Design of HVAC system for clean room and highly potent drug

By

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DEPARTMENT OF MECHANICAL ENGINEERING

INSTITUTE OF TECHNOLOGY
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AHMEDABAD-382481

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Design of HVAC system for clean room and highly potent drug

Major Project Report

Submitted in partial fulfillment of the requirements

For the Degree of

Master of Technology in Mechanical Engineering (Thermal Engineering)

By

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MAY 2016

Declaration

This is to certify that

1. The thesis comprises of my original work towards the degree of Master of Technology in Thermal Engineering at Nirma University and has not been submitted elsewhere for a degree or diploma.

2. Due acknowledgement has been made in the text to all other material used.

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Undertaking for Originality of the Work

I, Harshit sharma, Roll. No. **14MMET11**, give undertaking that the Major Project entitled **"Design of HVAC system for clean room and highly potent drug"** submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Mechanical Engineering (Thermal Engineering)** of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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This is to certify that the Major Project Report entitled **"Design of HVAC system for clean room and highly potent drug"** submitted by **Mr. Harshit Sharma (14MMET11)**, towards the partial fulfillment of the requirements for the award of Degree of **Master of Technology in Mechanical Engineering (Thermal Engineering)** of Institute of Technology, Nirma University, Ahmadabad is the record of work carried out by him under our supervision and guidance. In our opinion, the submitted work has reached a level required for being accepted for examination.The result embodied in this major project, to the best of our knowledge, has not been submitted to any other University or Institution for award of any degree.

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Harshit Sharma

Abstract

Heating ventilation and air conditioning (HVAC) plays an important role in modern building structures. HVAC is an important system for controlling of temperature, relative humidity and to maintain the specified conditions. Components like variable air volume and thermosts are used to control fluctuation of air volume entering with the help of valves, dampers and hence used to get higher energy efficiency. Air handling unit maintains flow of air with required conditions.

In the present study, HVAC system is designed for clean room and highly potent drug to control viable and non-viable particles, temperature, relative humidity, hygiene zone for different process area as per drug regulation. The methodology of design follows architectural layout study, area classification and pressure zoning, air handler zoning and calculations with design qualification sheet. Sensible as well as latent heat loads were considered in the calculations of capacity of air handling unit. The ASHRAE and Good Manufacturing Practices (GMP) guidelines were followed in the design. In the design, diversity factor and bypass factor were considered as 70% and 5% respectively. The total dehumidified rise was considered for summer and monsoon and was compensated by cooling coil. From the design, total reheat capacity and total chilling capacity were found as 84 kW and 542 TR respectively.

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Abbreviations

WB	Wet bulb temperature
DB	Dry bulb temperature
RSH	Room sensible heat
ERSH	Effective Room sensible Heat
(ERLH)	Effective Room Latent Heat
ERTH	Effective Room Total Heat
AHU	Air Handling Unit
CFM	Cubic feet per minute
(GTH)	Grand Total Heat
BTU	British Thermal Unit
TR	Tonnes of Refrigeration
SA	Supply Air
FPS	Foot Pound Second System
FA	Fresh Air
ACPH	Air Changes Per Hour

Chapter 1

Introduction

1.1 Company Profile

Doshi Consultants, started in 1986 provides turnkey consultancy services for projects following norms of world health orgainisation (WHO), good manufacturing practice (GMP), United States Food and Drug Administration(USFDA),Medicines and Healthcare products Regulatory Agency (MHRA), Therapeutic Goods Association (TGA) . Companys excellence is justified by the ISO 9001:2000 certification and companys expertise is acknowledged by several high profile projects successfully completed in India and abroad. Established in 1986 with an aim to be excellent in field of engineering as consultant. Today, the company is among top consulting companies related to engineering that provides turnkey solutions for medical applications, food processing. The firm has been involved in creating and applying innovative solutions for projects which are complex in various firms for the time span of past 29 years, determined to remain market leader.[25]

1.2 Introduction to HVAC

HVAC is an acronym for Heating Ventilation and Air Conditioning. Heating and air conditioning are used to control temperature. The field of heating, ventilation, and air conditioningHVACis a science and practice of controlling indoor climate, thereby providing health and comfortable interior conditions for occupants in a well-designed, energy-efficient, and low emissions manner. The term "H" in HVAC stands for heating that comprises of any number of heating systems from gas furnaces, electric furnaces, oil furnaces, oil and gas boilers, radiant heating systems, and heat pumps. The Term V in HVAC describes ventilation. This can be ventilating the facility using ductwork or ventilating a kitchen using ductwork and fans with a hood. It can also refer to combustion air or the air needed to have combustion for various heating systems. The Term "AC" in HVAC refers to air conditioning that comprises of 3 main methods mechanical compression, vapor absorption and evaporative cooling. Air conditioners (direct expansion DX systems) and chillers usually accomplish the job of air conditioning

1.3 Components of HVAC

Air-conditioning system has main function to regulate temperature, humidity and velocity of the air. System should be design in such a way that maintain the require condition, however if there is change in ambient condition of air. Air is to be cooled by means of DX system or chiller system that cool air passing through the air distribution channel and reach to the condition space. Air distribution channel consist of AHU, ducts, dampers, risers etc. Each component having particular functions which are as below,

Compressor: Moves the refrigerant through the system.

Condensers coils: Rejects heat absorbed from the air along with the heat added to the system during the compression process.

Condenser Fans: Draw ambient air across the condensing coil.

Expansion Device: Causes expansion cooling by creating a pressure loss between the high and low side of the system.

Filter-Dryer: Removes water, debris and other contaminants from the refrigerant.

Evaporator Coil: The evaporator coil transfers heat from the warm air to the cool refrigerant.

Water pipe lines: this pipes are used for transferring cool and chilled water.

Valve: Valves are used to maintain water flow rate.

Water Pumps : Pumps are used to pump up the water and that will passing to the insulated pipe.

Insulated pipes: In chiller system water is used as the coolant for air so,it must be passing through insulated pipe and reach to cooling coil in AHU so minimum heat gain taked place.

AHU (Air handling units) : This units are used in to supply and extract air from ducts it consists blower, motor, cooling coil, heating coil and filters. It has provision for inlet fresh air removal of exhaust air.

Ducts and Risers: Ducts are used for air transport, it has many shapes selection among them is depends upon aesthetic and pressure gradient parameters. Risers use for sucking foul air from the room and transferring it to duct and AHU.

Dampers and grills : Dampers and grills are use to direct the air flow and provide required air pattern. Amount of air supply to the room can also be manage by dampers.The schematic diagram of air handling unit,chiller and p-h diagram of chiller is shown in Figure 1.1, 1.2, 1.3 respectively.

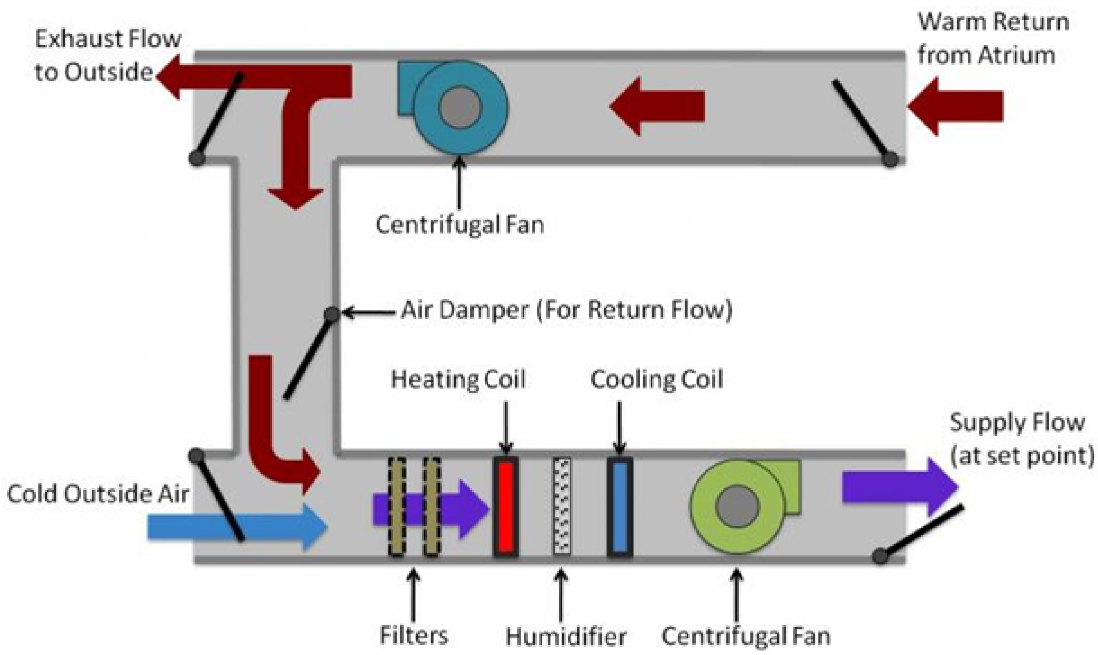


Figure 1.1: Schematic diagram of air handling unit [26]

