant effect on the health, comfort, and productivity of occupants. Issues like user discomfort, improper ventilation, and poor indoor air quality are linked to HVAC system design and operation and can be improved by better mechanical and ventilation systems. In existing buildings, envelope upgrades are often necessary to maximize comfort and energy efficiency, such as reducing envelope leakage.

The best HVAC design considers all the inter-related building systems while addressing indoor air quality, energy consumption, and environmental benefit. Optimizing the design and benefits requires that the mechanical system designer and the architect address these issues early in the schematic design phase and continually revise subsequent decisions throughout the remaining design process. It is also essential to implement well-thought-out commissioning processes and routine preventative maintenance programs.

To optimize the selection of efficient, cost-effective mechanical and ventilation systems, perform an energy analysis early in the process, during the schematic design phase. Several design and analysis software programs can provide building simulations on an hourly basis to predict the energy behavior of the building's structure, air conditioning system, and central plant equipment.
Following the whole building design approach will enable a reduction in HVAC requirements for new building construction. This design approach can save money and energy by reducing the size requirements of the HVAC system and its energy demand, while still meeting comfort requirements.

1.1.1 Heating
There are different types of standard heating systems. Central heating is often used in cold climates to heat private houses and public buildings. Such a system contains a boiler, furnace, or heat pump to heat water, steam, or air, all 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.

The system also contains either duct work for forced air systems or piping to distribute a heated fluid and 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 buried in the floor to give under-floor heat. In boiler fed or radiant heating systems, all but the simplest systems have a pump to circulate the water and ensure an equal supply of heat to all the radiators. The heated water can also be fed through another (secondary) heat exchanger inside a storage cylinder to provide hot running water.

Forced air systems send heated air through duct work. During warm weather the same ductwork can be used for air conditioning. The forced air can also be filtered or put through air cleaners.
Heating can also be provided from electric, or resistance heating using a filament that becomes hot when electric current is caused to pass through it. This type of heat can be found in electric baseboard heaters, portable electric heaters, and as backup or supplemental heating for heat pump (or reverse heating) system.

The heating elements (radiators or vents) should be located in the coldest part of the room, typically next to the windows to minimize condensation and offset the convective air current formed in the room due to the air next to the window becoming negatively buoyant due to the cold glass. Devices that directly vents away from windows to prevent "wasted" heat defeat this design intent. Cold air drafts can contribute significantly to subjectively feeling colder than the average room temperature. Therefore, it is important to control the air leaks from outside in addition to proper design of the heating system.

1.1.2 Cooling

Cooling refers to reduction of temperature level and it is achieved by a centralized or decentralized system using chillers. Chillers are heat exchangers which work on the concept of basic refrigeration cycle to produce chilled water. The chilled water is supplied to different air units which in turn use the coolness of water to supply the cool air. In an “Air-Water” system, both air and water are distributed to each space to cool the area. Air water systems use the beneficial features from all air and water systems. The energy is carried in the water that reduces the space and air is used primarily for ventilation.

Air-Water system rely on use of a dedicated outside air heating & cooling HVAC (AHU) unit with its own small duct system to introduce outside air to the various required spaces that are provided with water terminal delivery units. Two main delivery approaches are used in air-water systems, namely the fan-coil and the induction unit.

To warm air or water, energy in the form of heat must be added to it. The converse is also true to reduce the temperature of air or water as energy must be removed from it. The system which is used by the majority of air conditioning systems is based on the vapour compression cycle. A less common system is Absorption chilling.

1.1.3 Ventilation
Ventilating is the process of changing or replacing air in any space to control temperature or remove moisture, odours, smoke, heat, dust, airborne bacteria, carbon-dioxide, and to replenish oxygen. Ventilation includes both the exchange of air 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. Ventilation is used to remove unpleasant smells and excessive moisture, introduce outside air, to keep interior building air circulating, and to prevent stagnation of the interior air.

- Mechanical or forced ventilation:

Mechanical or Forced Ventilation is used to control indoor air quality. Excess humidity, odours, and contaminants can often be controlled through 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 exhaust to control odours and sometimes humidity.

