DESIGN OF CENTRAL AIR CONDITIONG SYSTEM FOR MIST TOWER BUILDING-2

A THESIS SUBMITTED TO THE DEPARTMENT OF "MECHANICAL ENGINEERING" IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

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SUPERVISOR CERTIFICATE

This is to certify that, Mashruf Ahmad Noman, Student ID: 201318041; Maimuna Torsa Rafique, Student ID: 201318051; Prionkari Banik Toma, Student ID: 201318064 have completed their thesis entitled **“DESIGN OF CENTRAL AIR CONDITIONG SYSTEM FOR MIST TOWER BUILDING-2”**under my supervision for partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering. To the best of my knowledge, this paper is their original work and was not submitted to elsewhere for any other purpose.

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ABSTRACT

In perspective of power consumption in the sector of energy in Bangladesh the central air conditioning system is a desirable solution nowadays. The purpose of this thesis is to design a central air conditioning system for Military Institute of Science and Technology (MIST) tower building-2. The suggested design includes cooling load calculation, duct design and the specification of system components (chiller, air handling unit etc.). The cooling load is calculated for individual classrooms, laboratories and departmental offices. The selection of ducting system consists of duct diameter, friction loss, air flow velocity and air flow rate passing through the ducts. The central air conditioning system will maintain a constant air temperature desired for human comfort for a defined space. This system can be efficiently maintained rather than a split or individual one. We are hoping that, this design will be productive for MIST in case of cost effectiveness and power consumption.

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Nomenclature

ASHRAE	- American Society of Heating, Refrigerating and Air-Conditioning Engineers
AHU	- Air Handling Unit
HVAC	- Heating, Ventilation and Air Conditioning
TETD	- Total Equivalent Temperature Difference
TFM	- Cooling Load by Transfer Function Method
CLTD	- Cooling Load Temperature Difference
Q_h	- Heat Transfer Rate
A	- Area
U	- Overall Heat Transfer Coefficient
TD	- Temperature Difference between Indoors and Outdoors
LM	- Latitude-Month Correlation
k	- Color Adjustment Coefficient
T_r	- Design Room Temperature
T_o	- Average Outdoor Temperature
f	- Attic Fan Factor
Q_{SHG}	- Solar Radiation Cooling Load
SC	- Shading Coefficient
SHGF	- Maximum Heat Gain Factor
CLF	- Cooling Load Factor
$Q_{appliances}$	- Cooling Load due to Appliances
Q_S	- Sensible Cooling Load due to Occupants
N	- Number of Occupants
G_S	- Sensible Heat Gain
Q_l	- Latent Heat Gain from Occupants
G_l	- Latent Heat Gain
T_{db}	- Dry Bulb Temperature
T_{wb}	- Wet Bulb Temperature
SHG	- Sensible Heat Gain
Q	- Flow Rate
ΔP	- Friction Loss

V	- Velocity
CFM	- Cubic Feet per Minute
D	- Duct Diameter
ρ	- Density of Air
C_0	- Coefficient for 90^o elbows
K_θ	- Angle Correction Factor
C_s	- Pressure Loss Coefficient for Diverging Tee in a Duct
C_b	- Pressure Loss Coefficient for Diverging Tee in a Duct
BPDB	- Bangladesh Power Development Board
TR	- Ton of Refrigeration

CHAPTER 1

INTRODUCTION

1.1 General

Central air conditioning system is one of the revolutionary attainments of modern engineering. Generally air conditioning is the process of removing heat from a confined space, thus cooling the air, and removing humidity. The process is used to achieve a better comfortable interior environment typically for humans. Though in common usage, air conditioning refers to system which cools air, in construction, a complete system of heating, ventilation, cooling and humidification.

Air conditioning system can be used to provide a clean, safe, hypoallergenic atmosphere. Excessive air conditioning can have a negative effect on skin, causing it to dry out and can also cause dehydration.

1.2 History of Air Conditioning System

The air conditioner is one of the most important inventions of modern times. In the 1840s, physician and inventor Dr. John Gorrie of Florida proposed the idea of cooling cities to relieve residents of "the evils of high temperature". He designed a machine that creates ice using a compressor powered by horse, water, wind-driven sails or stream. He successfully demonstrated the ice making machine in 1848 and was granted the U.S. patent for it in 1851. Due to the death of his chief financial backer, Gorrie was unsuccessful at bringing his patented technology to the marketplace.

The idea of artificial cooling went stagnant for several years until engineer Willis Carrier took a job that would result in the invention of the first modern electrical air conditioning unit. He designed a system that controlled humidity using cooling coils. He also devised and patented an automatic control system for regulating the humidity and temperature of air.

In 1931, H.H. Schultz and J.Q. Sherman invented the first room air conditioner. The unit sat on the ledge of a window, just as modern room air conditioners often do. Even so, these systems were still very expensive. For example, the 1938 Chrysler air conditioner cost $416; the average hourly wage was $0.64, so it took 650 hours of work to be able to afford this purchase.

Post WWII, air conditioning became something of a status symbol. Window units were a hot commodity, with over one million units sold in 1953. In the 1970s, central air conditioning systems made their way into homes, using Freon-12 (also known as R-12) as coolant.

Residential air conditioning has come such a long way in the past 100 years. Early air conditioners were loud, lacked efficiency and were expensive to operate. Today's air conditioning manufacturers have taken great strides to develop cooling technology that is efficient and convenient, providing consumers with seemingly endless equipment choices. Air conditioning has also become more environmentally friendly as research has shown that Freon is linked to ozone depletion; currently, R-22 refrigerant is being phased out and environment friendly R401A refrigerant is the new standard.

Air conditioning systems have become much more affordable over the years, leading to their widespread use in American homes. Today, more than 80 percent of homes in the United

States have an air conditioning system. The addition of the air conditioner has changed architecture, making it possible to have windowless buildings and dwellings without patios.

Air conditioning system didn't just change the nation's comfort; it has also played a significant role in lowering the number of heat-related deaths. Between 1960 and 2004, the number of heat-related deaths in the United States was a staggering 80 percent less than between 1900 and 1959. Air conditioning saves lives, providing respite from dangerous outdoor temperatures.

1.3 Objectives of Study

The main objectives of this thesis are-

- To introduce a central air conditioning system for MIST Tower Building-2.
- To design the duct of this system.
- To analyze the central air conditioning system with various aspects.

1.4 Overview of Study

- A complete idea of air conditioning system.
- A complete specification of different components of air conditioning system.
- A complete knowledge about the functions of components and working process of air conditioning system.
- Calculation of Cooling Load for MIST Tower Building-2.
- Design of Duct of the central air conditioning system.
- Selection of components.
- Analyze the system.

CHAPTER 2
LITERATURE REVIEW

2.1 Air Conditioning

The first functional definition of air-conditioning was created in 1908 and is credited to G. B. Wilson. It is the definition that Willis Carrier, the "father of air conditioning" subscribed to:

- Maintain suitable humidity in all parts of a building
- Free the air from excessive humidity during certain seasons
- Supply a constant and adequate supply of ventilation
- Efficiently remove from the air micro-organisms, dust, soot, and other foreign bodies
- Efficiently cool room air during certain seasons
- Heat or help heat the rooms in winter
- An apparatus that is not cost-prohibitive in purchase or maintenance

Air conditioning can refer to any form of technology that changes the condition of air - heating, cooling, (de-)humidification, cleaning, and ventilation or air movement. A complete system of heating, ventilation, and air conditioning is referred to as heating, ventilation, and air conditioning –HVAC.

2.2 Working Principle of Air Conditioning System

Air conditioners and refrigerators work the same way. Instead of cooling just a small, insulated space inside of a refrigerator, an air conditioner cools a room, a whole house, or an entire business.

Air conditioners work on reversed Carnot cycle.

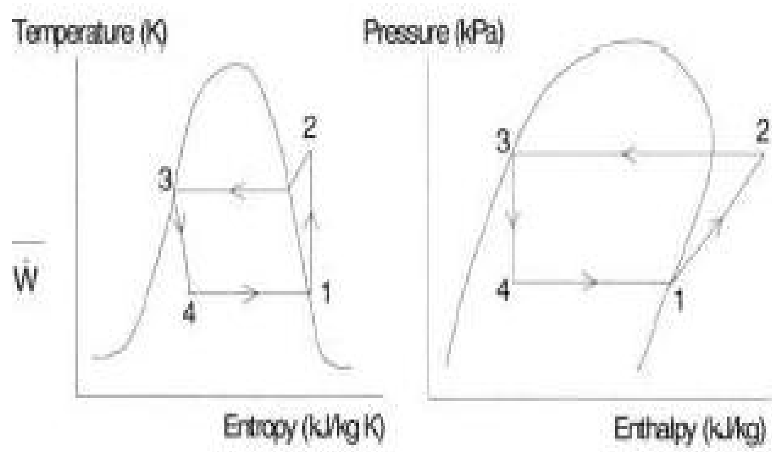

Fig 2.1: T-S and P-h Diagram

1-2: Reversible Adiabatic (Isentropic) Compression Process

2-3: Reversible Constant Pressure Heat Rejection Process

3-4: Irreversible Constant Enthalpy Throttling Process

4-1: Reversible Constant Pressure Heat Addition Process

Most air conditioning system has five mechanical components:

1. **Compressor**
2. **Condenser**
3. **Evaporator**
4. **Blower**
5. **Refrigerant**

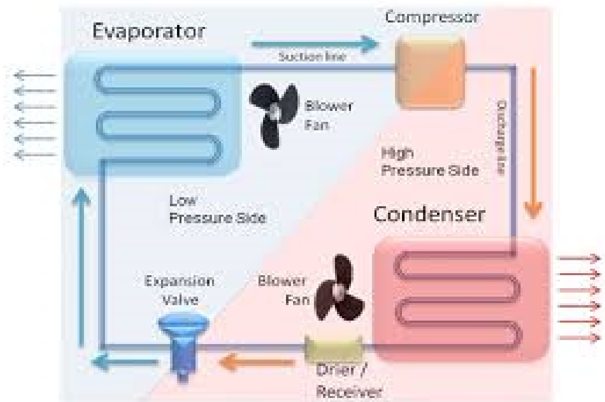

Fig 2.2: Working Principle of Air Conditioning System

Refrigerant is a medium of heat transfer which absorbs heat by evaporating at a lower temperature and gains up heat by condensing at a high temperature and pressure.

The compressor is the 'heart' of the system. It draws in low pressure and low temperature refrigerant in a gaseous state and by compressing the gas raises its pressure and temperature.

Then the gas flows to the condenser where the gas condenses to a liquid and gives off heat to the outside area.

The low pressure liquid then moves to the evaporator. As the liquid changes to gas and evaporates, it extracts heat from the air around it. The evaporator also has metal fins to help in exchange the thermal energy with the surrounding air.

When the refrigerant leaves the evaporator, it is a cool and low pressure gas which returns to the compressor to begin its trip all over again.

There is a blower connected to the evaporator which circulates the air inside the house. Hot air is lighter than cold air. Hence the hot air in the room rises to the top of a room.

There is a vent there where air is sucked into the air conditioner and goes down ducts. The hot air is used to cool the gas in the evaporator. As the heat is removed from the air, the air is cooled. It is then blown into the house through other ducts usually at the floor level.

