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# DESIGN OF DUCT FOR A THREE STOREY RETAIL SHOP

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**Abstract** - *In this paper importance of duct designing has been analyzed which create an impact on system performance. In this a duct system for a three storey retail shop has been designed, the main purpose of this is to make proper calculation of supply air quantity and to decide size of duct by using Equal Friction method so person in the shop can feel comfortable. In equal friction method, the frictional pressure drop per unit length of the duct is maintained constant throughout the duct system. This paper attempt to formulate a methodical approach to select the perfect duct design for a given situation.*

**Key words:** Duct design, Equal Friction Method

## 1. Introduction

In the present day, 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. The field of air conditioning design is more technologically challenging than ever before. Today the emphasis is no more on understanding air conditioning 'products' but on creating 'solutions' and not just solutions , but 'customized solutions'. One of the important modules in the process is the duct design. The efficient duct design process enables the proper supply of air quantity, equal distribution of air at every corner of the Air conditioned space.

The efficiency of air distribution systems has been found to be 60-75% or less in many houses because of insufficient and/or poorly installed duct insulation and leaks in the duct system. Properly designed and installed duct systems can have efficiencies of 80% or more for little or no additional cost. Duct systems that are undersized, are pinched, or have numerous bends and turns may lead to low air flow rates and high air velocities. Low air flow rates cause the heating and cooling equipment to operate inefficiently and the high air velocities increase noise.

A three storey retail shop has been selected for calculation of cooling loads on the basis of floor area, temperature of heat sources, humidity, climate structure, occupancy and location. These results will help in determining the duct design. The rectangular cross-section of the duct is selected as they are easy to fabricate.

## 2. Duct Sizing

The main goal of designing HVAC duct systems is to use the lowest cost (read smallest) duct sizes that can be used without violating certain sizing constraints. First and operating cost considerations in dictate that duct systems should be designed to operate at the lowest possible static pressure. The most widely used method to size duct is constant friction loss method. The other methods are velocity reduction method and static regain method.

### 2.1 Equal friction method

Duct systems in small buildings are generally sized using the equal friction or modified equal friction method. The equal friction method, as its name implies, is based on maintaining the same pressure drop per unit of duct length (or friction rate) throughout the system. The duct size is based on the flow rate through a particular section of duct, and design value for the friction rate. Each section is sized using the design friction rate criterion, and the total pressure drop for each run is simply the sum of the pressure drop of each individual section. The duct sections pressure drop includes straight duct friction loss, pressure losses through fittings such as elbows, takeoffs, and registers and /or diffusers. In the sections entering and leaving the HVAC unit, pressure losses associated with the flow transitions entering the leaving the unit (the system effect) are also included. The unit fan speed is selected to provide the design cfm and produce enough pressure difference to overcome pressure losses in the supply and return branches having the greatest pressure drop. Note that duct systems designed using the equal friction method is not self-balancing. Balancing dampers must be installed in lower pressure loss branches to balance the system.

### 2.2 Velocity Reduction Method

The velocity criterion for sizing duct is fairly simple and straightforward. With this method, the ducts are sized fixing the speed in the duct immediately downstream from the delivery fan and empirically reducing this speed over subsequent duct trunks, normally close to each branch. Velocity limits are commonly used as a surrogate for limiting duct breakout noise. Many argue it is a poor indicator since noise is more likely to result from turbulence than velocity; e.g., a high velocity system with smooth fittings may make less noise than a low velocity system with abrupt fittings. Nevertheless, limiting velocity to limit noise is a common practice. It is important to consult with the project's acoustical engineer on this issue. Many rules-of-thumb for velocity limits exist depending on the noise criteria of the spaces served and the location of the duct.

### 2.3 Static Regain Method

This method refers to increase or regain of static pressure in the ductwork when the air velocity decreases. The Static Regain method of duct sizing is based on Bernoulli's equation, which states that when a reduction of velocities takes place, a conversion of dynamic pressure into static pressure occurs.

With this method, the air speed in the duct is reduced near each branch or diffuser so that the dynamic pressure conversion obtained exactly balances the pressure drop of the air in the trunk of the next duct. This means there is the same static pressure near all the branches and all the diffusers, thereby obtaining an intrinsically balanced air distribution system without having to use throttling devices.