- Natural ventilation:

Natural ventilation is the ventilation of a building with outside air without the use of a fan or other mechanical system. It can be achieved with opened windows or trickle vents when the spaces to ventilate are small in the architecture permits. In more complex systems warm air in the building can be allowed to rise and flow out through the upper openings to outside (stack effect) thus forcing 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 the occupants' comfort. In warm or humid months and in different climatic conditions, 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' fans, ducts, dampers, and control systems to introduce and distribute cool outdoor air when appropriate.

1.1.4 Air conditioning

A simple definition of air conditioning is the simultaneous control of temperature, humidity, air movement and the quality of air in space. The use of conditioned space determines the temperature, humidity, air movement, and quality of air that must be maintained. The primary function of air conditioning is to maintain conditions that are (1) conducive to human comfort and (2) required by a product, or process within a space. To perform this function, equipment of the proper capacity must be installed and controlled throughout the year. The equipment capacity is determined by the actual instantaneous peak load requirements and the type of control is determined by the conditions to be maintained during peak and partial load. Generally, it is impossible to measure either the actual peak or the partial load in any given space. These loads must be estimated. The term 'Refrigeration' may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. In other words, the refrigeration means a continued extraction of heat from a body whose temperature is already below the temperature of its surroundings.

For example, if some space (say in cold storage) is to be kept at -2°C (271 K), we must continuously extract heat which flows into it due to leakage through the walls and also the heat which is brought into it with the articles stored after the temperature is once reduced to -2°C (271 K). Thus in a refrigerator, heat is virtually being pumped from a lower temperature to a higher temperature. According to second law of Thermodynamics, this process can only be performed with the aid of some external work. Thus it is obvious that supply of power (say electric motor) is regularly required to drive a refrigerator. Theoretically, a refrigerator is a reversed heat engine or a heat pump which pumps heat from a cold body. The substance which works in a heat pump to extract heat from a cold body and to deliver to a hot body is called a Refrigerant. The application of air-conditioning for the industrial purpose has opened a new era in the air-conditioning industry. The air-conditioning commonly used now a day is for the preservation of food, automobiles, railways, jute, cloth industries and many others. Air conditioning is a field of work that never stagnates. Air-conditioning is commonly used to ease men's environmental problems on earth and in space. The very adverse problems of space environment are also successfully solved with the advanced knowledge of air-conditioning that has made the space travel successful.

The refrigeration system is known to the man since the middle of nineteenth century. The scientists of that time developed a few stray machines to achieve some pleasure. But it paved the way by inviting the attention of scientists for proper studies and research. They were able to build a reasonably reliable machine by the end of nineteenth century for refrigeration purposes. But with the advent of efficient rotary compressors and gas turbines, the science of refrigeration reached the stage for the cooling of storage chambers in which perishable foods, drinks and medicines are stored. The refrigeration has also wide applications in submarine ships, aircraft and rockets.

Air conditioning has got wide range of applications and it is very much essential in these days. Air conditioning is provided for some of the following reasons

- To improve productivity in offices and factories by maintaining comfort conditions to the people.
- To maintain comfortable conditions for working in hotels, labs, etc.,
- To avoid malfunctioning of some control panels in Electrical Control Buildings.
- To maintain pressure inside the premises for avoiding outside (dusty) air in to the room.
- To create healthy atmosphere inside the room by supplying fresh and filtered air into the room.
- To provide clean, filtered, healthy, comfortable conditions in hospitals etc.,

III. AIR DISTRIBUTION SYSTEM

The Air Distribution Systems are designed for providing a proper channel for the flow and required supply of air to each zones/spaces of the building as per the CFM requirement. The flow of air will initiate from the source of air, till the terminal location and then back forth through a different pathway to the source. The ducts play an important role for the distribution of air in an HVAC System.

III.1 DUCT

Ducts are conduits or pathways for the transport of conditioned air from and to the Air Handling Units such as AHUs, FCUs etc to the subjected area. In other words, ducts are used in HVAC to deliver and remove air. These include supply air, return air, fresh air and exhaust air.
A duct can be described as a device used to provide an isolation path to carry an item from one place to other place without bringing the product in contact with the atmosphere before the delivery point.