This continues over and over and over until the room reaches the desired temperature. The thermostat senses that the temperature has reached the right setting and turns off the air conditioner. As the room warms up, the thermostat turns the air conditioner back on until the room reaches the temperature.

2.3 Types of Air Conditioning System

For different applications there are different types of air conditioning systems. Choosing which air conditioner is best for particular use depends on a variety of factors. Such factors include the size of the room to be cooled and the amount of heat normally generated in the space of concern.

Some types are:

- **Split System**
- **Heat Pump Unit**
- **Central Air Conditioning System**
- **Packaged Air Conditioner**
- **Portable Split System**
- **Portable Hose System**
- **Portable Evaporative System**
- **Window Air Conditioner**

2.3.1 Split or Ductless Air Conditioner

This system is called a 'split' system because it is made up of two units: one indoor and one outdoor. The former houses the evaporator and cooling fan. The later, meanwhile, houses the compressor, expansion valve, and condenser.

Modern split air conditioners do not take as much space as window units. These types are usually used in motels, hotels, and apartments to cool one or two rooms depending on its capacity.

Fig 2.3: Split or Ductless Air Conditioner

2.3.2 Heat Pump Unit

Heat pump is a variation of the traditional split system. During hot summer months, it pumps heat from the houses and releases it outside. In the season of winter, it extracts heat from the outdoor air and uses it to warm the house. Because of that, it can be used effectively for both heating and cooling in mild climates.

2.3.3 Central Air Conditioning System

This type of system makes use of a large compressor. Two separate packaged units are also used. The condensing unit is placed outside the establishment and contains the condensing fan, compressor, and condenser coil. The internal evaporative unit, consisting of the evaporator coil and expansion valve, is placed in the plenum of furnace. This unifies the ductwork of air conditioning and heating systems.

This type is best for large buildings, hotels, movie theatres, factories, and other bigger spaces. Fitting individual units like window air conditioners in each room of a big building can get super expensive. Having a central air conditioning system is the more practical choice when it comes to applications like this.

2.3.4 Packaged Air Conditioner

Packaged air conditioner combines the evaporator, condenser and compressor in a single unit. It is usually placed on the roof or on a concrete slab near the foundation. This type of air conditioner can be used in small commercial buildings.

Fig 2.4: Packaged Air Conditioner

2.3.5 Portable Split System

This is a variation of the unitary air conditioning system. This type has a mobile air conditioning system placed on the floor inside a room. It discharges exhaust heat through the exterior wall by means of a hose vent. While this type is noisier than other systems, it can cool even the most stubborn hot rooms.

Fig 2.5: Portable Split System

2.3.6 Window Air Conditioner

This type of unit is designed to cool a single room. In this air conditioner all the components, namely compressor, condenser, expansion valve or coil, evaporator and cooling coil are enclosed in a single box. This unit sits in the window. Because of this, it is not the most aesthetically pleasing option available. But to cool a single room, it is the most cost-effective option around.

This type is also referred to as a “unitary” air conditioning system. It blows out cooled air on one end (the one inside the room) and ejects heat on the other (the external end).

Fig 2.6: Window Air Conditioner

2.4 Overall Concept on Central Air Conditioning System

System in which air is treated at a central location and carried to and from the rooms by one or more fans and a system of ducts is called central air conditioning system.

Central air conditioners circulate cool air through a system of supply and return ducts. Supply ducts and registers (i.e. openings in the walls, floors or ceiling covered by grills) carry cooled air from the air conditioner to the particular space. This cooled air becomes warmer as it circulates through the space; then it flows back to central air conditioner through return ducts and registers.

The central air conditioning system is suitable for a large building which requires a very high air cooling system such as cinema, hotel, hospital, supermarket etc.

In central air conditioning system there is a plant room where large compressor, condenser, expansion valve and evaporator are placed. All of these perform all the functions of a basic refrigeration cycle. All these parts are larger in size and have higher capacities. Though the plant room is very noisy we get effective silence and highly effective air conditioning system in each room where outlets are being installed.

2.5 Main Components of Central Air Conditioning System

2.5.1 Chiller

Over 24 percent of energy in commercial building is used for heating, ventilation and cooling (HVAC). More than half goes to building cooling. Chillers are type of cooling equipment that produces chilled water to cool air. It is used to dehumidify air in commercial and industrial sites. A typical chiller is rated between fifteen to thousand tons (53KW to 3500KW) in cooling tower. Making cooling system as efficient as possible is an important component of reducing building operating costs and it addresses energy saving opportunities in chillers. Chillers can be air cooled or water cooled. Air cooled chillers is less efficient in heat rejection than water cooled chiller. In central air conditioning system, it is simpler to have the refrigerant unit located at one place and conditioned air by distributing water.

Fig 2.7: Chiller

The heart of central air conditioning system is the chiller. Four different types of chiller are listed below:

1. **Reciprocating Chiller**
2. **Centrifugal Chiller**
3. **Screw Chiller**
4. **Absorption Chiller**

A chiller basically consists of condenser, compressor, expansion valve and evaporator. A compressor is used to compress the refrigerant gas to a higher temperature. The heat is dissipated to the outdoors through cooling towers or fans. The hot gas is dissipated to the outdoors through cooling towers or fans. Then it reverts back to a liquid state after cooling. Liquid is led through a valve or orifice. This liquid becomes expanded in volume after passing through this restriction. The expansion through valve brings about a cooling effect. Heat is absorbed when liquid becomes a gas. This cooling effect is used to cool chilled water through a heat exchanger and this water is pumped and distribution to the air handling units at various floors in the building.

2.5.2 Air Handling Unit

The air handling unit is an integrated piece of equipment consisting of fans, heating and cooling coils, air-control dampers, filters and silencers. The purpose of this equipment is to collect and mix outdoor air with that returning from the building space. The air mixture is then cooled or heated, after which it is discharged into the building space through a duct system. Air handler is normally associated with HVAC systems in commercial buildings. They may be mounted on the top of the roof or in large mechanical rooms located in the building. They often have an economizer or inlet damper that allows for a small amount of outside air or make up air to be pulled in through the air handler. Air handling units are designed to perform ranging from 200 to 10000 cfm.

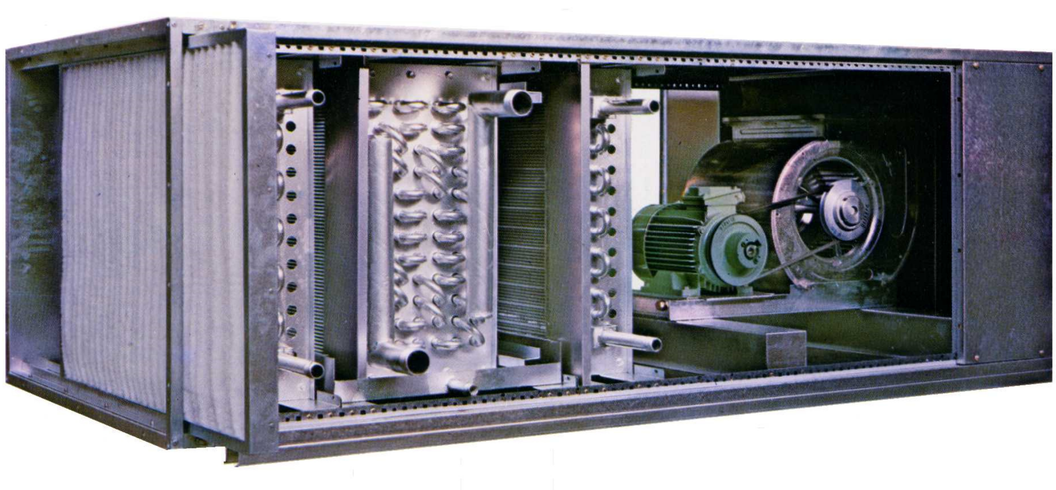

Fig 2.8: Air Handling Unit

2.5.3 Fans

A fan is an air pump that creates a pressure difference and causes airflow. The impeller does work on the air, imparting to it both static and kinetic energy which varying in proportion depending on the fan type. A fan produces pressure or flow because the rotating blades of the impeller impart kinetic energy to the air by changing its velocity. Here the fan or blower absorbs the hot return air from the cooled room and blows it over cooling coil and sends it to the conditioned room. The capacity of the fan can be 30000 cfm with the static pressure of about 75 to 100 mm of water gauge.

Fig 2.9: Fan

2.5.4 Cooling Coil

AHU cooling coil use chilled water or refrigerant as direct expansion system. Chilled water temperature varies between 5-7^{0}C and refrigerant temperature can be as low as 2^{0}C at direct expansion system. It is made up of copper tubing of several turns and covered with fins to increase the heat transfer efficiency of cooling coil. The hot air from room flows over it and gets cooled. The flow of chilled water or refrigerant to the cooling coil is controlled by the solenoid valve.

Fig 2.10: Cooling Coil

2.5.5 Air Filter

Filters require to keep the blower or motor clean and to keep the dust and dirt off the heating and cooling coils.

Fig 2.11: Air Filter

CHAPTER 3
COOLING LOAD CALCULATION

3.1 Cooling Load

In a space, the cooling load can be defined as the heat load which is removed by means of cooling equipment, equal to rate at which heat is arose from sources such as people, machinery and other processes. The cooling load is the amount of heat energy that would need to be removed from a space to maintain the temperature in an acceptable range.

3.2 Cooling Load Calculations

- Heat transmission through barriers such as walls, doors, windows, ceilings, floors and partitions and caused by the different temperatures existing on the two sides of the barrier.

  Therefore, heat conduction through composite walls, roofs or doors is Q.

  $$Q = U \times A \times (t_i - t_s)$$

  Here, $U = 1/R$ = overall heat transfer coefficient

  R = sum of individual thermal resistance

  $R = (1/f_i + x_0/k_0 + x_1/k_1 + \ldots + 1/f_0)$

  f_i, f_0 = inside and outside film resistance respectively

  x = film thickness

  k = thermal conductivity

  t_i = inside space temperature to be maintained in dry bulb

  t_s = supply air temperature entering space in dry bulb

  Heat transmission through glass, Q = U x A x CLTD

- Heat from solar effects which is transmitted by radiation through glass and absorbed by inside surfaces and furnishings. The following equation is for the calculation of cooling loads due to solar radiation.

  $$Q_{SHG} = A \times (SC) \times (SHGF) \times (CLF)$$

  Where,

  Q_{SHG} = solar radiation cooling load

  A = area

  SC = shading coefficient

  SHGF = solar heat gain factor

  CLF = cooling load factor

- Heat load from machinery, appliances, lights, fans, computer and combustion equipment needs to be considered. Here, the energy from lights is transferred to the room air by convection. The remaining portion is absorbed by walls, floor, furniture etc. The equation of cooling load is imposed by these sources is,

  $$Q = P \times (CLF)$$

  Here, P = input operating power rating of the appliances (watt)

  CLF = cooling load factor depending on operating hours, room construction etc.