Compared to the two previous methods, this method usually involves a larger surface area of the panels, but lower electric fan power and easier balancing of the plant.

## 3. Duct Design Criteria

Many factors are considered when designing a duct system.
a. Space availability
b. Installation cost
c. Air friction loss
d. Noise level
e. Duct heat transfer and airflow leakage

### 3.1 Steps in Duct Design

Following are the basic steps in Duct Design
a. First find out the air flow rate
b. Based on air flow rate select fan unit which is to be installed.
c. Select initial velocity [Main duct air velocity: -6 m/s, Branch duct air velocity: - 4 m/s
d. Duct area = Air flow rate/ Velocity
e. Determine Equivalent duct diameter and find Duct size/dimension from ASHRAE table for rectangular shape.
f. Then initial friction rate is determined by using equation on the basis of air quantity and equivalent duct diameter.
g. Determine the static and dynamic pressure drop for fittings from ASHRAE table for duct fitting codes.

## 4. Pressure Losses in Ducts

Pressure is lost due to friction between the moving particle of the fluid and the interior surfaces of a duct. When the pressure loss occurs in a straight duct, then this loss is known as friction loss. The pressure loss is due to the changes of direction of air flow such as bends, elbows etc. and at the change of cross section of the duct, this loss is known as dynamic losses.

The pressure drop due to friction is known as frictional pressure drop or friction loss, $\Delta p_f$. The pressure drop due to momentum change is known as momentum pressure drop or dynamic loss, $\Delta p_d$. Thus the total pressure drops $\Delta p_t$ is given by:

$$\Delta p_t = \Delta p_f + \Delta p_d$$

## 5. Dynamic Losses in Ducts

The dynamic losses are caused due to the change in direction or magnitude of velocity of the fluid in the duct. The change in the direction of the velocity occurs at bends and elbow. The change in the magnitude of velocity occurs when the area of duct changes i.e. enlargement, contraction, suction etc.

$$\Delta p_d = C\frac{\rho V^2}{2}$$

Where,
C is the dynamic loss coefficient, which is normally obtained from experiments. The values of C can be taken from ASHRAE table for various duct fittings.

## 6. Building Structure

The dimension of the building which is to be air conditioned is, 10.59×6.12 x 2.57 m in size. It has three floors including the ground floor. The exterior walls of building consist of 102 mm face bricks and 203 mm face brick with 15 mm cement mortar sand 6 mm plaster on each side. The roof consists of 102 mm HW concrete with 6 mm plaster& air gap with pop 457 mm below the slab. The front display glass consists of single glass materials of 12 mm thick with frame panel.

**Table - 1**: Summary of Building Specifications

| Item | Description | Ground Floor | 1st Floor | 2nd Floor |
|---|---|---|---|---|
| 1 | Total Interior Space (Volume) | 187.52 m² | 187.52 m² | 187.52 m² |
| 2 | Total Exterior Wall Area | 82.53 m² | 82.53 m² | 82.53 m² |
| 3 | Total Roof Area | 56.13 m² | 56.13 m² | 64.8 m² |
| 4 | Total Glass/ Window Area | 7.36 m² | 18.48 m² | 18.48 m² |

## 7. Duct Calculations

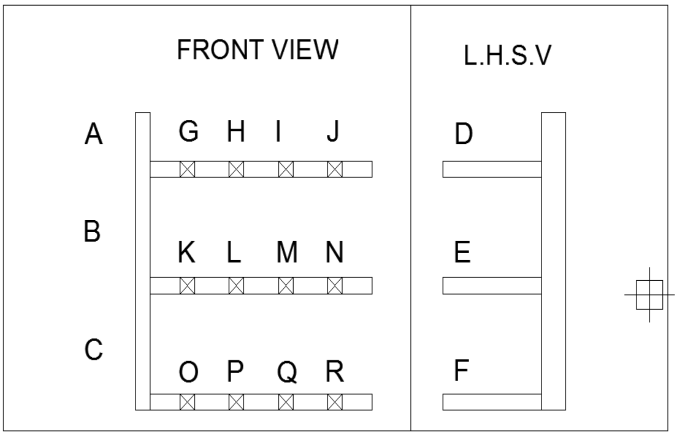


Fig – 1: Front view and Side view of duct layout.