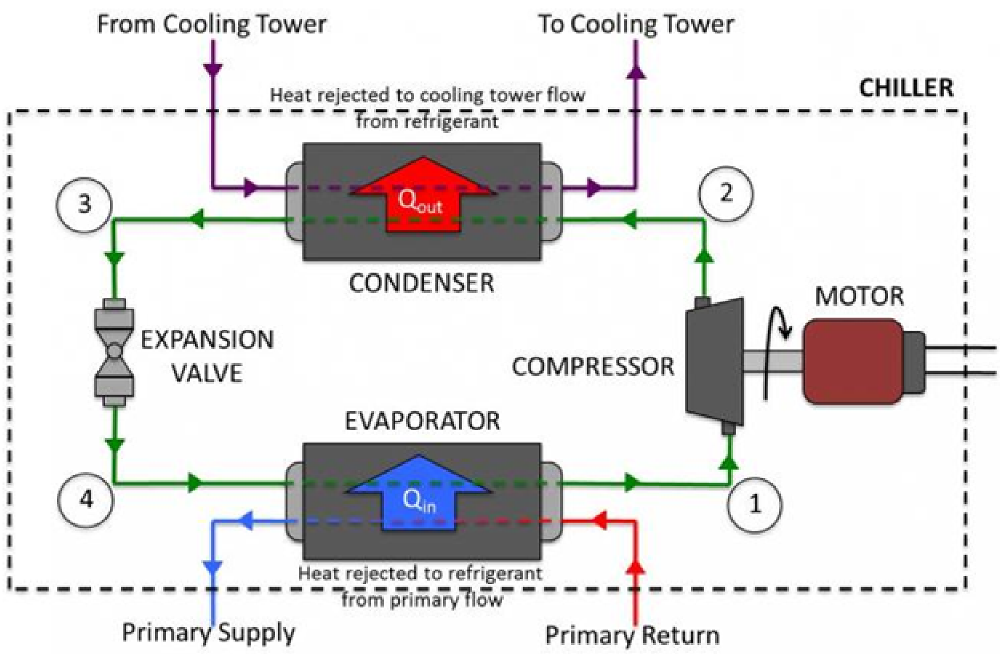


Figure 1.2: Schematic diagram of chiller [26]

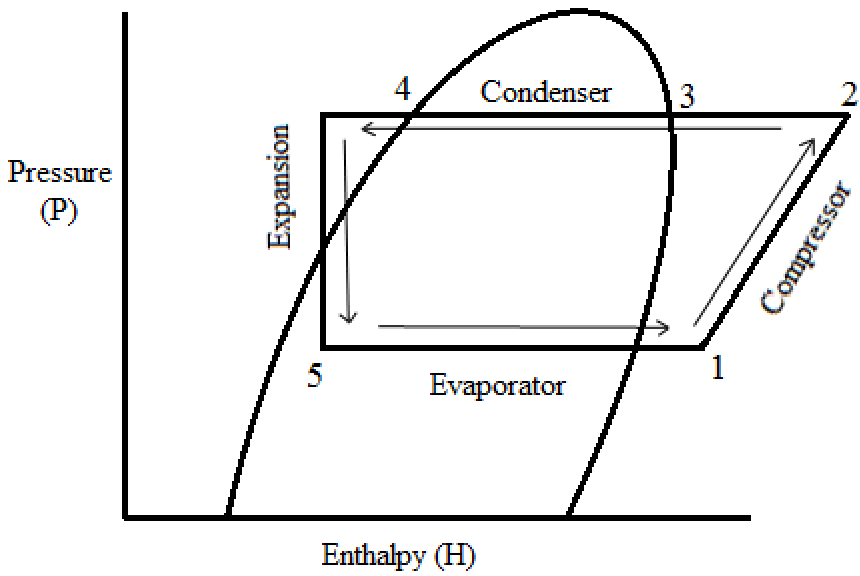


Figure 1.3: P- h diagram of chiller [21]

1.4 Cleanroom

1.4.1 What is Cleanroom?

A room in which the concentration of airborne particles is a room is controlled, and which is constructed and used to minimize the introduction, generation, and retention of particles inside the room and in which other relevant parameters e.g, temperature, pressure are controlled as necessary. Figure 1.4 shows the clean room.

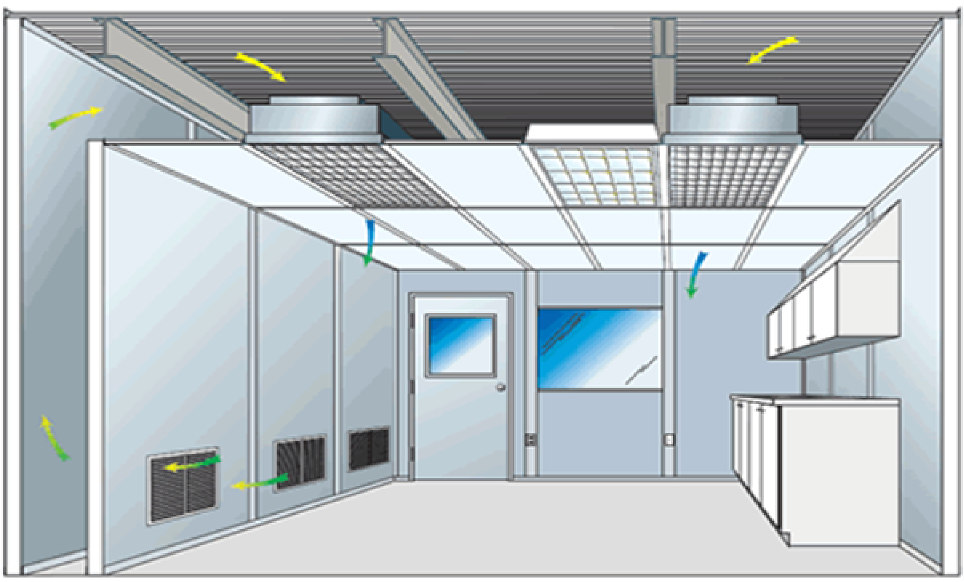


Figure 1.4: Clean room [22]

1.4.2 Cleanroom for Pharmaceutical Industry.

Within the pharmaceutical industry, and ,in particular, that part is related to manufacturing of sterile products, a single clean room is rarely encountered. Rather there are suits of rooms, integrating various grades or classes in room to accommodate different parts of manufacturing process. The relationship between the pharmaceutical clean area with in total quality assurance program is important to understand. The design and function of pharmaceutical manufacturing area is significant part of Good Pharmaceutical Manufacturing Practice (GPMP). It helps to understand behavior of microorganisms in drugs and medicines during production and stability of compositions.Pharmaceutical plants process classified into three segments 1. Injectables: those products which are injected into the person. 2. Tropicals: those that are applied to the outside of human body. 3. Orals: those that are injected.

Some of basic criteria to be consider which affects room cleanliness

Building structure

Air filtration

Air change per hour

Room pressure

Temperature and RH

Material and personnel flow

Occupancy.

Equipment movement

Type of products

Outside air condition

Clean room is classified by the cleanliness of their air. Its depends on dust particles remain in the room at at-rest, at-build, at-operation.

At-build: Condition where installation is complete with all services connected and functioning but with no production equipment, materials or personnel present.At-rest: Condition where installation is complete with equipment installed and operating in a manner agreed upon by the customers and suppliers, but with no personnel present. At-operation: Condition is normally carried out during the normal production process with equipment operating and total number of personnel in present in the room.

Air Patterns in clean rooms are playing major roles in case maintaining cleanliness. Types of cleanroom flow

Conventional type of cleanroom flow

Unidirectional flow

Mixed type of cleanroom flow

Minienvironment

1.5 shows Conventional clean room flow

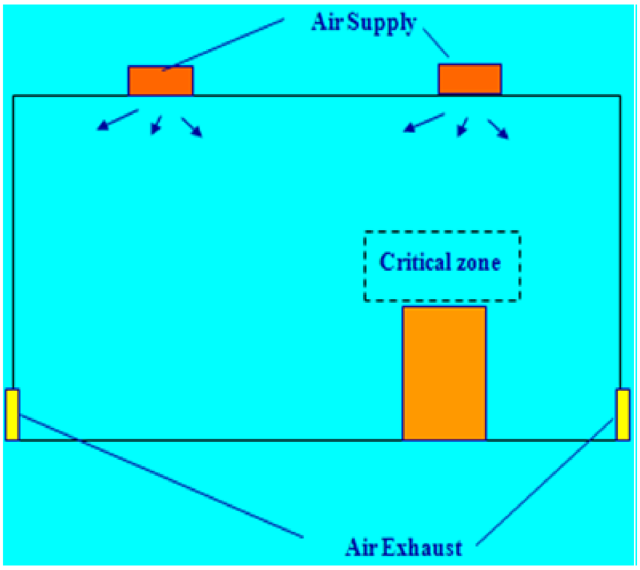


Figure 1.5: Conventional clean room flow [22]

1.6 shows unidirectional clean room flow

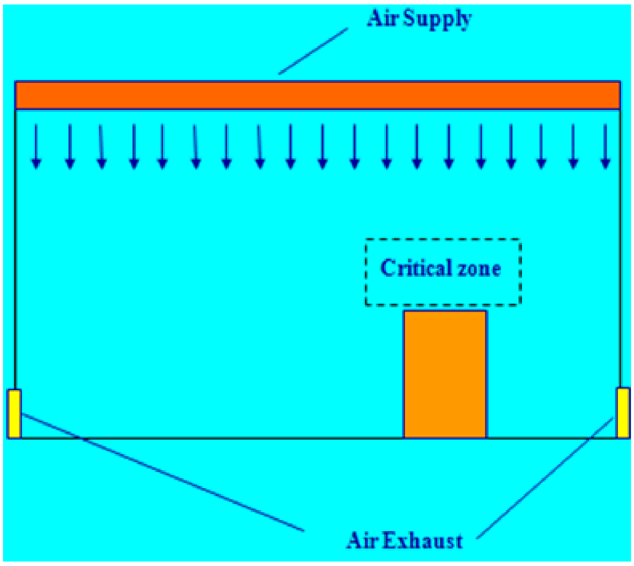


Figure 1.6: unidirectional clean room flow [22]