- Heat load from occupants (sensible and latent) which depends on the level and the type of activities in which people are engaged. For sensible portion of heat released, the sensible cooling load due to people is given below:

$$Q_s = N \times (SHG)$$

Here, Q_s = sensible cooling load due to occupants

N = number of occupants

SHG = sensible heat gain from occupants depending on activity and time (watt)

The latent heat gain from occupants is given by

$$Q_L = N \times (LHG)$$

Here, Q_L = latent cooling load due to occupants

N = number of occupants

LHG = latent heat gain from occupants depending on activity and time

- Heat and moisture introduced with infiltration and ventilation needs to be considered in the cooling load calculations.

ASHRE recommended that the change of air is 7.5litre/sec per person.

Ventilation = N x 7.5

Let 20% of volume is changed in one hour.

Infiltration = 0.2 x volume (length x width x height)

Now total volumetric flow of air, w = ventilation+ infiltration

The air quantity can be found most readily by using the sensible heat load in the following equation,

$$Q_s = \rho \times w \times C_p \times (t_i - t_s)$$

Here, ρ = density of air

C_p = specific heat of moist air

t_i = inside space temperature to be maintained in dry bulb

t_s = supply air temperature entering space in dry bulb

By using the latent heat load, the air quantity can be found in the following equation,

$$Q_L = \rho \times w \times (\omega_0 - \omega_i)$$

Here, ω_0, ω_i = relative humidity outside and inside space respectively.

Calculation: Maximum Outside Temperature = 102.2°F From BMD, Room and Desired Temperature = 89.8 & 69.8°F

Table 3.1: Heat Transmission of Classroom (303/304)

Name	Description	U (Btu/h.ft^2.°F)	A (ft^2)	Δt (°F)	Q (Btu/h)
Walls	North	.58	128.4	102.2-69.8	2412.89
	North (uncon.)	.468	117.6	89.8-69.8	1089.73
	South	.468	398.4	0	0
	East	.58	283.4	102.2-69.8	5358.53
	South (uncon.)	.468	57.6	89.6-69.8	533.75
	West	.468	481.32	89.6-69.8	4460.1
Door	Wood	.43	71.95	89.6-69.8	612.58

		U ($W/m^{2o}K$)	A (m^2)	CLTD	Q (Btu/h)
Glass	North	6.3	12.76	7	1918.86
	South	0	0	0	0
	East	6.3	17.53	7	2636.27
	West	6.3	3.5	7	526.33
Total					18936.46

Table 3.2: Heat Transmission of Heat Transfer Lab

Name	**Description**	**U ($Btu/h.ft^2.^oF$)**	**A (ft^2)**	**Δt (^oF)**	**Q (Btu/h)**
Walls	North	.468	734.4	0	0
	South	.468	698.41	89.6-69.8	6471.75
	East	.468	602.4	89.6-69.8	5582.08
	West (uncon.)	.468	363.6	89.6-69.8	3369.263
	West	.58	159.24	102.2-69.8	2992.44
Door	Wood	.43	35.99	89.6-69.8	306.42
		U ($W/m^{2o}K$)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	0	0	0	0
	South	0	0	0	0
	East	0	0	0	0
	West	6.3	7.4	7	1112.81
Total					19528.343

Table 3.3: Heat Transmission of Control Circuit Lab

Name	**Description**	**U ($Btu/h.ft^2.^oF$)**	**A (ft^2)**	**Δt (^oF)**	**Q (Btu/h)**
Walls	North	.468	740.7	0	0
	South	.58	418.62	102.2-69.8	7866.71
	East	.58	401.88	102.2-69.8	7552.13
	West	.468	539.46	89.6-69.8	4998.85
	Roof	.22	3128.19	102.2-69.8	22297.74
Door	Wood	.43	51.24	89.6-69.8	436.26
	Steel	.12	68.938	89.6-69.8	1063.79
		U ($W/m^{2o}K$)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	0	0	0	0
	South	6.3	29.93	7	4500.9
	East	6.3	19.54	7	2938.44
	West	0	0	0	0
Total					50154.77

Table 3.4: Heat Transmission of Thermodynamic Lab

Name	**Description**	**U (Btu/h.ft^2.^{0}F)**	**A (ft^2)**	**Δt (^{0}F)**	**Q (Btu/h)**
Walls	North	.58	418.62	102.2-69.8	7866.71
	South	.468	740.7	0	0
	East	.468	539.46	89.6-69.8	4998.85
	West	.58	401.88	102.2-69.8	7552.13
	Roof	.22	3128.19	102.2-69.8	22297.74
Door	Wood	.43	35.99	89.6-69.8	306.42
	Steel	.12	68.938	89.6-69.8	1063.79
		U (W/m^{2}^{0}K)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	6.3	29.93	7	4500.9
	South	0	0	0	0
	East	6.3	19.54	7	2938.44
	West	0	0	0	0
Total					50154.77

Table 3.5: Heat Transmission of Drawing Lab

Name	**Description**	**U (Btu/h.ft^2.^{0}F)**	**A (ft^2)**	**Δt (^{0}F)**	**Q (Btu/h)**
Walls	North	.58	418.62	102.2-69.8	7866.71
	South	.468	740.7	0	0
	East	.468	539.46	89.6-69.8	4998.85
	West	.58	401.88	102.2-69.8	7552.13
Door		.43	87.23	89.6-69.8	742.68
		U (W/m^{2}^{0}K)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	6.3	29.93	7	4500.9
	South	0	0	0	0
	East	0	0	0	0
	West	6.3	19.54	7	2938.44
Total					27857.03

Table 3.6: Heat Transmission of Girls' Common Room

Name	**Description**	**U (Btu/h.ft^2.^{0}F)**	**A (ft^2)**	**Δt (^{0}F)**	**Q (Btu/h)**
Walls	North	.468	338.41	89.6-69.8	3135.85
	South	.58	277	102.2-69.8	5205.38
	East	.468	464.41	89.6-69.8	4303.41

	West	.468	460.11	89.6-69.8	4263.56
Door	Wood	.43	35.99	89.6-69.8	306.42
		U (W/m^{2} ^{0}K)	**A (m^{2})**	**CLTD**	**Q (Btu/h)**
Glass	North	0	0	0	0
	South	6.3	9.1	7	1364
	East	0	0	0	0
	West	6.3	3.75	7	563.94
Total					18836.14

Table 3.7: Heat Transmission of Fluid Lab

Name	Description	U (Btu/h.ft^{2}.^{0}F)	A (ft^{2})	Δt (^{0}F)	Q (Btu/h)
Walls	North	.58	771.05	102.2-69.8	14488.632
	South	.58	746.3	102.2-69.8	14024.5
	East	.58	1042.3	102.2-69.8	23345.31
	West	.468	1860	89.6-69.8	17235.51
	Floor	.24	3819	89.6-69.8	18149
Door	Wood	.43	71.98	89.6-69.8	612.84
	Steel	.12	68.94	89.6-69.8	163.79
		U (W/m^{2} ^{0}K)	**A (m^{2})**	**CLTD**	**Q (Btu/h)**
Glass	North	6.3	36.83	7	5538.53
	South	0	0	0	0
	East	6.3	61.38	7	2706.858
	West	0	0	0	0
Total					95488.34

Table 3.8: Heat Transmission of Machine Lab

Name	Description	U (Btu/h.ft^{2}.^{0}F)	A (ft^{2})	Δt (^{0}F)	Q (Btu/h)
Walls	North	.58	761.05	102.2-69.8	14301.66
	South	.468	1172.3	89.6-69.8	10863
	East	.468	1776.17	89.6-69.8	16458.701
	West	.58	1404.3	102.2-69.8	26389.61
	Floor	.24	6274.89	89.6-69.8	29818.28
Door	Wood	.43	102.48	89.6-69.8	872.517
	Steel	.12	68.94	89.6-69.8	163.79

		U (W/m^{2} ^{0}K)	A (m^{2})	CLTD	Q (Btu/h)
Glass	North	6.3	36.83	7	5538.53
	South	0	0	0	0
	East	0	0	0	0
	West	6.3	49.104	7	7384.32
Total					110754.101

Table 3.9: Heat Transmission of Aerodynamics Lab

Name	Description	U (Btu/h.ft^{2}.^{0}F)	A (ft^{2})	Δt (^{0}F)	Q (Btu/h)
Walls	North	.468	1385.32	89.6-69.8	12836.93
	South	.58	754.6	102.2-69.8	14180.4432
	East	.58	396.3	102.2-69.8	7447.27
	West	.468	792.3	89.6-69.8	7341.77
	Floor	.24	3198.39	89.6-69.8	17385.62
Door	Wood	.43	107.97	89.6-69.8	919.25
		U (W/m^{2} ^{0}K)	**A (m^{2})**	**CLTD**	**Q (Btu/h)**
Glass	North	0	0	0	0
	South	6.3	65.35	7	9827.41
	East	6.3	36.83	7	5538.53
	West	0	0	0	0
Total					74557.9732

Table 3.10: Heat Transmission of Classroom (301/302)

Name	Description	U (Btu/h.ft^{2}.^{0}F)	A (ft^{2})	Δt (^{0}F)	Q (Btu/h)
Walls	North	.58	128.4	102.2-69.8	2412.89
	North (uncon.)	.468	117.6	89.8-69.8	1089.73
	South	.468	398.4	89.6-69.8	3691.73
	East	.468	481.32	89.6-69.8	4460.103
	West	.58	166.56	102.2-69.8	3130
	West (uncon.)	.468	285.6	89.6-69.8	2646.48
Door	Wood	.43	71.98	89.6-69.8	612.84
		U (W/m^{2} ^{0}K)	**A (m^{2})**	**CLTD**	**Q (Btu/h)**
Glass	North	6.3	12.76	7	1918.88
	South	0	0	0	0

	East	6.3	3.5	7	526.33
	West	6.3	6.72	7	1010.55
Total					20886.693

Table 3.11: Heat Transmission of Radar Engineering Lab

Name	**Description**	**U (Btu/h.ft^2.^{0}F)**	**A (ft^2)**	**Δt (^{0}F)**	**Q (Btu/h)**
Walls	North	.468	319.22	89.6-69.8	2958.02
	South	.58	497.4	102.2-69.8	5520.9
	East	.58	425.43	102.2-69.8	5407.03
	West	0	0	0	0
Door	Wood	.43	41.48	89.6-69.8	353.16
		U (W/m^{20}K)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	0	0	0	0
	South	6.3	9.1	7	1364
	East	6.3	19.78	7	2974.543
	West	6.3	46.53	7	6997.22
Total					25221.713

Table 3.12: Heat Transmission of 10th Floor (1002)

Name	**Description**	**U (Btu/h.ft^2.^{0}F)**	**A (ft^2)**	**Δt (^{0}F)**	**Q (Btu/h)**
Walls	North	0	0	0	0
	South	.468	54.72	89.6-69.8	507.058
	East	.468	219.6	89.6-69.8	2034.9
	West	0	0	0	0
		U (W/m^{20}K)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	6.3	12.7224	7	1913.207
	South	6.3	7.633	7	1174.92
	East	0	0	0	0
	West	0	0	0	0
Total					5630.085

Table 3.13: Heat Transmission of 10th Floor (1001)

Name	**Description**	**U (Btu/h.ft^2.^{0}F)**	**A (ft^2)**	**Δt (^{0}F)**	**Q (Btu/h)**
Walls	North	.58	108.9	102.2-69.8	2046.45
	South	0	0	0	0
	East	.468	47.66	89.8-69.8	441.67
	West	.58	288	102.2-69.8	5412.096