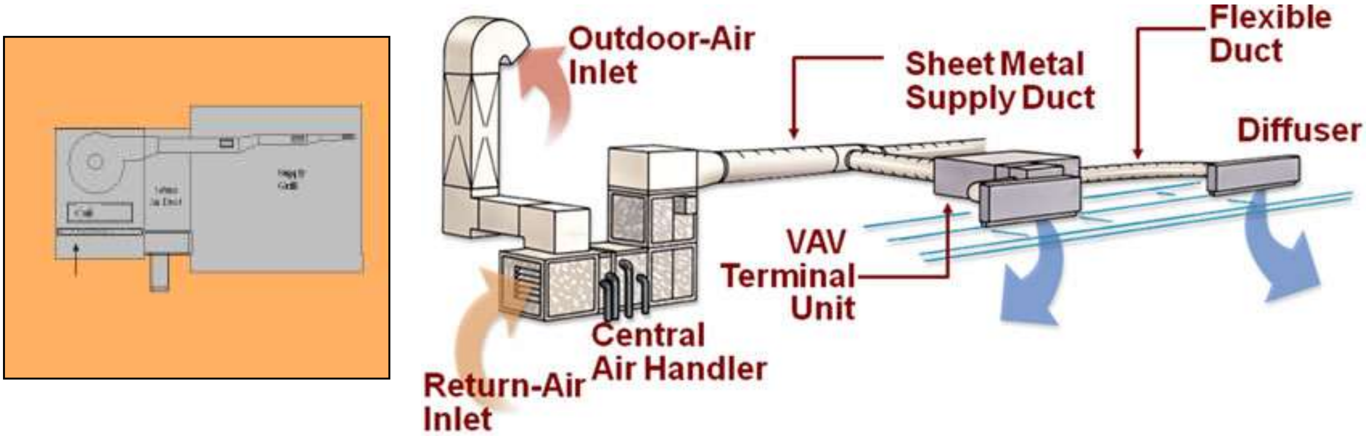


Fig 3.1 Air distributions System

Ducts are conduits or pathways for the transport of conditioned air from and to the Air Handling Units such as AHUs, FCUs etc to the subjected area. In other words, ducts are used in HVAC to deliver and remove air. These include supply air, return air, fresh air and exhaust air.
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.
Ducts can be made out of the materials like Galvanized mild steel is the standard and most common material used in fabricating ductwork. For insulation purposes, metal ducts are typically lined with faced fiber glass blanket (duct liner) or wrapped externally with fiber glass blankets (duct wrap). 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 reinsulated 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 degree, 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. A rigid phenolic insulation ductwork system is listed as a class 1 air duct to UL 181 Standard for Safety. Both polyurethane foam panels and phenolic foam panels are manufactured with factory applied aluminium facings on both sides. The thickness of the aluminium foil can vary from 25 micrometres for indoor use to 200 micrometres for external use or for higher mechanical characteristics. The finish for external ductwork exposed to the weather can be an aluminum or aluminium / zinc alloy coated sheet steel, a multilayer laminate, a fibre reinforced polymer or other waterproof coating. Fiberglass duct board panels provide built-in thermal insulation and the interior surface absorbs sound, helping to provide quiet operation of the HVAC system. The duct board is formed by sliding a specially-designed knife along the board using a straightedge as a guide; the knife automatically trims out a "valley" with 45° sides; the valley does not quite penetrate the entire depth of the duct board, providing a thin section that acts as a hinge. The duct board can then be folded along the valleys to produce 90° folds, making the rectangular duct shape in the fabricator's desired size. The duct is then closed with outward-clinching staples and special aluminum or similar 'metal-backed' tape. Commonly available duct tape should not be used on air ducts, metal, fiberglass, or otherwise, that are intended for long-term use; the adhesive on so called 'duct tape' dries and releases with time, further the 'duct tapes' do not meet the required UL standards for fire resistance. 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 ducting, usually made of special polyester material, fabric ducts can provide air to a space more effectively than a conventional exposed duct system. Fabric duct is a misnomer as "fabric duct" is actually an "air distribution device" and is not intended as a conduit (duct) for conditioned air. However, as it often replaces hard or metal ductwork it is easy to perceive it simply as duct. Fabric air dispersion systems, is the more definitive name. As they may be manufactured with venting or orifices for even air distribution along any length of the system, they commonly will provide a more even distribution and blending of the conditioned air in a given space. As "fabric duct" is used for air distribution, textile ducts are not rated for nor should they be used in ceilings or concealed attic spaces. Applications for fabric duct in raise floor applications; however, are available. Depending on the manufacturer, "fabric duct" is available in standard and custom colours with options for silk screening or other