1.7 shows Mixed clean room flow

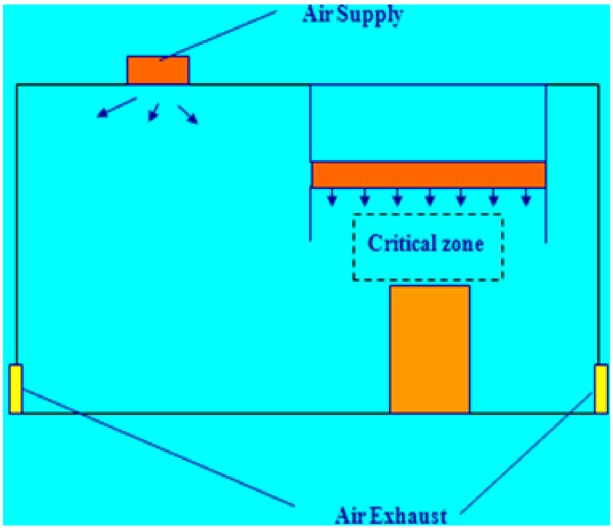


Figure 1.7: Mixed clean room flow [22]

1.8shows Minienviorment clean room flow

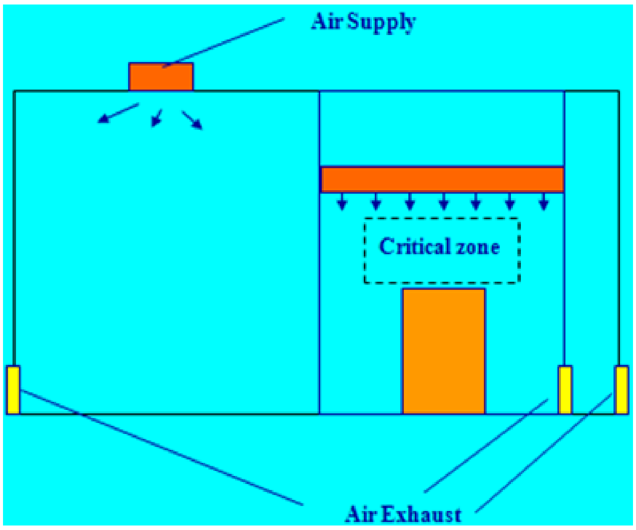


Figure 1.8: Minienviorment clean room flow [22]

1.1shows cleanliness (air particles) classification for manufacturing

Table 1.1: Cleanliness (Air particles) classification for manufacturing [23]

	At -Rest	At -Operation
Grade	Maximum permissible number of particles/m^3equal to or above	
	0.5μm	0.5μm
A	3500	3500
B	3500	350000
C	350000	35000000
D	3500000	NOT DEFINED

1.4.3 Application of Cleanroom

Demand for clean room is flourishing as manufacturing becomes widely increasing. More and more products require better manufacturing with contamination controlled environment. Some of industries listed below are using clean rooms for their product manufacturing.

1.2 shows clean room applications

Table 1.2: Clean room application [23]

S.No.	Indrustries	Products
1.	Electronics	Computers,TV tubes,Magnetic tapes
2.	Semiconductors	Integrated circuits
3.	Optics	Lenses,Films,Lasers
4.	Biotechnology	Antibiotics,Genetic engineering
5.	Pharmacy	Sterile Pharmaceuticals
6.	Medical devices	Heart valve,By pass system

1.4.4 HVAC System to Design Cleanroom

HVAC system provides ease of control for desired room condition. With help of cooling and heating system maintains room temperature and relative humidity and with help of ventilation system it provides dust control. One should understand the efficiency of system depends on the air handling system.

Provide filtered supply air at sufficient flow rate and with effective flow patterns to reach a specified class of cleanliness.

Provide filtered outdoor air for occupants and equipment.

Exhaust effectively unwanted chemicals.

Maintain specified cleanroom pressure.

Add or remove moisture to regulate cleanroom humidity.

Add or remove thermal energy to regulate cleanroom temperature.

1.5 Objective of Present Study

The major objectives of present study are as under:

- To design the HVAC system for clean room and highly potent drug to control viable and non-viable particles, temperature, relative humidity, hygiene zone for different process area as per drug regulation, ASHRAE and Good Manufacturing Practices (GMP) guidelines

- To prepare reflected ceiling plan and AHU location drawing for ducting drawing of HVAC system

- To carry out Air Handling Unit Design and to check and approve actual GA drawing from vendor
- To carry out designs of ducts, valves, thermostat etc. for HVAC system under consideration
- To carry out selection of grills, diffusers, registers

Chapter 2

Literature Review

In this chapter litereature review pertaining to optimization,analysis,experimental and case study of Heating Ventilation and Air Conditioning systems is presented

Zeng et al. [1] done optimization of energy requirement of HVAC with the help of data mining algorithm. Variables subjected to be optimized include supply air temperature, static pressure of supply air. With the help of data mining algorithm models were created and by using heuristic and firefly algorithm optimized result was found to carry out detailed study for the minimum energy use in a HVAC system which is divided into many zones at the same time providing required RH and Temperature in each part of system. In starting, statistical models were used to find energy usage in system and ambient conditions. After this, problem of energy optimization was defined with variables and solution was obtained for the optimal parameters for consumtion of energy is as low as possible as well as constraint of environment conditions were maintained. In this optimization sequence is followed to set pressure and temperature

Brooks et al. [2] suggested an algorithm based on number of persons feedback control for HVAC systems with variable air volume which was used in the constrained case one HVAC equipment was used in multiple rooms. The suggested algorithm was extendable to any buildings with any size without creating complexity. Results of experiments in five rooms revealed 2980% potential of savings in energy.Inspite of being unable to condition rooms individually by independent system because of the common HVAC equipment, well maintained comfort level was found inspite of one of the room was cooler and another was warmer. The experimental setup is shown in Fig. 2.1.

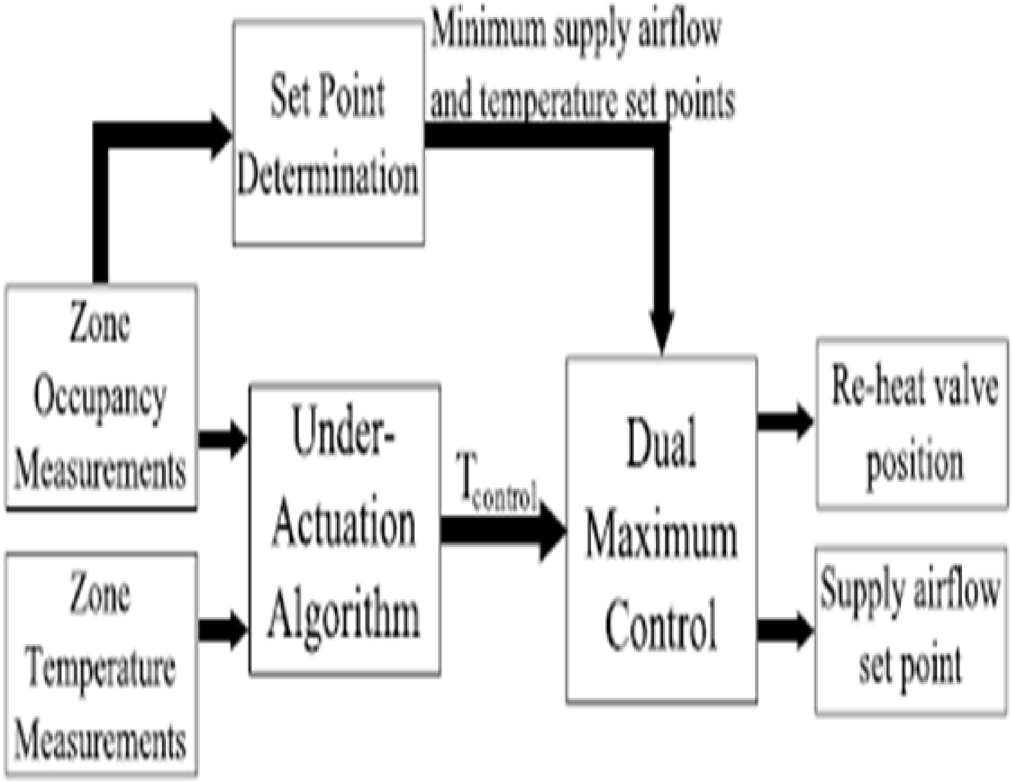


Figure 2.1: Experimental setup

Ghosh and Dincer [3] assessed new integrated system based on exergy analysis results for performance evaluation.Energy efficiency and exergy efficiency both were obtained for each components,and for each subprocesses and compared with integrated system for different capacities under different conditions. Studies of paremeters were done by varying properties of dead state and conditions of operations for analysis of their effects on the performance of system and a new integrated system including processes of psychrometry was suggested and analysed thermodynamically . Results show increase in exergy and energy efficiency of integrated system.