		U (W/m$^{2\,0}$K)	A (m^2)	CLTD	Q (Btu/h)
Glass	North	6.3	10.1277	7	1523.01
	South	0	0	0	0
	East	0	0	0	0
	West	0	0	0	0
Total					9423.226

Table 3.14: Heat Transmission of 10th Floor (1003)

Name	Description	U (Btu/h.ft^2.^{0}F)	A (ft^2)	Δt (^{0}F)	Q (Btu/h)
Walls	North	0	0	0	0
	South	.468	142.5	89.6-69.8	1297.89
	East	.468	223.2	89.6-69.8	2068.3
	West	.468	294	89.6-69.8	2724.3216
		U (W/m$^{2\,0}$K)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	6.3	12.7224	7	1913.2
	South	6.3	19.89	7	2991.08
	East	6.3	1.975	7	294.05
	West	0	0	0	0
Total					11288.8416

Table 3.15: Heat Transmission of 10th Floor (Office)

Name	Description	U (Btu/h.ft^2.^{0}F)	A (ft^2)	Δt (^{0}F)	Q (Btu/h)
Walls	North	.468	140.06	89.6-69.8	1297.85
	South	.468	140.06	89.6-69.8	1297.85
	East	.468	73.92	89.6-69.8	684.97
	West	.468	696.72	89.6-69.8	6456.08
		U (W/m$^{2\,0}$K)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	0	0	0	0
	South	0	0	0	0
	East	6.3	61.87	7	9304.23
	West	6.3	3.95	7	594.1
Total					19635.08

Table 3.16: Heat Transmission of 10th Floor (1005)

Name	Description	U (Btu/h.ft^2.^{0}F)	A (ft^2)	Δt (^{0}F)	Q (Btu/h)
Walls	North	.468	211.2	89.6-69.8	1957.07
	South	.468	211.2	89.6-69.8	1957.07
	East	0	0	0	0
	West	0	0	0	0

		U ($W/m^{2\,0}K$)	A (m^2)	CLTD	Q (Btu/h)
Glass	North	0	0	0	0
	South	0	0	0	0
	East	6.3	68.75	7	10338.03
	West	6.3	68.75	7	10338.03
Total					24590.2

Table 3.17: Heat Transmission of 10th Floor (1004)

Name	**Description**	**U ($Btu/h.ft^2.^0F$)**	**A (ft^2)**	**Δt (^0F)**	**Q (Btu/h)**
Walls	North	0	0	0	0
	South	.468	129.96	89.6-69.8	1204.261
	East	.58	18.15	102.2-69.8	4092.89
	West	.468	217.8	89.6-698	2018.22
		U ($W/m^{2\,0}K$)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	6.3	40.28	7	6058.5
	South	6.3	28.196	7	4236.98
	East	0	0	0	0
	West	0	0	0	0
Total					17610.851

Table 3.18: Heat Transmission of 11th Floor (MEGA Room)

Name	**Description**	**U ($Btu/h.ft^2.^0F$)**	**A (ft^2)**	**Δt (^0F)**	**Q (Btu/h)**
Walls	North	.58	404.4	102.2-69.8	7600
	South	.58	1268.4	102.2-69.8	23835.78
	East	.58	1204.98	102.2-69.8	22644
	West	.58	404.4	102.2-69.8	7600
	Roof	.22	3562.09	102.2-69.8	25390.58
		U ($W/m^{2\,0}K$)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	0	0	0	0
	South	0	0	0	0
	East	0	0	0	0
	West	6.3	117.84	7	886.05
Total					87956.41

Table 3.19: Heat Transmission of 11th Floor (Faculty)

Name	Description	U (Btu/h.ft^2.^{0}F)	A (ft^2)	Δt (^{0}F)	Q (Btu/h)
Walls	North	.58	355.68	102.2-69.8	6683.94
	South	.58	374.4	102.2-69.8	7035.73
	East	.58	767.67	102.2-69.8	14036.12
	West	.58	76.38	102.2-69.8	14074.83
	Roof	.22	2050	102.2-69.8	14612.4
		U (W/m^{20}K)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	6.3	1.74	7	261.78
	South	0	0	0	0
	East	6.3	3.857	7	580.02
	West	6.3	3.67	7	551.8
Total					57836.62

Table 3.20: Heat Transmission of 11th Floor (Conference Room)

Name	Description	U (Btu/h.ft^2.^{0}F)	A (ft^2)	Δt (^{0}F)	Q (Btu/h)
Walls	North	.58	456	102.2-69.8	8569.152
	South	.58	433.2	102.2-69.8	8140.7
	East	.58	274.38	102.2-69.8	5156.15
	West	.468	322.8	89.6-69.8	2991.19
	Roof	.22	1022.2	102.2-69.8	7286.2416
		U (W/m^{20}K)	**A (m^2)**	**CLTD**	**Q (Btu/h)**
Glass	North	0	0	0	0
	South	6.3	2.12	7	318.86
	East	6.3	4.5	7	676.71
	West	0	0	0	0
Total					33139.0036

Table 3.21: Heat Transmission of Department Library

Name	Description	U (Btu/h.ft^2.^{0}F)	A (ft^2)	Δt (^{0}F)	Q (Btu/h)
Walls	North	0	0	0	0
	South	0	0	0	0

	East	.58	94.53	102.2-69.8	1776.41
	West	.468	122.92	89.6-69.8	1139.03
Total					2915.44

<u>Table 3.22: Solar Radiation</u>

Room	Glass area	A (m^2)	SC	SHGF (W/m^2)	CLF	Q_{SHG} (Watt)	Q_{SHG} (Btu/h)
301	North	12.76	.9	117	.72	967.412	3298.88
	South	0	.9	237	.56	0	0
	East	0	.9	719	.32	0	0
	West	6.72	.9	719	.21	913.19	3113.97
304	North	12.76	.9	117	.72	967.412	3298.88
	South	0	.9	237	.56	0	0
	East	17.53	.9	719	.32	3629.97	12387.21
	West	0	.9	719	.21	0	0
Heat Transfer Lab	North	0	.9	117	.72	0	0
	South	0	.9	237	.56	0	0
	East	0	.9	719	.32	0	0
	West	7.4	.9	719	.21	1005.6	3429.07
Control Circuit Lab	North	0	.9	117	.72	0	0
	South	29.93	.9	237	.56	3575.08	12191.02
	East	19.54	.9	719	.32	4046.19	13797.5
	West	0	.9	719	.21	0	0
Thermodynamics Lab	North	29.93	.9	117	.72	2269.17	7737.88
	South	0	.9	237	.56	0	0
	East	19.54	.9	719	.32	4046.19	13797.5
	West	0	.9	719	.21	0	0
Drawing lab	North	29.93	.9	117	.72	2269.17	7737.88
	South	0	.9	237	.56	0	0
	East	0	.9	719	.32	0	0

	West	19.54	.9	719	.21	2655.31	9054.61
Fluid Lab	North	36.83	.9	117	.72	2792.30	9521.75
	South	0	.9	237	.56	0	0
	East	61.38	.9	719	.32	12710.08	43341.38
	West	0	.9	719	.21	0	0
Girls' Common Room	North	0	.9	117	.72	0	0
	South	9.06	.9	237	.56	1082.2	3690.3
	East	0	.9	719	.32	0	0
	West	3.75	.9	719	.21	509.6	1737.71
Aerodynamics Lab	North	0	.9	117	.72	0	0
	South	65.35	.9	237	.56	7805.93	26618.21
	East	36.83	.9	719	.32	7626.46	26006.23
	West	0	.9	719	.21	0	0
Radar Engineering Lab	North	0	.9	117	.72	0	0
	South	9.06	.9	237	.56	1082.2	3690.3
	East	19.78	.9	719	.32	4095.88	13966.96
	West	0	.9	719	.21	0	0
Machine Lab	North	36.83	.9	117	.72	2792.3	9521.75
	South	0	.9	237	.56	0	0
	East	0	.9	719	.32	0	0
	West	49.104	.9	719	.21	6672.8	22754.22
10th Floor (1002)	North	124.322	.9	117	.72	9425.6	32141.296
	South	0	.9	237	.56	0	0
	East	0	.9	719	.32	0	0
	West	0	.9	719	.21	0	0
10th Floor (1001)	North	10.13	.9	117	.72	768.02	2618.9482
	South	0	.9	237	.56	0	0
	East	0	.9	719	.32	0	0
	West	0	.9	719	.21	0	0

10th Floor (1004)	North	40.28	.9	117	.72	3053.87	10413.7
	South	0	.9	237	.56	0	0
	East	0	.9	719	.32	0	0
	West	0	.9	719	.21	0	0
10th Floor (1005)	North	0	.9	117	.72	0	0
	South	0	.9	237	.56	0	0
	East	68.75	.9	719	.32	14236.2	48545.442
	West	0	.9	719	.21	0	0
10th Floor (1001')	North	0	.9	117	.72	0	0
	South	10.13	.9	237	.56	1210.01	4126.13
	East	0	.9	719	.32	0	0
	West	0	.9	719	.21	0	0
10th Floor (1002')	North	0	.9	117	.72	0	0
	South	124.322	.9	237	.56	14850.02	50638.57
	East	0	.9	719	.32	0	0
	West	0	.9	719	.21	0	0
10th Floor (1004')	North	0	.9	117	.72	0	0
	South	40.28	.9	237	.56	4811.36	16406.76
	East	0	.9	719	.32	0	0
	West	0	.9	719	.21	0	0
11th Floor (MEGA Room)	North	0	.8	117	.72	0	0
	South	0	.8	237	.56	0	0
	East	0	.8	719	.32	0	0
	West	5.89	.8	719	.21	711.46	2426.1
11th Floor (Conference Room)	North	0	.8	117	.72	0	0
	South	2.12	.8	237	.56	225.09	767.57
	East	4.5	.8	719	.32	828.288	2824.46
	West	0	.8	719	.21	0	0
11th Floor	North	1.74	.8	117	.72	117.26	399.86

(Faculty)	South	0	.8	237	.56	0	0
	East	3.86	.8	719	.32	710.48	2422.76
	West	3.67	.8	719	.21	443.31	1511.68
Department Library	North	0	.9	117	.72	0	0
	South	0	.9	237	.56	0	0
	East	6.5	.9	719	.32	1345.968	4589.75
	West	0	.9	719	.21	0	0

Table 3.23: Internal Load

Room	**Item**	**Number**	**Power (watt)**	**CLF**	**Q (Btu/h)**
Any Classroom	Lights	15	600	.76	4956.06
	Fan	20	1200	.76	
	PC	1	110	.76	
	Projector	1	1	.76	
Heat Transfer Lab	Lights	20	800	.71	6565.83
	Fan	30	1800	.71	
	PC	1	110	.71	
Control Circuit Lab/ Drawing Lab/ Thermodynamics Lab	Lights	25	1000	.76	7391.3
	Fans	29	1740	.76	
	PC	1	110	.76	
Aerodynamics Lab	Lights	48	1920	.71	9570.12
	Fans	32	1920	.71	
	PC	1	110	.71	
Girls' Common Room	Lights	9	360	.76	2178.48
	Fan	8	480	.76	
Radar Engineering Lab	Lights	12	480	.76	5149.1
	Fan	8	480	.76	
	PC	5	550	.76	