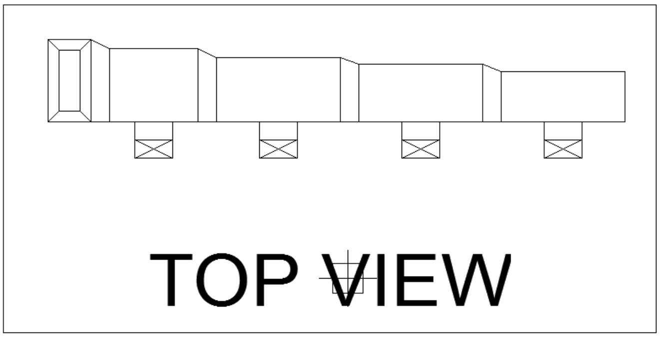


Fig – 2: Top view of duct for first floor

Supply Duct Calculations

The duct is to be designed for an evaporative cooler considering 22 air changes per hour in the space.

$$CFM = \frac{Volume\ X\ ACH}{60}$$

$$CFM = \frac{(34.75\ X\ 22.6\ X\ 8.42)X\ 3\ X\ 22}{60}$$

$$CFM = 7274\ f^3/min$$

$$Q_{air} = 3.43\ m^3/s$$

$$Q_{air} = 12360\ m^3/hr$$

Considering

Main duct air velocity: - 6 m/s

Branch duct air velocity: - 4 m/s

$$A_A = \frac{Q_A}{V_A} = \frac{3.43}{6} = 0.57\ m^2$$

Frictional pressure drop at section A is given by

$$\frac{\Delta P_f\ A}{L\ A} = \frac{0.022243\ Q_{air}^{1.852}}{D^{4.973}}$$

The frictional pressure drop for all sections should be same as 0.83 Pa/m for Equal Friction Method.

Hence,

$$\left(\frac{Q^{1.852}}{D_{eq}^{4.973}}\right)_A = \left(\frac{Q^{1.852}}{D_{eq}^{4.973}}\right)_B = \left(\frac{Q^{1.852}}{D_{eq}^{4.973}}\right)_C = \cdots$$

Equivalent diameter of Main Duct section $D_{eq}$ A

$$D_{eq}A = \left(\frac{0.022243\ Q_A^{1.852}}{\left(\frac{\Delta P_f}{L}\right)_A}\right)^{\frac{1}{4.973}}$$

$$D_{eq}A = 0.67\ m$$

$$D_{eq}A = 668\ mm$$

Rectangular duct dimensions for main duct

a=500 mm b= 750 mm

**Table - 2**: Frictional loss per unit length calculations

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Section | C | F | O | P | Q | R |
| | Ground Floor | $(\Delta P_f)$ C = 1.62 Pa | $(\Delta P_f)$ F = 1.49 Pa | $(\Delta P_f)$ O = 0.56 Pa | $(\Delta P_f)$ P = 0.74 Pa | $(\Delta P_f)$ Q = 0.74 Pa | $(\Delta P_f)$ R = 0.56 Pa |
| 2 | Section | B | E | K | L | M | N |
| | First Floor | $(\Delta P_f)$ B = 1.62 Pa | $(\Delta P_f)$ E = 1.49 Pa | $(\Delta P_f)$ K = 0.56 Pa | $(\Delta P_f)$ L = 0.74 Pa | $(\Delta P_f)$ M = 0.74 Pa | $(\Delta P_f)$ N = 0.56 Pa |
| 3 | Section | A | D | G | H | I | J |
| | Second Floor | $(\Delta P_f)$ A = 0.88 Pa | $(\Delta P_f)$ D = 1.49 Pa | $(\Delta P_f)$ G = 0.56 Pa | $(\Delta P_f)$ H = 0.74 Pa | $(\Delta P_f)$ I = 0.74 Pa | $(\Delta P_f)$ J = 0.56 Pa |