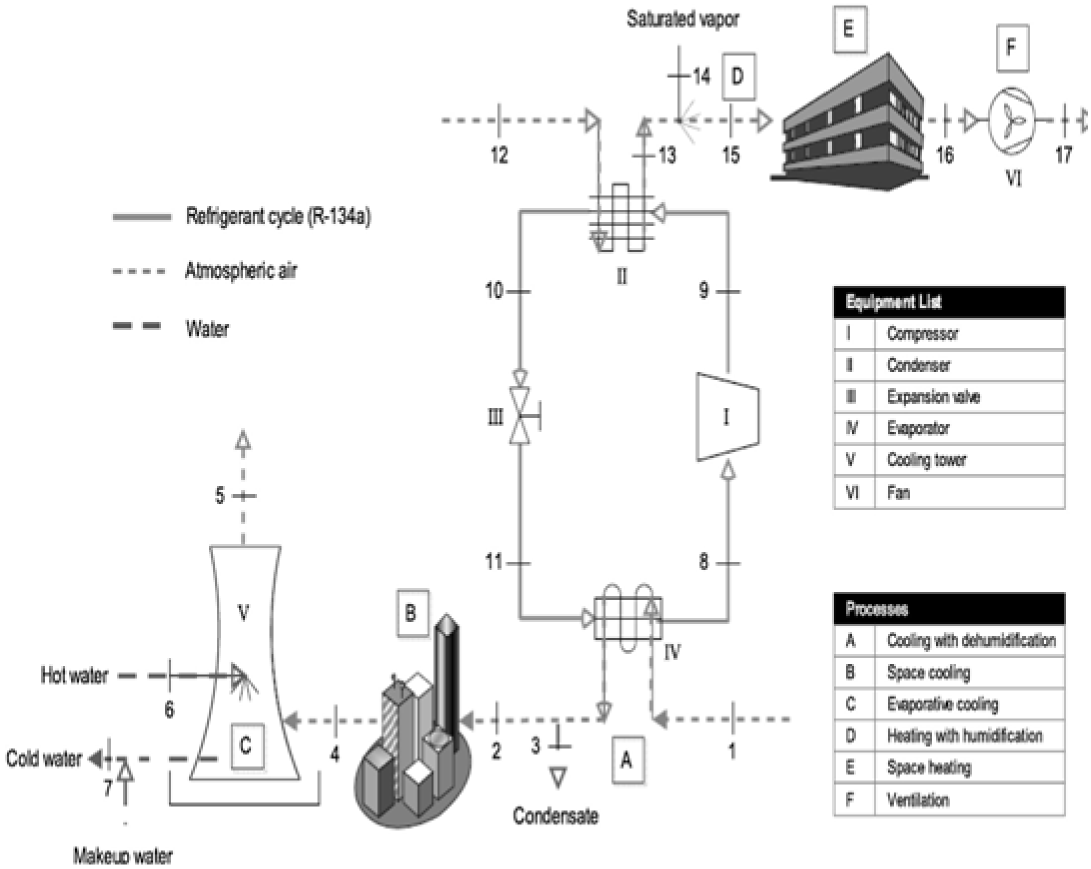


Figure 2.2: Integrated system

Liu et al. [4] performed, a series of field tests for investigation of the dust loading and contamination characteristics of culturable microorganisms in HVAC systems for 24 office buildings, including the investigation of temperature, RH, air velocity,dust loading, culturable fungi/bacteria loading,in the following: supply air segments, fresh air,mixture of air, cooling, and return air. On the basis of these measuring results, the culturablefungi/bacteria number present in each gram dust was obtained and the species of predominant culturable fungi/bacteria found. The fresh air segments were found to have maximum dust loading and number of culturable fungi/bacteria loading . Result measurements showed deposition of dust should be properly controlled in HVAC systems to check the growth of bacteria and culturable fungi . The schematic diagram of duct is shown in Fig.2.3.

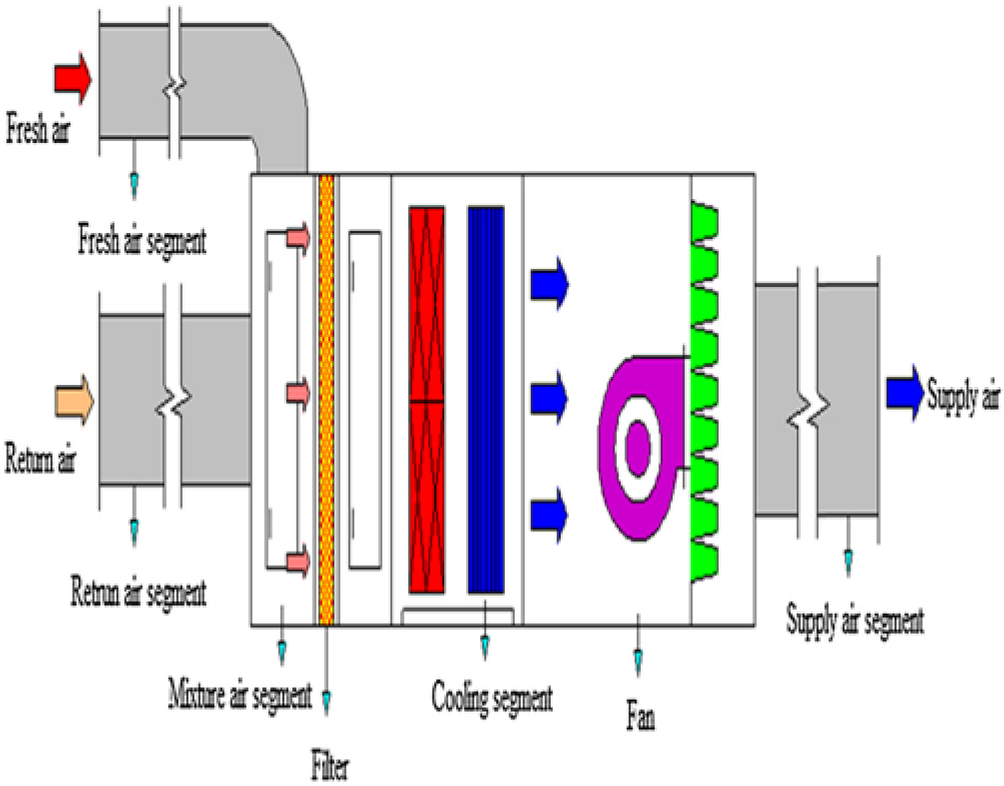


Figure 2.3: Schematic diagram of duct

Du et al. [5] developed, Method of CPI (control-perfect index) for evaluation of HVAC systems controls and to obtain the dissimilarity of ideal operation with strategy of candidate on the basis of the models of exergy analysis. By minimization of loss of the available energy in HVAC system, the nearly-ideal operation as compared to a particular operation condition was obtained by DEA (data envelopment analysis) method, the optimization limit is decided by limiting ideal operation treated as ideal operation

Razmara et al. [6] showed an available energy model for a building.Exergy is used extensively to evaluate efficiency of energy systems and the efficiency of energy conversion processes. exergy destruction, that is loss of work potential, was expressed as a function of physical parameters of the building model and of environment also. For minimization of destruction of exergy in HVAC system, the technique which was used was model predictive technique(MPC).As Compared to a traditional onoff controller the proposed exergy-based MPC (XMPC) is found to reduce the loss of exergy and consumption of energy

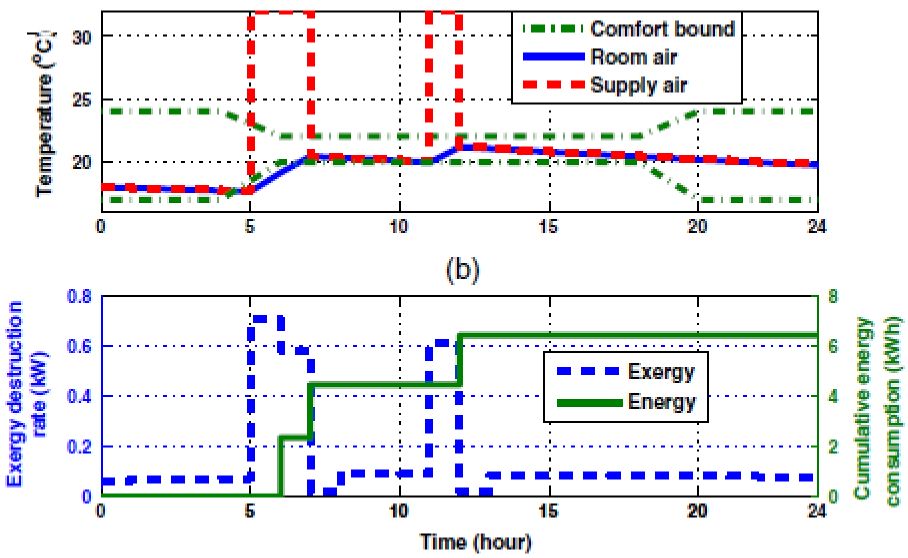


Figure 2.4: Exergy analysis result

Khalid et al. [7] suggested and assessed three systems which were newly developed for applications of heating and cooling applications in buildings . The performance of heating system, cooling system and overall systems was assessed by the analyses of energy and exergy for each condition, and the examination of effects of various parameters on the energy and exergy efficiencies is done. Also, the changing the energy input for each system was also expressed in terms of overall efficiency. The PhotoVoltaic and solar thermal operated system was found to be highest in overall efficiency

Lombard et al. [8] done analysis of the preparation of building energy codes. Objective is energy codes for buildings for value of efficiency of HVAC system get energy efficient design in new buildings . Important aspects for the development of Guidelines and performance regulatory paths for HVAC systems in non-residential buildings are collected for improvement in the understanding of HVAC energy efficiency topics and to enhance options to policy makers to strengthen the HVAC section by use of energy codes for buildings

Zhao et al. [9] suggested a direct method of using HVAC systems for providing FR and an indirect method for providing FR each of the methods were developed as models and simulation testing is also done which provides the support theoritically and showed the need for using HVAC systems to provide FR. A substantial amount of electric power is used in HVAC systems. frequency regulation (FR) can control passively consuming energy,in response to a signal to the electric grid by adjusting the power consumption by the electric grid operator. And problems of using HVAC systems of commercial buildings for FR is addressed and due to this a new supervisory control method for providing FR services to HVAC system is introduced.