Fluid Lab/ Machine Lab	Lights	70	2800	.71	12865.15
	Fans	40	2400	.71	
	PC	1	110	.71	
Cad Lab/ Mat Lab	Lights	28	40	.71	16584.535
	Fans	18	60	.71	
	PC	40	110	.71	
	Printer	1	250	.71	
Department Library	Lights	4	40	.76	881.144
	Fans	3	60	.76	
10th Floor	Lights	82	40	.76	32991.068
	Fans	43	60	.76	
	PC	42	110	.76	
	Printer	9	250	.76	
11th Floor	Lights	58	40	.76	18270.78
	Fans	31	60	.76	
	PC	17	110	.76	
	Printer	4	250	.76	

Table 3.24: Occupants

Room		**Number Of People**	**SHG**	**LHG**	**Q (Btu/h)**
Any Classroom	Sensible	70	195		28000
	Latent	70		205	
Any Lab	Sensible	75	200		33750
	Latent	75		250	
Girls' Common Room/ Radar Engineering Lab	Sensible	10	180		3300
	Latent	10		150	
Department Library	Sensible	2	195		800
	Latent	2		205	

CAD Lab/ Mat Lab	Sensible	40	195		16000
	Latent	40		205	
10th Floor	Sensible	50	200		22500
	Latent	50		250	
11th Floor	Sensible	30	200		13500
	Latent	30		250	

Table 3.25: Ventilation and Infiltration

Room		**ft^3/s**	**Total volume (ft^3/hr)**		**P (lb/ft^3)**	**Specific heat capacity, c_p (Btu/lb ◦F)**	**T_o-T_i**	**ω_o-ω_i**	**Q (Btu/h)**
301/ 302	Ventilation	18.5325	70437.96	Sensible Heat	.075	0.24	89.6-69.8		25104.09
	Infiltration	1.0336		Latent Heat				.023 - .012	58.11
Aerodynamics Lab	Ventilation	19.86	83664	Sensible Heat	.075	.24	89.6-69.8		29817.85
	Infiltration	3.38		Latent Heat				.023 - .012	69.03
Fluid Lab	Ventilation	19.86	86555.74	Sensible Heat	.075	.24	102.2-69.8		43914.2
	Infiltration	4.18		Latent Heat				.037 - .012	162.3
Machine Lab	Ventilation	19.86	95340.582	Sensible Heat	.075	.24	89.6-69.8		33979.38
	Infiltration	6.62		Latent Heat				.023 - .012	78.66
Radar	Ventilation	2.65		Sensible Heat		.24	102.2-69.8		6800.31

Engineering Lab	Infiltration	0.556	11541.6	Latent Heat	.075			.037 - .012	21.64
Girls' Common Room	Ventilation	2.65	12672	Sensible Heat	.075	.24	89.6-69.8		4516.3
	Infiltration	0.87		Latent Heat				.023 - .012	10.45
Electrical Lab	Ventilation	19.86	79003.565	Sensible Heat	.075	.24	102.2-69.8		46074.9
	Infiltration	2.08		Latent Heat				.037 - .012	148.13
Thermodynamics Lab	Ventilation	19.86	79056	Sensible Heat	.075	.24	102.2-69.8		46105.46
	Infiltration	2.1		Latent Heat				.037 - .012	148.23
Heat transfer Lab	Ventilation	19.86	78868.8	Sensible Heat	.075	.24	89.6-69.8		281008.84
	Infiltration	2.048		Latent Heat				.023 - .012	65.07
Drawing Lab	Ventilation	19.86	79056	Sensible Heat	.075	.24	89.6-69.8		28175.56
	Infiltration	2.1		Latent Heat				.023 - .012	65.22
303/304	Ventilation	18.5325	69957	Sensible Heat	.075	.24	102.2-69.8		41079.42
	Infiltration	.9		Latent Heat				.037 - .012	132.07
CAD Lab/ Mat	Ventilation	10.6	43200	Sensible Heat	.075	.24	102.2-69.8		25194.24
	Infiltration	1.4		Latent				.037 -	

Lab				Heat				.012	81
Department Library	Ventilation	.53	2977.2	Sensible Heat	.075	.24	102.2-69.8		1736.3
	Infiltration	.297		Latent Heat				.037-.012	5.6
10th Floor	Ventilation	6.62	31536	Sensible Heat		.24	102.2-69.8		18391.8
	Infiltration	2.14		Latent Heat				.037-.012	59.13
	Ventilation	6.62	30420	Sensible Heat	.075	.24	89.6-69.8		10841.7
	Infiltration	1.83		Latent Heat				.023-.012	25.1
11th Floor	Ventilation	26.475	102682.896	Sensible Heat		.24	102.2-69.8		59884.66495
	Infiltration	2.048		Latent Heat				.037-.012	192.5304
	Ventilation	6.62	32381.016	Sensible Heat	.075	.24	89.6-69.8		11540.59
	Infiltration	2.3747		Latent Heat				.023-.012	26.7143

Table 3.26: Total Cooling Load

Floor	**Room**	**Calculated Tor**	**Units**	**Total Tor**
Ground Floor	Fluid Lab	19.13 Ton	1	19.13 Ton
	Machine Lab	18.65 Ton	1	18.65 Ton
	Aerodynamics Lab	16.7 Ton	1	16.7 Ton
1st Floor	Thermodynamics Lab	13.25 Ton	1	13.25 Ton

	Drawing Lab	9.51 Ton	1	9.51 Ton
	Control Circuit Lab	13.63 Ton	1	13.63 Ton
	Heat Transfer Lab	28.67 Ton	1	28.67 Ton
	Radar Engineering Lab	7.39 Ton	1	7.39 Ton
	Girls' Common Room	2.86 Ton	1	2.86 Ton
Classroom	301	7.12 Ton	8	56.96 Ton
	302	7.12 Ton	8	56.96 Ton
	303	9.065 Ton	7	63.455 Ton
	304	9.065 Ton	7	63.455 Ton
	CAD Lab/ Mat Lab	6.72 Ton	2	13.44 Ton
10th Floor		31.28 Ton	2	63.56 Ton
11th Floor		24.19 Ton	1	24.19 Ton
Total				443.53 Ton

CHAPTER 4

DUCT DESIGN

4.1 Duct System

In any mechanical circulation heating, cooling, or ventilation system the fan or fans must have adequate capacity to deliver the air quantity required at a static pressure equal to or slightly greater than the total resistance offered by the duct system. Here airflows through duct include supply air, return air and exhaust air. Air ducts are one of the method of ensuring acceptable indoor air quality as well as thermal comfort.

4.2 How Duct System Works

The first section is introduced with return air. This part provides a path for air from the individual rooms to the inlet of the air handler. In this section, air is cleaned and fresh air is introduced here. In some cases, moisture is required and added here as well. Next the air passes into the furnace or air handler where heat is removed to make the temperature in an acceptable range. In this part, filtering is performed here and finally this conditioned air enters the supply section of the duct system. The size of the duct is reduced as necessary to maintain the adequate air flow. The branch ducts attach to the main ducts and carry the conditioned air to the individual registers.

4.3 Duct Design Considerations

- The sizes of the ducts are set by the maximum air velocities which can be used without causing undue noise or excessive friction loss.
- Large ducts will reduce frictional losses, but the space and investment requirements offset the power saving at the fan.
- In general, the layout should be made as directly as possible, sharp blends should be avoided and if the duct is rectangular cross section, it should not be too flattened.
- Rectangular duct should be made nearly square as possible and aspect ratio (width to depth) should not exceed 6:1.
- In order to energy cost, material and space, an economic balance must be made in designing the installation.
- In the layout, sudden changes of air in direction should be avoided.

4.4 Duct Design Method

A number of duct design methods for air conditioning systems are listed. The first three are the ASHRAE recommended methods and used regularly by the designers.

- **Equal Friction Method**
- **Static Regain Method**
- **T-Method**
- **Velocity Reduction Method**
- **Balanced-Pressure Method**

4.4.1 Equal Friction Method

In this method, the duct is proportioned so that the frictional loss per foot of length is constant. The duct is sized so as to cause equal pressure losses per unit length of duct. It is also called constant pressure drop method. When this method is used, it is customary to establish the constant pressure drop on the basis of desirable velocity in the duct main beyond the fan. The branches must be dampened for control.

The design method is widely used for low or medium velocity duct systems. Here, the known flow rate then establishes the duct size and the pressure loss per unit length from the duct friction loss chart. The same pressure loss per unit length is then used throughout the system. After sizing the system, the total pressure loss of the circuit having the largest pressure loss, should be calculated including that of fittings and transitions.

4.5 Factors for Preferring Equal Friction Method

- For medium velocity, equal friction method is more relevant and followed.
- This method is suitable for constant air volume systems having long runs of ducts with many branches take-offs.
- The total pressure requirement of each part of duct system is not readily apparent.
- The process is easy to determine the duct size that will produce an acceptable pressure loss.
- Very low velocities and large duct sizes may result at the end of long runs.

4.6 Selection of Duct

Generally round or rectangular in shape, duct are always preferable for the selection of duct. Duct in round shape has advantages over the rectangular shape due to less friction loss. Here, some advantages for choosing round shape over rectangular shape:

- Ducts are designed to tolerate a faster air flow with less friction, which prevents ducts from experiencing less wear and tear over long period of time.
- Ducts offer a high level of sound absorption.
- Ducts can be run in length up to thirty feet with minimal joints, connections and sealing requirements. Rectangular duct is shop fabricated in lengths up to ten feet that require sealing both longitudinally and at the connecting assemblies.
- Duct is more economical to install that is on medium or high pressure duct system and is easier and faster to install.
- It requires less material to transfer the same amount of air.
- Efficient way to convey air with low pressure drop.
- Better acoustic performance because the curved surface allows less breakout noise.

Some disadvantages for choosing round shape are as follows:

- Architecturally awkward rectangular to round ductwork, transition fitting from fan coil unit to main duct.
- Small height in clearance.