forms of appliques. "Fabric duct", depending on the manufacturer, may be available in air permeable(porous) or non-porous fabric. As a benchmark, a designer may make the determination of which fabric is more applicable by asking the question if the application would require insulated metal duct? If metal duct would be insulated in a given application or installation, air permeable fabric would be recommended as it will not commonly create condensation on its surface and can therefore be used where air is to be supplied below the dew point. Again; depending on the material and manufacturer, material that eliminates moisture may also be healthier and may also be provided with an active anti-microbial agent to inhibit bacteria growth. Porous material also tends to require less maintenance as it repels dust and other airborne contaminants.

- Supply Air: it is defined as the conditioned air being supplied from the air conditioner outlet. This air is treated air &contains all the desired qualities as provided by the air conditioning system.
- Return Air: It is defined as the air being supplied back to the air conditioner from the air conditioned area. This air is returned back to the air conditioner after being circulated in the conditioned area.
  Return air path should be 1.25to 1.5 times the supply air path.
- Fresh air: It is defined as the ambient air being supplied to the air conditioner inlet from the outside atmosphere; this air is supplied to the air conditioner inlet from the outside atmosphere after being initially treated.

3.2 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

a) Round Duct:
Advantages:
- Lowest friction
- Less material required for fabrication

Disadvantages:
- Height required to install round Duct is more.

b) Square Duct:
Advantages:
- Less friction as compare to rectangular duct.
- Less material required for fabrication as compared to rectangular duct.

Disadvantages:
- Height required to install square Duct is more as compared to rectangular duct

c) Rectangular Duct:
Advantages:
- Height required to install duct is less.
- Easy to fabricate at site.

Disadvantages:
- Friction is more in rectangular duct as compared to round and square duct.

3.3 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

3.4 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 subdivide 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.

3.5 DUCT MATERIAL

The ducts are usually made from galvanized iron sheet metal, aluminum sheet metal or black steel. The most commonly used duct material in air conditioning system is galvanized sheet metal, because the zinc coating of this metal prevents rusting and avoids the cost of painting. The sheet thickness of galvanized iron (G.I) duct varies from 26 gauges (0.55 mm) to 16 gauges (1.6 mm). The aluminum is used because if it's lighter weight and resistance to moisture. The black sheet metal is always painted unless they withstand high temperature.

Now-a-days, the use of non-metal ducts has increased. The resin bonded glass fiber ducts are used because they are quite strong and easy to manufacture according to the desired shape and size. They are used in low velocity applications less than 600 m/min and for static pressure below 5mm gauge. The cement asbestos ducts may be used for underground air distribution and for exhausting corrosive materials. The wooden ducts may be used in places where moisture content in the air is not very large. The following figure shows various air ducts:

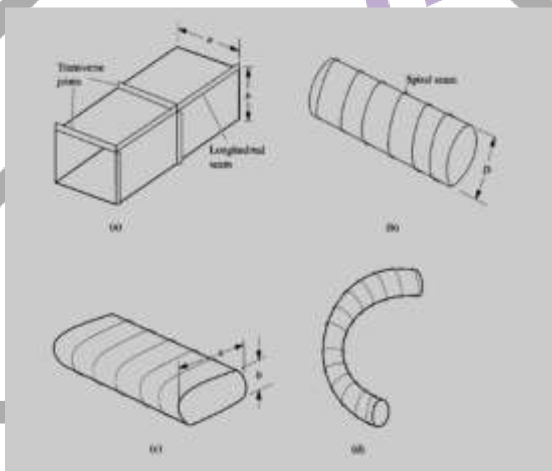


Figure 3.2 Various type of air duct:
(a) Rectangular duct; (b) round duct with spiral beam;
(c) Flat oval duct; (d) flexible duct.