Results based on simulations on the rules based on performance are evaluated suggested by the PJM regional transmission organization and provide guidelines for future testing

Gruber et al. [10] for controlling temperature of air supplied investigated four alternative strategies in offices through simulations. In this study conventional outdoor air temperature based method was compared with two HVAC systems and set as benchmark .As compared to the benchmark,alternative strategies which were evaluated by simulation showed in lower energy usages while maintaing thermal comfort and indoor air quality,dependence on type of HVAC system and upto some extent on building structure is shown.

Lombard et al. [11] discussed the energy flow map to provide comfort that is the energy chain of HVAC systems.In this approach comfort is analysed as the final service to occupants. The spaces which were conditioned were analysed as control volume where usefull energy is used to provide comfort. HVAC systems use major part of building energy almost 50% in developing countries and 10% to 20% in developed countries. This study was done to establish common guidelines for energy analysis. Next the analysis of HVAC systems as control volume devices in which coolth and heat that is thermal comfort is obtained by energy carriers,and finally, the effect of energy consumption in hvac system is analysed with respect to available energy resources

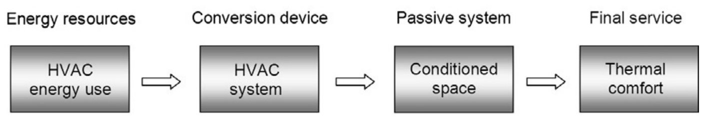


Figure 2.5: Map of energy flow

Seo et al. [12] proposed an optimal design method for the HVAC system in apartment using a genetic algorithm and to examine the possibility for the energy conservation of a designed HVAC system. The energy demand for cooling and heating in apartment house was determined by using TRNSYS. By a modified genetic algorithm called multi-island genetic algorithm, the optimal running pattern of HVAC systems was decided to minimize the energy consumption. An optimal design method for the HVAC system of the apartment house was proposed using both genetic algorithm and data of cooling/heating demand load simulated by TRNSYS. It had been confirmed that energy for equipment systems in apartment house can be saved by using operation plan of HVAC systems. The results showed that the proposed method was significantly capable of determining optimal system design for saving energy in apartment house

Kusiak et al. [13] optimized the energy consumption of a heating, ventilating and air conditioning (HVAC) system by using a data-driven approach. Predictive models with controllable and uncontrollable input and output variables utilized the concept of a dynamic neural network. The minimization of the energy consumed while maintaining indoor room temperature at an acceptable level was accomplished with a bi-objective optimization. The model was solved with three variants of the multi-objective particle swarm optimization algorithm. The optimization model and the multi-objective algorithm had been implemented in an existing HVAC system. The test results performed in the existing environment demonstrate significant improvement of the system

Huang et al. [14] suggested a working model of design of HVAC system capable of dealing with uncertainty within the design directly , and evaluation of the performance of a design in intermediate states of various index of performance as well as requirements of customers and choices, that is the concept of this new design method is of more than one criteria for deciding system.HVAC systems are extensively used in modern buildings for maintaining desired conditions indoor and ensure the quality of supply air. In existing design methodology, the parts of an HVAC system are designed according to a estimated peak load, calculated as per typical ambient condition, building material and load due to occupancy,appliances that is internal load.Certain level of uncertainties are always with this prediction as shown by studies. Analysis of a particular case is done for the explanation of procedure of design and the comparison of result with the method of conventional design is shown.

Yu et al. [15] made a test chamber in a way to represent the characteristics of an office room, In order to study the cooling performance of this system. A novel HVAC system combining natural ventilation with diffuse ceiling inlet and thermally activated building systems (TABS) has the ability to fulfill the requirements of cooling and ventilation in future Danish office buildings. Twenty cases were tested under steady-state conditions, including ten cases without ceiling panel and ten cases with ceiling panel. An energy balance analysis showed that the tests had quite good accuracy, with an error of less than 10%. Both the cooling capacity of TABS and the influence of ceiling panel were investigated. The U-value of TABS water side to the room side was almost constant, but the effectiveness of TABS decreased with log mean temperature difference (LMTD) for both cases with and without ceiling panel. Experimental data was used to evaluate the thermal performance of this system, and it is also beneficial to the design of this system

Wang et al. [16] investigated energy conservation performance of one passive school building and classroom thermal comfort enhancement simultaneously. Decreasing the building energy consumption and improving thermal comfort through optimization of heating, ventilation and air conditioning (HVAC) control systems are becoming increasingly significant due to global energy crisis, carbon emission and requirement of high life quality for people. Therefore, evaluation on building energy efficiency and human thermal comfort is extremely necessary. In this work, energy conservation performance of one passive school building and classroom thermal comfort enhancement was simultaneously investigated. Energy performance of single reference classroom under six design points and whole school building with two scenarios had been numerically investigated concerning the effects of different indoor set-point temperatures, pre-ventilation, sunshading system, and the efficiency of the heat recovery facility. Numerical results demonstrated that heating and cooling demands heavily depend on indoor set-point temperature, occupancy and heat recovery rate. Building energy performance analysis illuminates that the optimized control systems for HVAC and sun-shading systems show an expectedly energy efficient performance

Shahrestani et al. [17]analysed problem of the effect of the variety of HVAC&R systems on building energy performance was not taken in benchmark and the existing building energy benchmarks were not able to assist decision-makers with HVAC&R system selection. Heating, ventilation, air conditioning and refrigeration (HVAC&R) systems accounted for more than 60% of the energy consumption of buildings in the UK. The study attempted to overcome these two deficiencies through the performance characterisation of 36 HVAC&R systems based on the simultaneous dynamic simulation of a building and a variety of HVAC&R systems using TRNSYS software. To characterise the performance of HVAC&R systems, four criteria were considered; energy consumption, CO_2 emissions, thermal comfort and indoor air quality. The results of the simulations showed that, all the studied systems were able to provide an acceptable level of indoor air quality and thermal comfort. However, the energy consumption and amount of CO_2 emissions vary. One of the significant outcomes of this study revealed that combined heating, cooling and power systems (CCHP) had the highest energy consumption with the lowest energy related CO_2 emissions among the studied HVAC&R systems

Lucentini et al. [18] deeply analysed the performance of Renewable Energy Sources HVAC systems for buildings.The indoor climate control of buildings represents today the highest percentage of energy consumption in European Union. Hence the evaluation of the best performing HVAC system is a strategic target for both energy consumption and greenhouse gas emissions reduction. The technologies considered are biomass boiler, aerothermal, geothermal and absorption heat pumps. The proposed method estimated all the parameters according to the theory of the big is better. For each parameter a function has been defined to evaluate how much the performance of each technology depends from it. The analysis took in account also the environment in which each technology operates. The result was a set of dimensionless parameters, through which it is possible to extrapolate the assessments of performance. It can include both cost-effectiveness and feasibility of a given technology

Sun et al. [19] explored a new framework to guide the use of uncertainty analysis (UA) and sensitivity analysis (SA) in HVAC system sizing. In current practice, HVAC systems are sized based on standardized procedures that were mostly developed by ASHRAE. The standard approach only implicitly deals with uncertainty in peak system demand through the selection of an appropriate design day and the choice of a safety factor. Although this method works satisfactorily in most cases, it offers no support to a system designer who wants to track the risk associated with an undersized system. The opposite, i.e. avoiding that the system is needlessly oversized deserves even more attention given the fact that current practice of defensive sizing leads to oversized systems which leads to wasted capital investment and systems that operate far away from the optimum efficiency loads. UA will replace the safety factor with quantified margins based on comprehensive quantification of different sources of uncertainty. A probabilistic-based SA was then used to identify the important individual factors or groups of factors that contribute to uncertainty

AuYong et al. [20] investigated the maintenance characteristics of HVAC system that affect occupants' satisfaction and subsequently establish a relationship between the characteristics and occupants' satisfaction through questionnaire surveys and interviews; and finally developed a regression model for prediction purpose Office buildings were equipped with HVAC system to provide a comfortable working environment.The, the proper maintenance of HVAC system is necessary to ensure the smooth operations of an organisation. The study suggested that an effective communication platform which involves all key participants in the maintenance activities should be developed by the management to improve the maintenance outcomes

Chapter 3

Design of HVAC System

3.1 Design methodology

- The design methodology adopted for HVAC system is as under
- Firstly, Study of architechtural layout with process planning was done
- Area classifaction was done on the basis of layout,class B,class C,class D
- Various pressure zones were made
- On the basis of requirement air handling unit zoning was done
- Data was collected from design qualification sheet