4.7 Duct Design

Table 4.1: Duct Type and Duct Loss of Ground Floor

Section	V (m^3/s)	V (m/s)	D_{eq} (mm)	$\Delta P_f/L$	L (m)	Duct Loss (Pa)	Types
A-B	10.44	8	1300	.45	3	1.35	0
B-C	10.44	8	1300	.45	12.33	5.54	E
C-H	1.77	5.4	650	.45	11.5	5.175	T
C-J	1.89	5.5	670	.45	11.5	5.175	T
C-D	6.78	7.4	1150	.45	10.33	4.65	T
D-I	1.77	5.4	650	.45	11.5	5.175	T
D-K	1.89	5.5	670	.45	11.5	5.175	T
D-E	3.12	6.1	820	.45	12.372	5.5674	T
E-L	3.12	6.1	820	.45	5.72	2.574	E
L-F	1.56	5.1	600	.45	8.3448	3.8016	T
L-M	1.56	5.1	600	.45	13.55	6.09	T
M-G	1.56	5.1	600	.45	8.448	3.8016	E

Table 4.2: Friction Loss of Ground Floor

Section	Duct Loss (Pa)	Type	Fitting Loss (Pa)	Loss For Grille (Pa)	Total Friction Loss (Pa)
A-B	1.35	0	0		
B-C	5.54	EL	12.67	25	
C-H	5.175	T	3.85		
A-B-C-H	12.065	1EL+1T	16.52	25	53.59
A-B	1.35	0	0		
B-C	5.54	EL	12.67	25	
C-J	5.175	T	3.85		
A-B-C-J	12.065	1EL+1T	16.52	25	53.59
A-B	1.35	0	0		

B-C	5.54	EL	12.67	25	
C-D	4.65	T	4.34		
D-I	5.175	T	3.74		
A-B-C-D-I	16.715	1EL+2T	20.75	25	62.465
A-B	1.35	0	0	25	
B-C	5.54	EL	12.67		
C-D	4.65	T	4.34		
D-K	5.175	T	4.2		
A-B-C-D-K	16.715	1EL+2T	21.21	25	62.92
A-B	1.35	0	0	25	
B-C	5.54	EL	12.67		
C-D	4.65	T	4.34		
D-E	5.6	T	3.2		
E-L	2.6	EL	7.37		
L-F	3.8	T	4.68		
A-B-C-D-E-L-F	23.54	2EL+3T	32.26	25	80.8
A-B	1.35	0	0	25	
B-C	5.54	EL	12.67		
C-D	4.65	T	4.34		
D-E	5.6	T	3.2		
E-L	2.6	EL	7.37		
L-M	6.09	T	2.18		
M-G	3.8	EL	5.2		
A-B-C-D-E-L-M-G	29.63	3EL+3T	34.96	25	89.59

Table 4.3: Duct Type and Duct Loss of 1st Floor

Section	V (m^3/s)	V (m/s)	D_{eq} (mm)	$\Delta P_f/L$	L (m)	Duct Loss (Pa)	Types
A-B	13.74	8	1450	.38	3	1.14	0
B-C	13.74	8	1450	.38	5.88	2.24	EL
C-D	.9	4.3	540	.38	14.63	5.56	T
D-E	.9	4.3	540	.38	3.88	1.48	EL
C-F	1.25	4.5	560	.38	14.63	5.56	T
F-G	1.25	4.5	560	.38	3.88	1.48	EL
C-H	11.59	7.8	1300	.38	3.89	1.4782	T
H-J	.9	4.	540	.38	8.36	3.18	T
H-I	1.25	4.5	560	.38	8.36	3.18	T
H-K	9.44	7.5	1260	.38	11.65	4.427	T
K-L	1.29	4.6	570	.38	14.63	5.5594	T
L-M	1.29	4.6	570	.38	3.88	1.48	EL
K-N	8.15	7.3	1180	.38	3.88	1.48	T
N-O	1.29	4.6	570	.38	8.36	3.18	T
N-P	6.86	6.9	1100	.38	9.63	3.66	T
P-Q	.92	4.35	545	.38	8.44	3.207	T
Q-R	.92	4.35	545	.38	2.88	1.0944	EL
P-S	5.94	6.7	1000	.38	8.3	3.154	T
S-T	2.7	5.75	800	.38	9.74	3.7	T
S-U	3.24	5.9	820	.38	6.23	2.37	T
U-V	2.7	5.75	800	.38	9.74	3.7	T
U-W	.54	3.75	450	.38	2.24	.8512	T
W-X	.54	3.75	450	.38	8.44	3.2072	EL

Table 4.4: Friction Loss of 1st Floor

Section	Duct Loss (Pa)	Type	Fitting Loss (Pa)	Loss For Grille (Pa)	Total Friction Loss (Pa)
A-B	1.14	0	0	25	
B-C	2.24	EL	12.67		
C-D	5.56	T	0		
D-E	1.48	EL	3.66		
A-B-C-D-E	10.42	2EL+1T	16.33	25	51.75
A-B	1.14	0	0	25	
B-C	2.24	EL	12.67		
C-F	5.56	T	0		
F-G	1.48	EL	4		
A-B-C-F-G	10.42	2EL+1T	16.67	25	52.09
A-B	1.14	0	0	25	
B-C	2.24	EL	12.67		
C-H	1.48	T	4.75		
H-J	3.18	T	1.9		
A-B-C-H-J	8.04	1EL+2T	19.32	25	52.36
A-B	1.14	0	0	25	
B-C	2.24	EL	12.67		
C-H	1.48	T	4.75		
H-I	3.18	T	0		
A-B-C-H-I	8.04	1EL+2T	17.42	25	50.46
A-B	1.14	0	0	25	
B-C	2.24	EL	12.67		
C-H	1.48	T	4.75		
H-K	4.4	T	4.3		
K-L	5.6	T	0		
L-M	1.48	EL	4.19		

A-B-C-H-K-L-M	16.34	2EL+3T	25.91	25	67.25
A-B	1.14	0	0	25	
B-C	2.24	EL	12.67		
C-H	1.48	T	4.75		
H-K	4.4	T	4.3		
K-N	1.48	T	4.16		
N-O	3.18	T	0		
A-B-C-H-K-N-O	13.92	1EL+4T	25.88	25	64.8
A-B	1.14	0	0	25	
B-C	2.24	EL	12.67		
C-H	1.48	T	4.75		
H-K	4.4	T	4.3		
K-N	1.48	T	4.16		
N-P	3.66	T	3.71		
P-Q	3.207	T	0		
Q-R	1.0944	EL	3.75		
A-B-C-H-K-N-P-Q-R	18.7	2EL+5T	33.34	25	77.04
A-B	1.14	0	0	25	
B-C	2.24	EL	12.67		
C-H	1.48	T	4.75		
H-K	4.4	T	4.3		
K-N	1.48	T	4.16		
N-P	3.66	T	3.71		
P-S	3.154	T	14		
S-T	3.7	T	6.54		
A-B-C-H-K-N-P-S-T	21.254	1EL+6T	50.13	25	96.384
A-B	1.14	0	0		

B-C	2.24	EL	12.67	25	
C-H	1.48	T	4.75		
H-K	4.4	T	4.3		
K-N	1.48	T	4.16		
N-P	3.66	T	3.71		
P-S	3.154	T	14		
S-U	2.37	T	3.14		
U-V	3.7	T	13		
A-B-C-H-K-N-P-S-U-V	23.624	1EL+7T	59.73	25	108.354
A-B	1.14	0	0	25	
B-C	2.24	EL	12.67		
C-H	1.48	T	4.75		
H-K	4.4	T	4.3		
K-N	1.48	T	4.16		
N-P	3.66	T	3.71		
P-S	3.154	T	14		
S-U	2.37	T	3.14		
U-W	.8512	T	1.35		
W-X	3.2072	EL	2.78		
A-B-C-H-K-N-P-S-U-W-X	23.9824	2EL+7T	50.86	25	99.8424

Table 4.5: Duct Type and Duct Loss of Classroom

Section	V (m^3/s)	V (m/s)	D_{eq} (mm)	$\Delta P_f/L$	L (m)	Duct Loss (Pa)	Types
A-B	6.3	8	1100	.55	3	1.65	0
B-C	6.3	8	1100	.55	6.44	3.542	EL
C-D	.67	4.8	430	.55	6.84	3.76	T
C-E	5.63	7.9	975	.55	.3	.165	T
E-F	.85	4.9	470	.55	7.15	3.93	T
E-G	4.78	7.5	915	.55	4.14	2.3	T
G-H	.67	4.8	430	.55	6.84	3.76	T
G-I	4.11	7.2	900	.55	.6	.33	T
I-J	.85	4.9	470	.55	7.15	3.93	T
I-K	3.26	6.9	800	.55	6.82	3.751	T
K-L	.188	3.3	270	.55	7.15	3.93	T
K-M	3.072	6.7	780	.55	3.64	2	T
M-N	.67	4.8	430	.55	6.84	3.76	T
M-O	2.402	6.3	700	.55	3.2	1.76	T
O-P	.85	4.9	470	.55	7.15	3.93	T
O-Q	1.552	5.6	575	.55	3.34	1.837	T
Q-R	.67	4.8	430	.55	6.84	3.76	T
Q-S	.882	4.95	490	.55	1.4	.77	T
S-T	.882	4.95	490	.55	7.15	3.93	EL

Table 4.6: Friction Loss of Classroom

Section	Duct Loss (Pa)	Type	Fitting Loss (Pa)	Loss For Grille (Pa)	Total Friction Loss (Pa)
A-B	1.65	0	0	25	
B-C	3.542	EL	12.68		
C-D	3.76	T	0		

A-B-C-D	8.952	1EL+1T	12.68	25	46.632
A-B	1.65	0	0	25	
B-C	3.542	EL	12.68		
C-E	.165	T	4.87		
E-F	3.93	T	3.46		
A-B-C-E-F	9.287	1EL+2T	21.01	25	55.297
A-B	1.65	0	0	25	
B-C	3.542	EL	12.68		
C-E	.165	T	4.87		
E-G	2.3	T	4.39		
G-H	3.76	T	2.77		
A-B-C-E-G-H	11.417	1EL+3T	24.71	25	61.127
A-B	1.65	0	0	25	
B-C	3.542	EL	12.68		
C-E	.165	T	4.87		
E-G	2.3	T	4.39		
G-I	.33	T	4.05		
I-J	3.93	T	2.89		
A-B-C-E-G-I-J	11.917	1EL+4T	28.88	25	65.797
A-B	1.65	0	0	25	
B-C	3.542	EL	12.68		
C-E	.165	T	4.87		
E-G	2.3	T	4.39		
G-I	.33	T	4.05		
I-K	3.751	T	3.72		
K-L	3.93	T	0		
A-B-C-E-G-I-K-L	15.668	1EL+5T	29.71	25	70.378

A-B	1.65	0	0		
B-C	3.542	EL	12.68		
C-E	.165	T	4.87		
E-G	2.3	T	4.39	25	
G-I	.33	T	4.05		
I-K	3.751	T	3.72		
K-M	2	T	3.5		
M-N	3.76	T	2.77		
A-B-C-E-G-I-K-M-N	17.498	1EL+6T	35.98	25	78.478
A-B	1.65	0	0		
B-C	3.542	EL	12.68		
C-E	.165	T	4.87		
E-G	2.3	T	4.39		
G-I	.33	T	4.05	25	
I-K	3.751	T	3.72		
K-M	2	T	3.5		
M-O	1.76	T	3.1		
O-P	3.93	T	3.46		
A-B-C-E-G-I-K-M-O-P	19.428	1EL+7T	39.77	25	84.198
A-B	1.65	0	0		
B-C	3.542	EL	12.68		
C-E	.165	T	4.87		
E-G	2.3	T	4.39		
G-I	.33	T	4.05	25	
I-K	3.751	T	3.72		
K-M	2	T	3.5		
M-O	1.76	T	3.1		
O-Q	1.837	T	2.64		

Q-R	3.76	T	5.4		
A-B-C-E-G-I-K-M-O-Q-R	21.095	1EL+8T	44.35	25	90.445
A-B	1.65	0	0	25	
B-C	3.542	EL	12.68		
C-E	.165	T	4.87		
E-G	2.3	T	4.39		
G-I	.33	T	4.05		
I-K	3.751	T	3.72		
K-M	2	T	3.5		
M-O	1.76	T	3.1		
O-Q	1.837	T	2.64		
Q-S	.77	T	2.06		
S-T	3.93	EL	4.85		
A-B-C-E-G-I-K-M-O-Q-S-T	22.035	2EL+8T	45.86	25	82.895