**Table - 3**: Air Flow Rate at Each Grill

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Section | C | F | O | P | Q | R |
| | Ground Floor | $Q_C$ = 1.144m³/s | $Q_F$ = 1.144m³/s | $Q_O$ = 1.144m³/s | $Q_P$ = 0.858m³/s | $Q_Q$ = 0.572m³/s | $Q_R$ = 0.286m³/s |
| 2 | Section | B | E | K | L | M | N |
| | First Floor | $Q_B$= 2.286 m³/s | $Q_E$= 1.144m³/s | $Q_K$ = 1.144m³/s | $Q_L$ = 0.858m³/s | $Q_M$ = 0.572m³/s | $Q_N$ = 0.286m³/s |
| 3 | Section | A | D | G | H | I | J |
| | Second Floor | $Q_A$ = 3.43 m³/s | $Q_D$= 1.144m³/s | $Q_G$ = 1.144m³/s | $Q_H$ = 0.858m³/s | $Q_I$ = 0.572m³/s | $Q_J$ = 0.286m³/s |

**Table - 4**: Calculated Dimensions of Ducts

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | Section | C | F | O | P | Q | R |
| | Ground Floor | a=400 mm b=450mm | a=400 mm b=450mm | a=400 mm b=450mm | a=300 mm b=450mm | a=225 mm b=450mm | a=150 mm b=450mm |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | Section | B | E | K | L | M | N |
| | First Floor | a=500 mm b=550mm | a=400 mm b=450mm | a=400 mm b=450mm | a=300 mm b=450mm | a=225 mm b=450mm | a=150 mm b=450mm |
| 3 | Section | A | D | G | H | I | J |
| | Second Floor | a=500 mm b=750mm | a=400 mm b=450mm | a=400 mm b=450mm | a=300 mm b=450mm | a=225 mm b=450mm | a=150 mm b=450mm |

For GI sheet, as duct material, the pressure drop per unit length is given by equation below

$$\frac{\Delta P_f A}{L A} = \frac{0.022243\ Q_{air}^{1.852}}{D^{4.973}}$$

The section A-B-C-F-O-P-Q-R after calculations is found to be index run.

Total static frictional pressure loss at A-B-C-F-O-P-Q-R

$$(\Delta P_f)_{A-R} = (\Delta P_f)A + (\Delta P_f)B + (\Delta P_f)C + (\Delta P_f)F + (\Delta P_f)O + (\Delta P_f)P + (\Delta P_f)Q + (\Delta P_f)R$$

$$(\Delta P_f)_{A-J} = 0.88 + 1.62 + 1.62 + 1.49 + 0.56 + 0.74 + 0.74 + 0.56$$

$= 8.21$ Pa.

Dynamic losses in section A-B-C-F-O-P-Q-R are Suction, 2 no. of Tee, 2 no. of Elbow, 3 no. of Contraction, 1 fire damper followed by Discharge.

Total Dynamic Pressure loss

$$(\Delta P)_{dy} = \Delta P_{tee} + \Delta P_{elbow} + \Delta P_{contraction} + \Delta P_{fire\ damper} + \Delta P_{suction} + \Delta P_{grill}$$

$$(\Delta P)_{dy} = 25.33 + 22.08 + 2.21 + 4.10 + 2.59 + 38.4$$

$= 94.71$ Pa

Pressure loss = Total static + Total dynamic

$= 8.21 + 94.71 = 102.92$ Pa

Pressure loss across the cooling pad

$(\Delta P_{cp})$= 55 Pa or 5.6 mm of wg

Total pressure loss = 102.92 +55

$$(\Delta P)_T = 157.92\ P_a$$

$$(\Delta P)_T = 16.10 \approx 16\ \text{mm of water gauge}$$

## Conclusion

For designing the duct, building cooling load and air flow rate is calculated and the duct design for building is done by using equal friction method. Frictional pressure drop are different for all three duct runs. Reducing trunk system is used for duct layout. The total pressure loss is calculated is 16 mm of $H_2O$ gauge, due to lower value of pressure loss fan power for circulation in duct will be small. Aspect ratio could not be maintained near to 1 since the duct is designed for height constraint of 18 inch due to the use of false ceiling. The loss through duct fittings is the major loss component (compared with the frictional loss) in our evaporative cooled air distribution system. The value of total pressure is critical since it affects fan selection of evaporative cooling system.

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