3.1shows zoning for cleanliness

Figure 3.1: Zoning for cleanliness

3.2 shows pressure zoning

Figure 3.2: Zoning for pressure

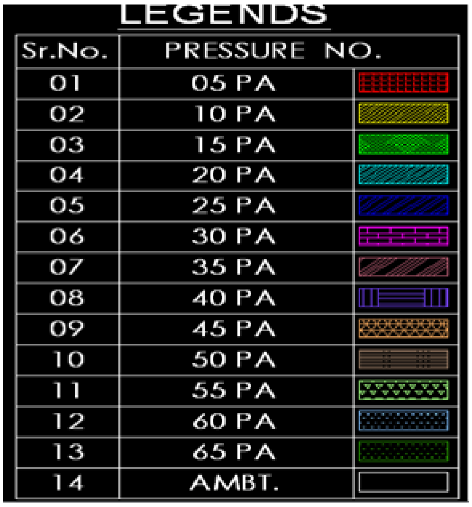
3.3 shows legends in class of cleanliness drawing

LEGENDS

Sr.No.	CLASSIFICATION	
01	CLASS B	
02	CLASS C	
03	CLASS D	
04	UNCLASSIFIED	

Figure 3.3: Class of cleanliness

3.4 shows legends in pressure zoning



LEGENDS

Sr.No.	PRESSURE NO.	
01	05 PA	
02	10 PA	
03	15 PA	
04	20 PA	
05	25 PA	
06	30 PA	
07	35 PA	
08	40 PA	
09	45 PA	
10	50 PA	
11	55 PA	
12	60 PA	
13	65 PA	
14	AMBT.	

Figure 3.4: Class of pressure

3.2 Input parameters

The various input parameters for the calculation of tone of refrigeration (TR) are as follow:

- Room dimensions
- Area
- Temprature inside and outside of room
- Relative humidity
- Occupancy
- Machine connected load
- Load for calculation of heat load
- Pressure with respect to ambient.

The temperature inside and outside the room is shown in Table 3.5.

3.1shows design qualification sheet

Table 3.1: DQ SHEET

Sr. No.	Sys. No.	Room	Area(M^2)	Temp (^0C)	RH(%)
1	AHU-GF-01	2.0 M WIDE PASSAGE	99.11	23	30
2	AHU-GF-01	2.0 M WIDE PASSAGE	77.62	23	30
3	AHU-GF-01	2.0 M WIDE PASSAGE	79.29	23	30
4	AHU-GF-01	2.0 M WIDE PASSAGE		23	55
5	AHU-GF-01	A/L	6.325	23	55
6	AHU-GF-01	A/L	7.442	23	55
7	AHU-GF-01	A/L	3.077	23	30
8	AHU-GF-01	A/L	4.093	23	30
9	AHU-GF-01	OFFICE	42.26	23	30
10	AHU-GF-01	SPARE ROOM	20.32	23	55
11	AHU-GF-01	SPARE ROOM	12.592	23	55

3.2 shows other aspects of design qualification sheet

Table 3.2: DQ SHEET

Sr. No.	Sys. No.	Room	Occupancy	Pressure w.r.t ambient (Pa)
1	AHU-GF-01	2.0 M WIDE PASSAGE	1	5
2	AHU-GF-01	2.0 M WIDE PASSAGE	1	5
3	AHU-GF-01	2.0 M WIDE PASSAGE	1	5
4	AHU-GF-01	2.0 M WIDE PASSAGE	1	5
5	AHU-GF-01	A/L	1	20
6	AHU-GF-01	A/L	1	20
7	AHU-GF-01	A/L	1	20
8	AHU-GF-01	A/L	1	20
9	AHU-GF-01	OFFICE	1	5
10	AHU-GF-01	SPARE ROOM	2	10
11	AHU-GF-01	SPARE ROOM	2	10

3.3 shows inspection room and siring filling room specification

Table 3.3: Inspection room and siring filling room specification

Room name	Length (m)	Width (m)	Area (m^2)	Height (m)	Volume(FT^3)
Pre filled siring filing	3.55	4.05	14.38	3	1522
Inspection room	3	4.07	12.21	2.74	1181

3.4 shows inspection room and siring filling room design

Table 3.4: Inspection room and siring filling room design

Room name	ACPH	Temp($^\circ C$)	RH (%)	Supply CFM
Pre filled siring filing	90	25	55	2283
Inspection room	90	25	55	1771

3.5shows temperature inside and outside the room

Table 3.5: Temperature inside and outside the room

	DBT($^\circ F$)	WBT($^\circ F$)	RH(%)	DP($^\circ F$)	Gr/lb	Month
Outside Room	116.6	82.3	58	70.5	112.9	Summer
	88.0	79.0	68	75.9	135.6	Monsoon
	50.0	43.0	24	35	29.8	Winter
Inside Room	73.4	61.1	50.0	53.7	61.5	All months

3.3 System Design Calculation

Design calculation in selection of HVAC system is very critical process for selecting right equipment, one should design system in such a way that it can handle cooling load in summer and heating load in winter season. Precise care in calculation will provide trouble-free successful operation of an air-conditioning plant, after installation would depend. Components that may cause cooling loads include the following : External: Walls, roofs, Windows, Partitions, Ceilings and floor. Internal: Lights, people(occupancy), appliances, and equipment. Infiltration: Air leakage and moisture migration. System: Outside air (ventilation air), duct gain, reheat, fan and pump energy. Here, calculation of heat loads for PRE FILLED SYRING FILLING AND STOPPERING ROOM UNDER LAF,INSPECTION ROOM

3.3.1 Heating Load Estimation

Room: PRE FILLED SYRING FILLING & STOPPERING ROOM. Site location: Baroda. , Latitude: 22.220N 72.680E and Altitude (ft): 112. As per client data;

Volume=Lenght*Width*Height=3.55*4.05*3*35.29=1573 ft^3

Minimum Fresh air = 2.0 ac/hr Minimum fresh air quantity= (Minimum fresh air*Volume)/60=(2.0*1573)/60=52 ft^3 Minimum Air change per hour = 90

Pressure level in room = 65.0 Pa

3.3.2 Sensible Heat Gain

Gain through Ceiling and Floors

Heat gain=Area*T.D*Gain Factor(for ceiling)

3.6 shows heat gain for ceilings

Table 3.6: Heat gain

Area	Temperature Difference(^{0}F)			Gain Factor	Heat gain (BTU/hr)		
(ft^2)	Summer	Monsoon	Winter	(FPS units)	Summer	Monsoon	Winter
159.9	36.6	16.6	-13.4	0.31	1806	819	-661

Heatgain(floor)

3.7 shows heat gain through floor

Table 3.7: Heat gain

Area	Temperature Difference(^{0}F)			Gain Factor	Heat gain (BTU/hr)		
(ft^2)	Summer	Monsoon	Winter	(FPS units)	Summer	Monsoon	Winter
159.9	36.6	16.6	-13.4	0.38	2234	1013	-818

$$Heatgain = Area{*}\Delta T.D{*}GainFactor \tag{3.1}$$

$$GainfromInternalsources = (no.ofpeople) * (factor)(BTU/h)(perperson)+ \tag{3.2}$$

$$lighting + equipment$$

=2*255.0=510 BTU/hr

Equipment Heat gain=kW of equipment *Gain Factor =6*3400.0 =20400 BTU/hr

Lights Heat gain=W of light *Gain Factor *Ballast Factor =240*3.4*1.25 =1019BTU/hr

$$Trans.GainthroughWallsRoofs = (Exp.Wall)(area) * (sungain) * (Factors) \tag{3.3}$$

$$Roomsensibleheatsubtotal(RSH) = (1) + (2) + (3) \tag{3.4}$$

RSH=25969 BTU/hr(Summer),23762 BTU/hr(Monsoon),20450 BTU/hr(Winter)

$$SAductHeatGainLeakloss + blowthruAHUmotor+ \tag{3.5}$$

$$BypassedFA(cfm) * (temperaturedifference)$$

$$EffectiveRoomsensibleheat(ERSH) = (4) + (5) \quad (3.6)$$

Heat Gain from Internal sources: People (occupancy) Heat gain=No.Persons *Gain Factor =2*255.0=510 BTU/hr

Heat gain value is same for summer and monsoon.

Equipment Heat gain=kW of equipment *Gain Factor =6*3400.0 =20400 BTU/hr

Heat gain value is same for summer and monsoon.

Lights Heat gain=W of light *Gain Factor *Ballast Factor =240*3.4*1.25 =1019BTU/hr

Heat gain value is same for summer,monsoon and winter

Room Sensible Heat Sub-Total (RSH) For summer, RSH=Heat gain through floor and ceiling+ Heat gain through internal sorces. =1806+2234+510+20400+1019

RSH=25969BTU/hr

Similarly

For monsoon, RSH=Heat gain through floor and ceiling+ Heat gain through internal sorces. =819+1013+510+20400+1019 RSH=23762BTU/hr

For Winter,

RSH=Heat gain through floor and ceiling+ Heat gain through internal sorces. =-661+(-818)+1019+510+20400 RSH=20450BTU/hr

Heat gain for Supply Air duct and leak loss with safety factor. Heat gain is 6.5% of RSH heat gain value.