IV.1 DUCT DESIGN PROCEDURE AND DUCT LAYOUT

a. 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.

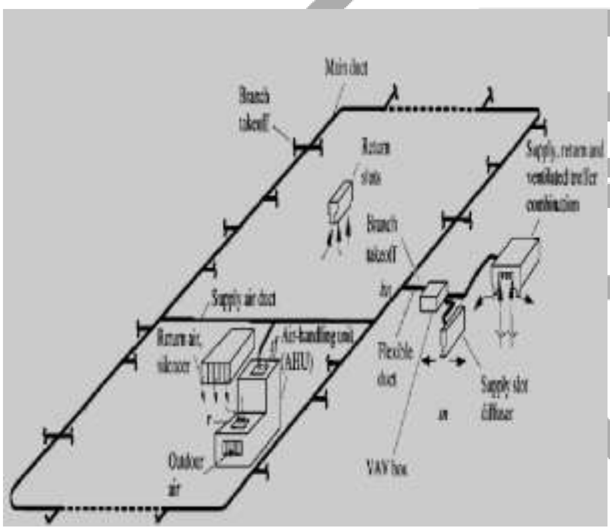


Figure A typical supply duct system with symmetric duct

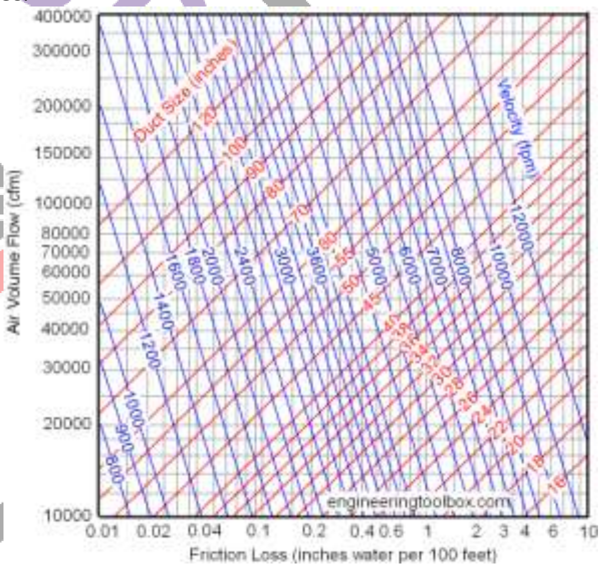


Figure Friction loss chart

Layout for a typical floor in a high-rise building.

IV.2 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. When sizing a duct system, the designer will usually choose a design friction rate. This is the desired friction loss in inches w.g. per 100 ft. of equivalent length (in. w.g./100 ft. E.L.) of duct. The design friction rate is generally determined based on the velocity of the air in the first section of ductwork. Most designers use a design friction rate somewhere between 0.08 and 0.10 in. w.g. per 100 ft. E.L.

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. Below table represent different velocity that we need to maintain inside the ducting system as per the project.

Table : Recommendation velocities for low velocity system

Application	Controlling Factor Noise Generation Main Ducts	Controlling Factor – Duct Friction			
		Main Ducts		Branch Ducts	
		Supply	Return	Supply	Return
Residences	600	800	640	600	500
Apartments, Hotel Bedrooms, Hospital Bedrooms	1000	1000	800	900	700
Private Offices, Directors Rooms, Libraries	1200	1400	1100	1200	1000
Theatres, Auditoriums	800	800	650	800	600
General Offices, High Class Restaurants, High Class Stores, Banks	1500	1600	1300	1200	1000
Average Stores, Cafeterias	1500	1800	1400	1400	1100

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

$0.5 \{(V_1^2 - V_2^2) / 2g\}$ 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.