Table 4.7: Duct Type and Duct Loss of 10th Floor

Section	V (m^3/s)	V (m/s)	D_{eq} (mm)	$\Delta P_f/L$	L (m)	Duct Loss (Pa)	Types
A-B	5.263	8	930	.65	3	1.95	0
B-C	5.263	8	930	.65	4.8	3.12	EL
C-D	.65	4.9	420	.65	3.958	2.573	T
C-E	.167	3.4	245	.65	4.913	3.193	T
C-F	4.446	7.8	870	.65	.85	.5525	T
F-G	.25	3.8	290	.65	8.673	5.637	T
F-H	4.196	7.7	840	.65	2.038	1.3247	T
H-I	1.134	5.5	500	.65	7.053	4.58	T
I-J	.734	5	430	.65	.685	.445	T
J-K	.167	3.4	245	.65	4.888	3.1772	T
J-L	.567	4.7	390	.65	2.825	1.836	T
L-M	.167	3.4	245	.65	4.888	3.1772	T
L-N	.4	4.4	350	.65	.16	.104	T
N-O	.4	4.4	350	.65	6.783	4.4089	EL
I-P	.4	4.4	350	.65	11.478	7.4607	T
P-Q	.4	4.4	350	.65	3.67	2.38	EL
H-R	3.062	7	680	.65	7.327	4.76	T
R-S	.08	2.9	190	.65	4.513	2.933	T
R-T	2.982	6.95	678	.65	1.456	.9464	T
T-α	.123	3.2	220	.65	4.068	2.6442	T
T-U	2.86	6.9	670	.65	2.347	1.53	T
U-V	.32	4.1	320	.65	6.938	4.51	T
V-W	.08	2.9	190	.65	5.8	3.77	T
V-A´	.08	2.9	190	.65	5.8	3.77	T
V-X	.16	3.35	240	.65	2.425	1.576	T
X-Y	.08	2.9	190	.65	5.8	3.77	T

X-Z	.08	2.9	190	.65	5.8	3.77	T
U-B´	2.54	6.7	650	.65	2.348	1.526	T
B´-C´	.123	3.2	220	.65	4.068	2.6442	T
B´-D´	2.417	6.65	645	.65	3.455	2.246	T
D´-E´	.08	2.9	190	.65	4.513	2.93	T
D´-F´	2.337	6.6	640	.65	1.24	.806	T
F´-α´	.123	3.2	220	.65	4.068	2.6442	T
F´-G´	2.214	6.5	635	.65	6.125	3.981	T
G´-H´	.273	3.9	290	.65	8.673	5.64	T
G´-I´	1.941	6.4	620	.65	.658	.427	T
I´-J´	1.141	5.5	500	.65	.192	.1248	T
J´-K´	.94	5.4	475	.65	3.958	3.72	T
J´-L´	.201	3.7	235	.65	4.696	3.0524	T
L´-M´	.2	3.7	235	.65	4.913	3.193	EL
I´-N´	.8	5.1	450	.65	7.738	5.03	T
N´-O´	.2	3.7	265	.65	4.888	3.1772	T
N´-P´	.6	4.8	400	.65	2.825	1.836	T
P´-Q´	.2	3.7	265	.65	4.888	3.1772	T
P´-R´	.4	4.4	350	.65	.16	.104	T
R´-S´	.4	4.4	350	.65	6.783	4.409	EL

Table 4.8: Friction Loss of 10th Floor

Section	Duct Loss (Pa)	Type	Fitting Loss (Pa)	Loss For Grille (Pa)	Total Friction Loss (Pa)
A-B	1.95	0	0	25	
B-C	3.12	EL	12.67		
C-D	2.573	T	0		
A-B-C-D	7.643	1EL+1T	12.67	25	45.313
A-B	1.95	0	0		

B-C	3.12	EL	12.67	25	
C-E	3.193	T	.07		
A-B-C-E	8.263	1EL+1T	12.74	25	46
A-B	1.95	0	0		
B-C	3.12	EL	12.67	25	
C-F	.5525	T	4.75		
F-G	5.637	T	0		
A-B-C-F-G	11.26	1EL+2T	17.42	25	53.68
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63	25	
H-I	4.58	T	4.9		
I-P	7.4607	T	3.48		
P-Q	2.38	EL	3.833		
A-B-C-F-H-I-P-Q	21.368	2EL+4T	34.263	25	80.63
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63	25	
H-I	4.58	T	4.9		
I-J	.445	T	2.1		
J-K	3.177	T	1.39		
A-B-C-F-H-I-J-K	15.15	1EL+5T	30.44	25	70.6
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63	25	

H-I	4.58	T	4.9		
I-J	.445	T	2.1		
J-L	1.836	T	1.72		
L-M	3.177	T	1.87		
A-B-C-F-H-I-J-L-M	16.99	1EL+6T	32.64	25	74.63
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-I	4.58	T	4.9	25	
I-J	.445	T	2.1		
J-L	1.836	T	1.72		
L-N	.104	T	1.5		
N-O	4.4	EL	3.83		
A-B-C-F-H-I-J-L-N-O	18.32	2EL+6T	36.1	25	79.42
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75	25	
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-S	2.933	T	0		
A-B-C-F-H-R-S	14.64	1EL+4T	26.46	25	66.1
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63	25	
H-R	4.76	T	4.41		

R-T	.9464	T	3.77		
T-α	2.6442	T	0		
A-B-C-F-H-R-T-α	15.3	1EL+5T	30.23	25	70.53
A-B	1.95	0	0	25	
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-V	4.51	T	0		
V-W	3.77	T	1.36		
A-B-C-F-H-R-T-U-V-W	22.4636	1EL+7T	35.3	25	82.77
A-B	1.95	0	0	25	
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-V	4.51	T	0		
V-A´	3.77	T	1.36		
A-B-C-F-H-R-T-U-V-A´	22.4636	1EL+7T	35.3	25	82.77
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		

H-R	4.76	T	4.41	25	
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-V	4.51	T	0		
V-X	1.576	T	.94		
X-Y	3.77	T	1.66		
A-B-C-F-H-R-T-U-V-X-Y	24.04	1EL+8T	36.54	25	85.58
A-B	1.95	0	0	25	
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-V	4.51	T	0		
V-X	1.576	T	.94		
X-Z	3.77	T	1.66		
A-B-C-F-H-R-T-U-V-X-Z	24.04	1EL+8T	36.54	25	85.58
A-B	1.95	0	0	25	
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-B´	1.526	T	3.5		
B-C´	2.6442	T	0		

A-B-C-F-H-R-T-U-B´-C´	18.36	1EL+7T	37.44	25	80.8
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41	25	
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-B´	1.526	T	3.5		
B´-D´	2.246	T	3.5		
D´-E´	2.93	T	0		
A-B-C-F-H-R-T-U-B´-D´-E´	20.89	1EL+8T	40.94	25	86.83
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77	25	
T-U	1.53	T	3.71		
U-B´	1.526	T	3.5		
B´-D´	2.246	T	3.5		
D´-F´	.806	T	3.42		
F´-α´	2.6442	T	0		
A-B-C-F-H-R-T-U-B´-D´-F´-α´	21.406	1EL+9T	44.36	25	90.77
A-B	1.95	0	0		
B-C	3.12	EL	12.67		

C-F	.5525	T	4.75	25	
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-B´	1.526	T	3.5		
B´-D´	2.246	T	3.5		
D´-F´	.806	T	3.42		
F´-G´	3.981	T	3.3		
G´-H´	5.64	T	0		
A-B-C-F-H-R-T-U-B´-D´-F´-G´-H´	28.38	1EL+10T	47.66	25	101.04
A-B	1.95	0	0	25	
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-B´	1.526	T	3.5		
B´-D´	2.246	T	3.5		
D´-F´	.806	T	3.42		
F´-G´	3.981	T	3.3		
G´-I´	.427	T	3.2		
I´-N´	5.03	T	4.68		
N´-O´	3.1772	T	1.64		
A-B-C-F-H-R-T-U-B´-D´-F´-G´-I´-N´-O´	31.38	1EL+12T	57.18	25	113.56

A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-B´	1.526	T	3.5	25	
B´-D´	2.246	T	3.5		
D´-F´	.806	T	3.42		
F´-G´	3.981	T	3.3		
G´-I´	.427	T	3.2		
I´-N´	5.03	T	4.68		
N´-P´	1.836	T	1.8		
P´-Q´	3.1772	T	1.97		
A-B-C-F-H-R-T-U-B´-D´-F´-G´-I´-N´-P´-Q´	33.22	1EL+13T	59.31	25	117.53
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-B´	1.526	T	3.5	25	
B´-D´	2.246	T	3.5		
D´-F´	.806	T	3.42		
F´-G´	3.981	T	3.3		

G´-I´	.427	T	3.2		
I´-N´	5.03	T	4.68		
N´-P´	1.836	T	1.8		
P´-R´	.104	T	1.51		
R´-S´	4.409	EL	3.833		
A-B-C-F-H-R-T-U-B´-D´-F´-G´-I´-N´-P´-R´-S´	34.55	2EL+13T	62.68	25	122.23
A-B	1.95	0	0	25	
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		
H-R	4.76	T	4.41		
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-B´	1.526	T	3.5		
B´-D´	2.246	T	3.5		
D´-F´	.806	T	3.42		
F´-G´	3.981	T	3.3		
G´-I´	.427	T	3.2		
I´-J´	.1248	T	2.541		
J´-K´	3.72	T	2.76		
A-B-C-F-H-R-T-U-B´-D´-F´-G´-I´-J´-K´	27.01	1EL+12T	56.16	25	108.17
A-B	1.95	0	0		
B-C	3.12	EL	12.67		
C-F	.5525	T	4.75		
F-H	1.3247	T	4.63		

H-R	4.76	T	4.41	25	
R-T	.9464	T	3.77		
T-U	1.53	T	3.71		
U-B´	1.526	T	3.5		
B´-D´	2.246	T	3.5		
D´-F´	.806	T	3.42		
F´-G´	3.981	T	3.3		
G´-I´	.427	T	3.2		
I´-J´	.1248	T	2.541		
J´-L´	3.0524	T	0		
L´-M´	3.193	EL	2.71		
A-B-C-F-H-R-T-U-B´-D´-F´-G´-I´-J´-L´M´	29.54	2EL+12T	56.11	25	110.65