Heat gain=0.065ŒRSH

3.8 shows supply air heat gain

Table 3.8: Supply air heat gain

Heat gain BTU/hr		
Summer	Monsoon	Winter
1688	1545	1330

Heat gain through Bypassed Fresh air. For Summer Heat Gain=cfm*Temperature differnace*1.08*Bypass factor =160*36.60*1.08*0.05 =316BTU/hr

For Monsoon Heat Gain=cfm*Temperature differnace

Effective room sensible heat (ERSH) =RSH+Heat gain through Bypassed Fresh air+Heat gain for Supply Air duct and leak loss with safety factor

3.9 shows effective room sensible heat

Table 3.9: Effective room sensible heat

Heat gain BTU/hr		
Summer	Monsoon	Winter
27973	25,450	21579

$$(No.ofperson)*(latentheatFactor/person) = (245)(BTU/HRPERPERSON)*(No.ofperson) \quad (3.7)$$

Heat gain by people (occupancy) Heat gain=No.Persons *latent heat Gain Factor =2 *245.0=490BTU/hr

Value remains same for all three seasons

$$Appliances(KW) * (3400) * (factors) \quad (3.8)$$

$$Steam(kg/hr) * (1050BTU/kg) \quad (3.9)$$

$$Roomlatentheatsubtotal = (7) + (8) + (9) \quad (3.10)$$

$$SAductHeatGainLeakloss+BypassedFA(cfm)*(temperaturedifference)*factors \quad (3.11)$$

Heat gain for Supply Air duct and leak loss with safety factor. Heat gain is 6.5% of RLH heat gain value

Heat gain=0.065*RLH

3.10 shows Latent heat gain by supply air

Table 3.10: Latent heat gain by supply air

Heat gain BTU/hr		
Summer	Monsoon	Winter
32	32	32

Heat gain through Bypassed Fresh air. For Summer

Heat Gain=cfm*Humidity differnace*1.08*Bypass factor. =160*32.60*1.08*0.05 =117BTU/hr

Heat gain through Bypassed Fresh air.

For monsoon Heat Gain=cfm*Humidity differance*1.08*Bypass factor. =160*36.60*100.30*0.05 =546BTU/hr Effective room latent heat (ERLH)

Effective Room Latent Heat (ERLH)=RLH+Heat gain through Bypassed Fresh air+Heat gain for Supply Air duct and leak loss with safety factor

$$EffectiveRoomlatentheat(ERLH) = (10) + (11) \tag{3.12}$$

3.11 shows effective room latent heat

Table 3.11: Effective Room Latent Heat

Effective Room Latent Heat		
Summer	Monsoon	Winter
699	1067	522

$$EffectiveRoomTotalheat(ERTH) = (6) + (12) \tag{3.13}$$

3.12 shows effective room total heat

Table 3.12: Effective room total heat

Effective Room Total Heat		
Summer	Monsoon	Winter
28672	26517	22101

Outside Air Heat on coil

$$Solargainthroughexposedglasses + solarandTrans.GainThruWallsandroofs \tag{3.14}$$

$$Trans.GainThruAllExceptroofsandwalls + RADuctHeatGainandLeakLoss(\%) \tag{3.15}$$

$$Outside(Freshairheatoncoil)Sensiblepart = (CFM) * (\Delta T) * (factors) \tag{3.16}$$

Outside Air Heat on coil. Sensible heating Part Heat Gain=cfm *T*1.08*(1-BPF) =160 *T*1.08*(1-0.05)

3.13 shows Outside (Fresh) Air sensible Heat

Table 3.13: Outside (Fresh) Air sensible Heat

Outside (Fresh) Air sensible Heat on Coil BTU/hr		
Summer	Monsoon	Winter
6008	2725	-2200

$$BypassedFA = (CFM) * (\Delta T) * (factors) \quad (3.17)$$

Bypassed Fresh Air Part. (Latent Heating Part.) Heat Gain=cfm *Humidity differance*1.08*(1-BPF) =160 *Humidity Differance*1.08*(1-0.05)

3.14 shows bypassed fresh air part. (Latent Heating Part)

Table 3.14: Bypassed Fresh Air Part. (Latent Heating Part)

Outside (Fresh) Air latent Heat on Coil BTU/hr		
Summer	Monsoon	Winter
3370	10367	-2067

$$Totalfreshairheatoncoil = (15) + (16) + (17) \quad (3.18)$$

3.15 shows outside (Fresh) Air Heat on Coil (OAH) BTU/hr

Table 3.15: Outside (Fresh) Air Heat on Coil (OAH) BTU/hr

Outside (Fresh) Air Heat on Coil (OAH) BTU/hr		
Summer	Monsoon	Winter
9378	13092	-4267

$$Subtotalofallheatgains = (13) + (18) \quad (3.19)$$

3.16 shows SUB TOTAL OF ALL ABOVE HEAT GAINS BTU/hr

Table 3.16: SUB TOTAL OF ALL ABOVE HEAT GAINS BTU/hr

SUB TOTAL OF ALL ABOVE HEAT GAINS BTU/hr		
Summer	Monsoon	Winter
38,050	39,409	12438

3.17 shows Blow-through AHU motor heat gain Heat Gain=10% of RSH

Table 3.17: Blow-through AHU motor heat gain. BTU/hr

Blow-through AHU motor heat gain. BTU/hr		
Summer	Monsoon	Winter
2,597	2376	2045

3.18 shows Dehumidify pipe and safety factor Heat Gain=6.5% of RSH

Table 3.18: Dehumidify pipe and safety factor Heat Gain

Dehumidify pipe and safety factor BTU/hr		
Summer	Monsoon	Winter
2,473	2,575	-1330

$$Dehumidificationheatgainbyair + BlowthruAHUmotor \tag{3.20}$$

$$subtotalofallheatgain + CHWpumpmotor \tag{3.21}$$

$$Grandtotalheat = (20) + (21) \tag{3.22}$$

3.19 shows Grand Total Heat. BTU/hr

Table 3.19: Grand Total Heat. BTU/hr

Grand Total Heat. BTU/hr		
Summer	Monsoon	Winter
43,121	44,781	13153

Heat Gain in TR= (Grand Total heat gain)/12000 TR

3.20 shows Grand Total Heat. TR

Table 3.20: Grand Total Heat. TR

Grand Total Heat. TR		
Summer	Monsoon	Winter
3.59	3.73	1.09

Dehumidified Air Quantity

Effective sensible heat factor=(ERSH/ERTH)

3.21shows Effective sensible heat factor

Table 3.21: Effective sensible heat factor

Effective Sensible Heat Factor	
Summer	Monsoon
0.98	0.96

Minimum Possible ESHF w/o reheat (psychrometric chart)

3.22 minimum possible ESHF without reheat

Table 3.22: Minimum Possible ESHF w/o reheat

Minimum Possible ESHF w/o reheat	
Summer	Monsoon
0.92	0.92

Indicated apparatus dew point (psychrometric chart) (F)

Selected apparatus dew point (psychrometric chart) (F)

Selected Apparatus Dew Point = 53 (F)

Dehumidified Rise = (1-BF)*(Inside DB-ADP) (F)

For summer

Dehumidified Rise=(1-BPF)*(inside DB-ADP) =(1-0.05)*(73.4-53.0) =19.38 (F)

For Monsoon

Dehumidified Rise = (1-BPF) * (inside DB-ADP) = (1-0.05) * (73.4-53.0) = 19.38 (F)

Dehumidified air quantity =(ERSH)/(1.08*DR) (CFM)

For Summer

Dehumidifier Air quantity=ERSH/(1.08*DR) =27973/(1.08*19.38) =1336 CFM

For Monsoon

Dehumidifier Air quantity=ERSH/(1.08*DR) =25450/(1.08*19.38)

=1215 (CFM)

Reheating Coil Capacity for winter

Reheating Coil Capacity for winter Capacity of coil=(outside air heat on coil+RSH(winter))/3400 =(4267+490)/3400 =1.40 kW

Supply air quantity=(volume)*(acph)/60(CFM)

Supply Air quantity on ACPH= (Volume *No.Air change)/60 =(1573 *90)/60 =2360 CFM.

Fresh air quantity=(volume)*(circulation)/60(CFM)

Minimum Fresh air = 2.0 ac/hr Minimum fresh air quantity= (Minimum fresh air ŒVolume)/60=(2.0*1573)/60=52 CFM

Tonnage Revised

We consider maximum value of TR among three different seasons values Same way we can calculate Heat load for Inspection room

3.23 shows System Specifications

Table 3.23: System Specifications

Room Name	Tonnage (TR)	Supply CFM	Deh. CFM
PRE FILLED SYRING FILLING ROOM	3.73	2,360	1,405
INSPECTION ROOM	2.98	1,771	993

3.24 shows system specifications

Table 3.24: System Specifications

Room Name	Fresh Air CFM	Return Air CFM
PRE FILLED SYRING FILLING ROOM	160	2,200
INSPECTION ROOM	160	1,611

3.4 Results and Discussion

- Result obtained are tabulated as under
- Results obtained for peak load at particular location at particular time
- In summer and monsoon dehumidified rise is calculated
- Supply air duct and return air duct heat gain and leakage loss is also considered

3.25 shows AHU summary sheet

Table 3.25: AHU Sumaary Sheet

Sr. No.	Sys. No.	Room	Tonnage (TR)	Supply Air CFM	Dehumid CFM
1	AHU-GF-01	2.0 M WIDE PASSAGE	3.44	2623	750
2	AHU-GF-01	2.0 M WIDE PASSAGE	3.78	2055	1238
3	AHU-GF-01	2.0 M WIDE PASSAGE	3.79	2099	1226
4	AHU-GF-01	2.0 M WIDE PASSAGE	3.16	1816	998
5	AHU-GF-01	A/L	1.52	435	435
6	AHU-GF-01	A/L	1.51	435	435
7	AHU-GF-01	A/L	1.51	435	435
8	AHU-GF-01	A/L	1.52	435	435
9	AHU-GF-01	OFFICE	0.74	303	303
10	AHU-GF-01	SPARE ROOM	0.66	291	291
11	AHU-GF-01	SPARE ROOM	0.75	306	306
	BLOWTHR,MOTOR		3.42		
	SYSTEM TOTAL		25.80	11233	6852