5.3 SOFTWARE IMPLEMENTATION FOR DUCT DESIGN

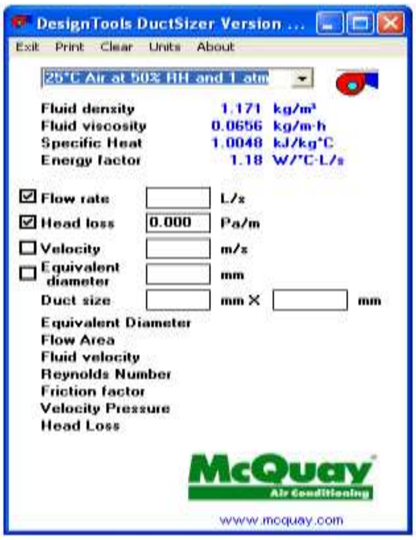


Figure: McQuay Software *FIG NO:5.2* *VIBRATION ISOLATOR*

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.

5.4 COMPONENTS OF DUCTING SYSTEM

Besides the ducts themselves, complete ducting systems contain many other components.

Vibration isolator

A duct system often begins at an air handler. The blowers in the air handlers can create substantial vibration and the large area of the duct system would transmit this noise and vibration to the inhabitants of the building. To avoid this, vibration isolators (flexible sections) are normally inserted into the duct immediately before and after the air handler. The rubberized canvas-like material of these sections allows the air handler to vibrate without transmitting much vibration to the attached ducts. The same flexible section can reduce the "bang" that can occur when the blower engages and positive air pressure is introduced to the ductwork.

Take-offs

Downstream of the air handler, the supply air trunk duct will commonly fork, providing air to many individual air outlets such as diffusers, grilles, and registers. When the system is designed with a main duct branching into many subsidiary branch ducts, fittings called take-offs allow a small portion of the flow in the main duct to be diverted into each branch duct. Take-offs may be fitted into round or rectangular openings cut into the wall of the main duct. The take-off commonly has many small metal tabs that are then bent to retain the take-off on the main duct; round versions are called spin-in fittings. Other take-off designs use a snap-in attachment method, sometimes coupled with an adhesive foam gasket to provide improved sealing. The outlet of the take-off then connects to the rectangular, oval, or round branch duct.



FIG NO: TAKE-OFFS **FIG.NO:**BOOTS **FIG NO:** VOLUME CONTROL DAMPER

Stacks, boots, and heads

Ducts, especially in homes, must often allow air to travel vertically within relatively thin walls. These vertical ducts are called stacks and are formed with either very wide and relatively thin rectangular sections or oval sections. At the bottom of the stack, a stack boot provides a transition from an ordinary large round or rectangular duct to the thin wall-mounted duct. At the top, a stack head can provide a transition back to ordinary ducting while a register head allows the transition to a wall-mounted air register.

Volume Control Dampers

Ducting systems must often provide a method of adjusting the volume of air flow to various parts of the system. VCDs (Volume Control Dampers - Not to Be confused with Smoke/Fire Dampers) provide this function. Besides the regulation provided at the registers or diffusers that spread air into individual rooms, dampers can be fitted within the ducts themselves. These dampers may be manual or automatic. Zone dampers provide automatic control in simple systems while VAVs allow control in sophisticated systems.

Smoke/Fire Dampers

Smoke and Fire dampers are found in ductwork, where the duct passes through a firewall or fire curtain. Smoke dampers are automated with the use of a mechanical motor often referred to as an Actuator. A probe connected to the motor is installed in the run of duct, and detects smoke within the duct system which has been extracted from a room, or which is being supplied from the AHU (Air Handling Unit) or elsewhere within the run. Once smoke is detected within the duct, the Actuator triggers the motor release and the smoke damper will automatically close until manually re-opened.

You will also find Fire dampers in the same places as smoke dampers, depending on the application of the area after the firewall. Unlike smoke dampers, they are not triggered by any electrical system, which is perfect in the event of an electrical failure where the Smoke dampers would fail to close. Fire dampers may be mounted in either horizontal or vertical configurations. Vertically mounted fire dampers are gravity operated while horizontal fire dampers are spring powered. In either case, a fire damper's most important feature is known as a fusible link. A fusible link is a piece of metal that will fail at a specified temperature allowing the damper to open under gravity or spring power, effectively sealing the duct, containing the fire, and denying it the necessary air to burn.