Table 4.9: Duct Type and Duct Loss of 11th Floor

Section	V (m^3/s)	V (m/s)	D_{eq} (mm)	$\Delta P_f/L$	L (m)	Duct Loss (Pa)	Types
A-B	4.608	8	920	.69	3	2.07	0
B-C	4.608	8	920	.69	4.04	2.78	EL
C-D	.425	4.5	350	.69	8.3	5.73	T
D-E	.425	4.5	350	.69	2.04	1.4	EL
C-F	4.183	7.8	840	.69	2.035	1.4	T
F-G	.425	4.5	350	.69	5.12	3.53	T
F-H	3.76	7.5	800	.69	.665	.46	T
H-I	.32	4.25	315	.69	7.56	5.21	T
H-J	3.44	7.4	780	.69	4.74	3.27	T
J-K	.32	4.25	315	.69	7.56	5.21	T
J-L	3.12	7.2	760	.69	4.74	3.27	T
L-M	.32	4.25	315	.69	7.56	5.21	T
L-N	2.8	7	730	.69	4.08	2.82	T
N-O	.506	4.7	360	.69	6.71	4.63	T
N-P	2.294	6.8	660	.69	4.75	3.27	T
P-Q	.506	4.7	360	.69	6.71	4.63	T
P-R	1.788	6.2	600	.69	2.71	1.87	T
R-S	1.28	5.8	520	.69	5.68	3.92	T
S-T	.32	4.25	315	.69	2.72	1.88	T
S-U	.32	4.25	315	.69	2.72	1.88	T
S-V	.64	5	420	.69	3.74	2.58	T
V-W	.32	4.25	315	.69	2.72	1.88	T
V-X	.32	4.25	315	.69	2.72	1.88	T
R-Y	.508	4.7	360	.69	2.04	1.4076	T
Y-Z	.508	4.7	360	.69	6.71	4.63	EL

Table 4.10: Friction Loss of 11th Floor

Section	Duct Loss (Pa)	Type	Fitting Loss (Pa)	Loss For Grille (Pa)	Total Friction Loss (Pa)
A-B	2.07	0	0	25	
B-C	2.78	EL	12.67		
C-D	5.73	T	2.19		
D-E	1.4	EL	4		
A-B-C-D-E	11.98	2EL+1T	18.86	25	55.84
A-B	2.07	0	0	25	
B-C	2.78	EL	12.67		
C-F	1.4	T	4.75		
F-G	3.53	T	2.19		
A-B-C-F-G	9.78	1EL+2T	19.61	25	54.39
A-B	2.07	0	0	25	
B-C	2.78	EL	12.67		
C-F	1.4	T	4.75		
F-H	.46	T	4.2		
H-I	5.21	T	5.92		
A-B-C-F-H-I	11.92	1EL+3T	27.54	25	64.46
A-B	2.07	0	0	25	
B-C	2.78	EL	12.67		
C-F	1.4	T	4.75		
F-H	.46	T	4.2		
H-J	3.27	T	4.28		
J-K	5.21	T	1.95		
A-B-C-F-H-J-K	15.19	1EL+4T	27.85	25	68.04
A-B	2.07	0	0		
B-C	2.78	EL	12.67		

C-F	1.4	T	4.75	25	
F-H	.46	T	4.2		
H-J	3.27	T	4.28		
J-L	3.27	T	4.05		
L-M	5.21	T	0		
A-B-C-F-H-J-L-M	18.46	1EL+5T	29.95	25	73.41
A-B	2.07	0	0	25	
B-C	2.78	EL	12.67		
C-F	1.4	T	4.75		
F-H	.46	T	4.2		
H-J	3.27	T	4.28		
J-L	3.27	T	4.05		
L-N	2.82	T	3.82		
N-O	4.63	T	2.65		
A-B-B-F-H-J-L-N-O	20.7	1EL+6T	36.42	25	82.12
A-B	2.07	0	0	25	
B-C	2.78	EL	12.67		
C-F	1.4	T	4.75		
F-H	.46	T	4.2		
H-J	3.27	T	4.28		
J-L	3.27	T	4.05		
L-N	2.82	T	3.82		
N-P	3.27	T	3.6		
P-Q	4.63	T	2.65		
A-B-C-F-H-J-L-N-P-Q	23.97	1EL+7T	40.02	25	88.99
A-B	2.07	0	0		
B-C	2.78	EL	12.67		

C-F	1.4	T	4.75	25	
F-H	.46	T	4.2		
H-J	3.27	T	4.28		
J-L	3.27	T	4.05		
L-N	2.82	T	3.82		
N-P	3.27	T	3.6		
P-R	1.87	T	3		
R-S	3.92	T	10.5		
S-U	1.88	T	2.92		
A-B-C-F-H-J-L-N-P-R-S-U	27.01	1EL+9T	53.79	25	105.8
A-B	2.07	0	0	25	
B-C	2.78	EL	12.67		
C-F	1.4	T	4.75		
F-H	.46	T	4.2		
H-J	3.27	T	4.28		
J-L	3.27	T	4.05		
L-N	2.82	T	3.82		
N-P	3.27	T	3.6		
P-R	1.87	T	3		
R-S	3.92	T	10.5		
S-V	2.58	T	2.1		
V-X	1.88	T	3.25		
A-B-C-F-H-J-L-N-P-R-S-V-X	29.59	1EL+10T	56.22	25	110.81
A-B	2.07	0	0		
B-C	2.78	EL	12.67		
C-F	1.4	T	4.75		
F-H	.46	T	4.2		

H-J	3.27	T	4.28	25	
J-L	3.27	T	4.05		
L-N	2.82	T	3.82		
N-P	3.27	T	3.6		
P-R	1.87	T	3		
R-S	3.92	T	10.5		
S-V	2.58	T	2.1		
V-W	1.88	T	3.25		
A-B-C-F-H-J-L-N-P-R-S-V-W	29.59	1EL+10T	56.22	25	110.81
A-B	2.07	0	0	25	
B-C	2.78	EL	12.67		
C-F	1.4	T	4.75		
F-H	.46	T	4.2		
H-J	3.27	T	4.28		
J-L	3.27	T	4.05		
L-N	2.82	T	3.82		
N-P	3.27	T	3.6		
P-R	1.87	T	3		
R-Y	1.4076	T	2.13		
Y-Z	4.63	T	4.374		
A-B-C-F-H-J-L-N-P-R-Y-Z	27.2476	1EL+9T	46.874	25	99.1216

CHAPTER 5

AIR CONDITIONING SYSTEM ANALYSIS

5.1 Central Air Conditioning System Analysis

Central Air Conditioning system is based on three important system analyses:

1. Duct Design

2. Selection of Chiller

3. Selection of Air Handling Unit (AHU)

5.2 Selection of Chiller

Chillers provide heat removal for a wide variety of processes and equipment. When properly sized and selected, a chiller increases production speed and accuracy, protects valuable process equipment, and reduces water consumption and related costs. If it is undersized, the chiller will not cool properly; if it is oversized, it will be inefficient due to excessive cycling. In addition to having an adequate cooling capacity, the chiller must deliver the cooling fluid at the proper pressure and flow rate. There are also some significant features for choosing a particular model:

- The installation of the unit is flexible.
- Open type model is highly convenience for maintenance and reduces service space.
- It should be controlled at the site over long distance.
- The brand of the chiller should be recognized in international market.
- It has shell and tube evaporator structure with fire proof and water proof material as heat preservation.
- Heat gain can be minimized by insulating the cooling line and positioning the chiller as close as practical to the equipment or process being cooled.
- It is crucial that chiller should deliver coolant at the proper flow rate and pressure. If the flow rate or pressure is too high, the equipment being cooled may be damaged; if it is too low, the heat removal will be inadequate.
- High automatic management with completely features to realize unit start up and shut down, timing control, water pump control, malfunction alarm and self diagnosis features.

5.2.1 Specification of Chiller

- Brand Name : Trane, Optimus
- Model Number : RTHD
- Type : Water Cooled
- Cooling Capacity : 225 Ton
- Power Required : 174 KW
- Refrigerant Type : R134a
- Evaporator Type : Shell and Tube
- Overall Size : Length 3048mm*Width

1070mm*height 2000mm

- Weight : 4266 Kg

5.3 Selection of Air Handling Unit

The AHU consists of several section like casing, mixing, inlet, cooling, filter, heating, access, humidifier, fan and silencer section.

- The brand of this AHU should be recognized in international market.
- It should fulfill required cooling load for each floor.
- It should be internally insulated.
- Variable speed fan and blow through design.
- It should have main circuit breaker and phase protection.
- It should be economical and less maintenance cost.
- The fan used inside, should be belt type.
- Cam and groove type water connections.

5.3.1 Specification of AHU

1st AHU:

- Brand Name : Trane, Quantum
- Model Number : Quantum XP 060
- Power Required : 30 KW
- Voltage : 230 V
- Dimensions (L*W*H) : 4040*3260*2450
- Cooling Capacity : 421.31 KW
- Frequency Phase : 60 Hz
- Weight : 2479 Kg
- Flow Rate : 18.26 L/s

2nd AHU:

- Brand Name : Trane, Quantum
- Model Number : Quantum XP 050
- Power Required : 22 KW
- Voltage : 230 V
- Dimensions (L*W*H) : 3885*3260*2140
- Cooling Capacity : 356.42 KW
- Frequency Phase : 60 Hz
- Weight : 2160 Kg
- Flow Rate : 15.45 L/s

CHAPTER 6
ECONOMIC ANALYSIS

6.1 Economic Analysis

6.1.1 For Central Air Conditioning System

Power Consumption for different elements of a Central Air Conditioning System are given below,

1. Pump 35 KW
2. Compressor- For water cooled Chiller it is 170 KW
3. Motor for cooling tower fan 10 KW
4. Air cooled chiller blower 10 KW

Total power consumption = (170+35+35+10) ×2 KW

= 500 KW

Total power consumption of AHU = 156 KW

Total units of electricity used in a month = (500+156) ×8×5 = 26240 units

Total cost = 1,171,110 × 9.8 taka = 257152 taka where 9.8 is tariff rate approved by DESCO

6.1.2 For Split Air Conditioning System

Power consumption by Split AC,

1. 4 ton 6.1 KW

2. 3 ton 4.6 KW

3. 2 ton 2.8 KW

4. 1.5 ton 1.6 KW

Total power consumption = (75*6.1+39*4.6+19*2.8+9*1.6)*8*5

=28180 units

Total cost = 28180*9.8 = 276164 taka

6.2 Comparison between Costs

Table 6.1: Comparison between Costs

Time	Cost in Central AC (Taka)	Cost in Split AC (Taka)	Profit (Taka)
1 month	257152	2761764	19012
1 year	3085824	3313968	228144
5 year	15429120	16569840	1140720
10 year	30858240	33139680	2281440

CHAPTER 7
CONCLUSION

7.1 Conclusion

Central air conditioner offers major benefit over individual window units and it improves indoor air quality than split system. It is the most efficient ways to circulate cool air throughout the space other than split system or window units.

In this design the cooling load has been calculated using different equations for heat transmission through barriers such as walls, glass, roof, doors, floors, partitions, solar radiation, occupants, internal load, ventilation, infiltration and other miscellaneous. This process is an ASHRAE recommended method. The duct system for the floors has been done in equal friction method as it is applicable for medium pressure and velocity duct systems. So, equal friction method is more relevant to apply on our proposed system.

Chillers and Air Handling Units (AHU) have been selected in a way that can fulfill the requirement. The whole system must run effectively.

There is an economic analysis which can show the differences of monthly and annual costs between the central and the split air conditioning system.

Though the power production in Bangladesh is increasing day by day with the increasing population, there is still some lacking in power generation to provide power in all sectors. To reduce the large amount of power consumption and economic cost, a central air conditioning system is much more effective and relevant than window or split system.

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