FIG.NO: Smoke Fire Dampers, Turning Vanes, Plenums, Air Terminals

Turning vanes

Turning vanes inside of large fire-resistance rated Durasteel pressurization ductwork.

Turning vanes are installed inside of ductwork at changes of direction in order to minimize turbulence and resistance to smooth air flow.

Plenums

Plenums are the central distribution and collection units for an HVAC system. The return plenum carries the air from several large return grills (vents) or bell mouths to a central air handler. The supply plenum directs air from the central unit to the rooms which the system is designed to heat or cool. They must be carefully looked at in ventilation design.

Terminal units

While single-zone constant air volume systems typically don't have them, other types of air distribution systems often have terminal units in the branch ducts. Usually there is one terminal unit per thermal zone. Some types of terminal units are VAV 'boxes' of either single or dual duct, fan-powered mixing boxes of either parallel or series arrangement, and induction terminal units. Terminal units may also include either, or both, a heating or cooling coil.

Air terminals

'Air terminals' are the supply air outlets and 'return' or 'exhaust air inlets'. For supply, diffusers are most common, but grilles, and for very small HVAC systems such as in residences, 'registers' are also used widely. Return or 'exhaust grilles' are used primarily for appearance reasons, but some also incorporate an air filter and are known as 'filter returns'.

Duct sealing

Duct Sealing is the sealing of leaks in air ducts in order to reduce air leakage, optimize efficiency, and control entry of pollutants into the home or building. Air pressure combined with air duct leakage can lead to a loss of energy in a HVAC system and duct sealing solves issues of energy loss in the system.
Before sealing duct work it is imperative to ensure the total external static pressure of your duct work and equipment will fall within your equipment manufacturer's specifications. If not, higher energy usage and reduced equipment performance may be expected.

Duct tape is not used for sealing ducts. Building codes call for special fire-resistant tapes, often with foil backings and long lasting adhesives.
Signs of leaky or poorly performing air ducts include:

- Utility bills in winter and summer months above average relative to rate fluctuation
- Spaces or rooms that is difficult to heat or cool
- Duct location in an attic, attached garage, leaky floor cavity, crawl space or unheated basement.

V. RESULTS & DISCUSSION

Proper duct design is important because delivering good airflow distribution will result in good temperature control, good air quality, no drafts (warm/cold pockets) and very importantly, a system that is as quiet as it possibly can be. Several key points must be remembered to achieve these results and please remember, this is not a comprehensive list, just several things we as a manufacturer have seen repeated often enough to write about.
The duct sizing done for the project is as shown in the drawings with a extra act to draw the entire ducting system for air distribution. The list of the drawing is given in Appendix I as given a t the end of the report.

S.NO	FLOOR NAME	DRAWING NAME	DWG NO:	FLOOR AREA
1	GROUND FLOOR	GROUND FLOOR DUCTING LAYOUT	DT-01	9500 Sq.Ft
2	FIRSST FLOOR	FIRSST FLOOR DUCTING LAYOUT	DT-02	9500 Sq.Ft
3	SECOND FLOOR	SECOND FLOOR DUCTING LAYOUT	DT-03	9500 Sq.Ft
4	ROOF FLOOR	ROOF FLOOR DUCTING LAYOUT	DT-04	9500 Sq.Ft

Table 6.1 Drawing Results with ducting

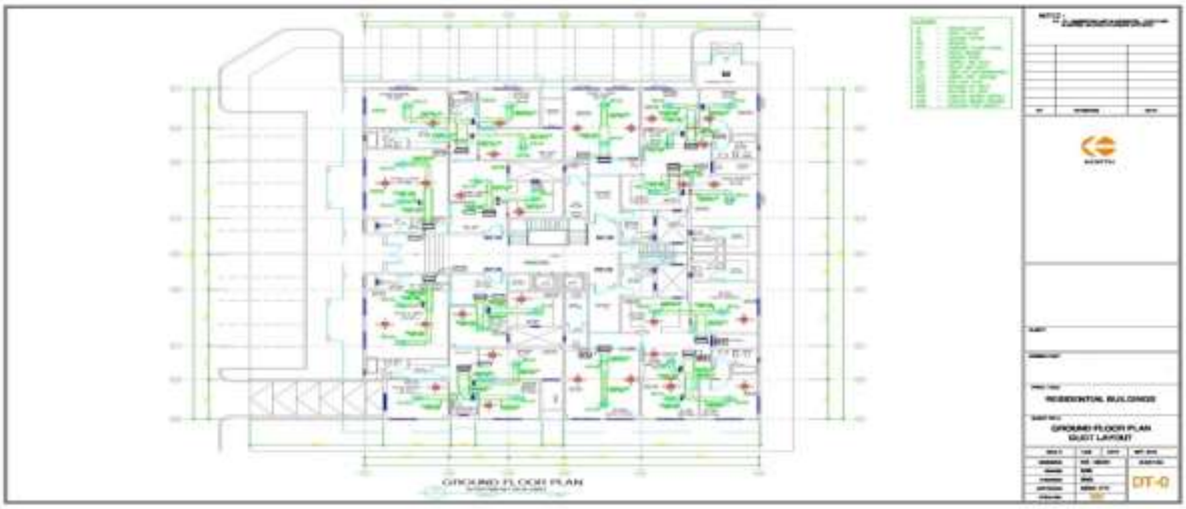
Design of the ducting system plays a major role in the efficient supply of air to each and every room space to maintain the HVAC system and to maintain the indoor conditions of the building space. Some of the good practices that can be adopted while designing are:

- Sound: Everyone wants equipment that can't be heard and for the equipment to operate at its optimal sound level. To do this, the duct distribution must be designed properly. To maintain proper sound levels, the plenum and main trunk line should be properly sized (Cfm-Velocity/Static Pressure) and acoustically lined. Options inside the duct are acoustic insulation or perforated liner.

- Velocity: To eliminate stratification, the branch ducts must be sized properly and the correct diffuser/grille must be selected. Always check the neck size, face size, neck Velocity, Cfm, NC and throw (with regards to your ceiling height).
- CFM/Circulation: The amount of total CFM should be at least 1 Cfm per 10 CuFt. of air space.
- Ventilation: The National building code calls for a capacity of 450 Cfm and maintain CO2 levels below 1000ppm or no more than 600ppm above ambient. To ventilate efficiently, design mechanical equipment with multispeed Energy Recovery Fans and monitor/ control CO2 levels by varying ventilation rates.

7. ANALYSIS: -
Case 01: - Consider Room GF-003 required 370 L/s of cool air for thermal comfort of human being. For designing the duct size, consider 0.7 Pa/m head loss or friction loss in duct and we get the following result:-

RESULT:-
From the above analysis, we found that when we increasing the head loss or friction loss in duct for same flow rate, velocity is increasing and because of increasing in velocity the equivalent diameter of duct decreasing. So head loss or friction loss plays a vital while designing ducting system. We need to maintain a proper head loss while designing duct for air distribution.



VI CONCLUSION

The Design of an Air Distribution Ducting System is a major component while designing a Centralized Air-Conditioning System for any Residential or Commercial building done as per the standards of ASHRAE & SMACNA. The project report concludes that;
- The main motive of design of a Ducting system for the building industry purely depends on the Human Comfort values, should be maintained irrespective of location of the project.
- The Duct designing is usually done as per SMACNA Standards, providing the most economical and effective routing to deliver the cool air with least losses.
- Aspect ratio, economical designs are the two major factors driving the final selection of type and size of the ducting as per the air supply required.

Thus the Project Report clearly identifies the requirements of the project and provides an effective way of Air-Conditioning to achieve Human comfort for the occupants. The design and drawings as approved will be sent to the site installation process. Therefore, the project defines the requirement and process of achieving the Human Comfort and Environment.
The following conclusion summarizes the design work presented in this thesis: -
1. The duct design for apartment building is done, by using equal friction method. All values are comparable with duct software called ductulator.
2. The calculated value of frictional is less or near as calculated by software. Due to less value of friction drop, duct sizes are increased but loss in total pressure (i.e. static pressure, velocity pressure) can be avoided.
3. Due to increased duct size the use of damper may be decreased.
4. Pressure loss in duct fitting can be minimized by proper design the elbow shape.

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