Chapter 4

Design of Ducting system

4.1 Air Distribution System

Air distribution system plays effective rolls for air ventilation and supply air in the room. Supply and extract grilles should be such as to provide effective room flushing. However, where this is not possible, a higher air change rate may be needed to achieve a specific clean room condition. Air distribution consists AHU, filters, duct, riser, volume control dampers designing of HVAC system.Many type of air circulation and distribution systems are used in pharmaceutical plants i.e. recirculation system and full-fresh air system. Air distribution consists AHU, filters, duct, riser, volume control dampers designing of HVAC system. Many type of air circulation and distribution systems are used in pharmaceutical plants i.e. recirculation system and full-fresh air system

AHU System is meant for providing Cleaned and conditioned air (Temperature & RH), Ventilation and maintaining the pressure balance across the room The Air Handling Unit is a cabinet made up of GSS powder coated sheet metal of double skin modular construction

- Main Body : Main body part consists of handling of fresh and re circulated Return air, cooling coil and Blower for Sucking of air (Fresh and return air) 4131 CFM & 150mm static with DIDW Backward Curved fan. AHU cabinet consists of a port for 10-15% fresh air

Figure 4.1 shows top view of AHU

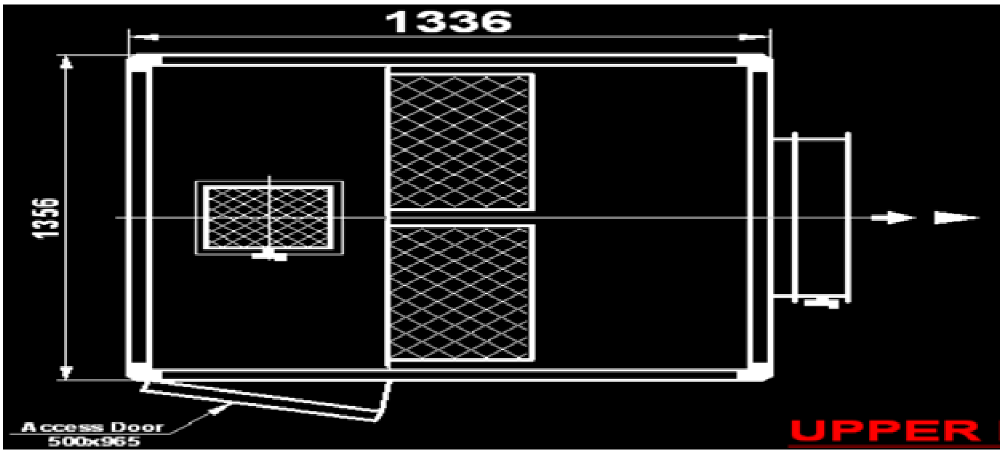


Figure 4.1: Top plan of AHU

4.2 shows lower plan of AHU

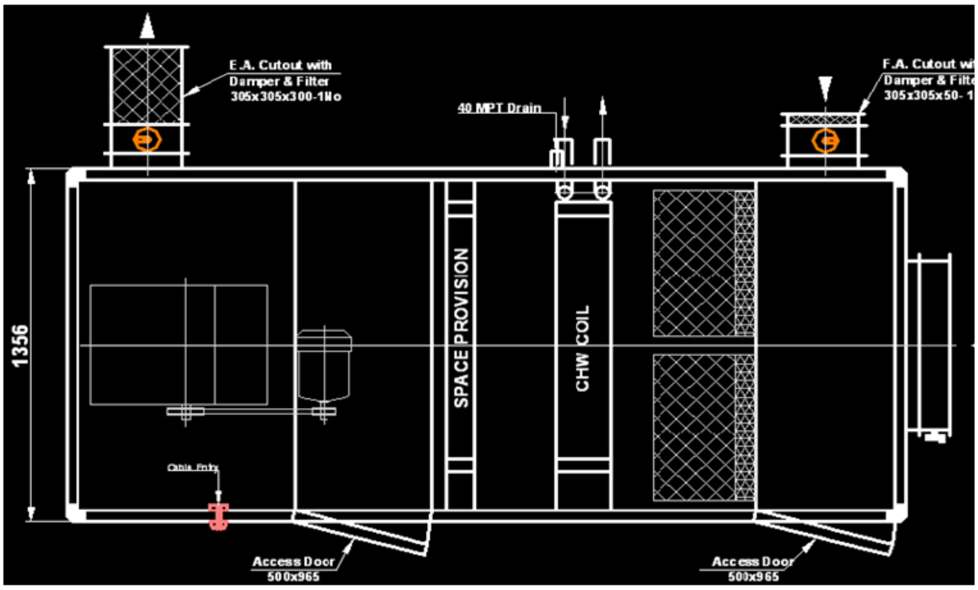


Figure 4.2: lower plan of AHU

4.3 shows front view of AHU

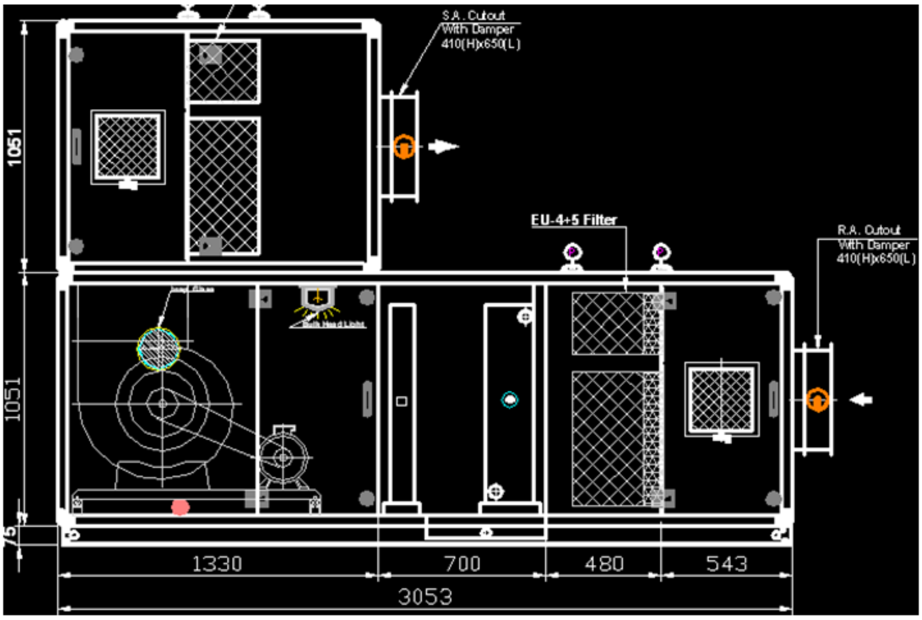


Figure 4.3: front view of AHU

4.2 Ducting Design

- Designing of duct is done by the equal friction method, in which, the frictional pressure drop per unit length of the duct is maintained constant throughout the duct system. The procedure is to select a suitable velocity in the main duct from sound level consideration. Knowing the air flow rate and the velocity in the main duct, the size and friction loss are determined from chart. The remaining ducts are then seized; maintain the friction loss per unit length at this value for their prospective air flow rates. This method of seizing the ducts automatically reduces their velocity in direction of flow.Supply ducts having conditions air with will blow in the room from top grills. Risers grills are at lower in room which sucked dirty and hot air and supplied to return duct and then that air will reach to AHU for conditioning.

4.2.1 Constant frictional pressure drop per unit length method

- pressure drop due to friction is selected for optimum savings in cost
- Then main header duct equivalent diameter is calculated by pressure drop and flow rate
- Air flow rate in main header is equal to sum of individual air flow rates in all ducts

- From volumetric flow rate and frictional pressure drop coefficient the equivalent diameter of main header is known
- From frictional pressure drop and air flow rates equivalent diameter of individual ducts are calculated
- For rectangular ducts cross section can be calculated from equivalent diameter by defining aspect ratio
- Total frictional pressure drop is calculated by increasing frictional pressure drop per unit length to total runing length
- Dynamic friction drop is accounted for turns,elbows or bends and total frictional pressure drop is obtained.
- Next a fan suitable for maximum pressure drop is selected[24]

4.2.2 Calculations

In this method pressure drop per unit length due to friction is considered to be constant

$$\triangle p_f/L = constant \tag{4.1}$$

The air flow rate in each zone is calculated beforehand and from it equivalent diameter is calculated

$$D_{eq,A} = \left(0.022243 Q_A^{1.852}/\triangle p_f/L\right)^{(1/4.973)} \tag{4.2}$$

$$(Q^{1.852}/D_{eq}^{4.973})_A = (Q^{1.852}/D_{eq}^{4.973})_B = (Q^{1.852}/D_{eq}^{4.973})_C \tag{4.3}$$

Total frictional pressure drop of main header is calculated

$$\triangle p_{f,A} = (\triangle p_f/L)_A * L_A \tag{4.4}$$

Air flow rate through main duct is equal to sum of individual air flow rates

$$Q_A = \sum Q \tag{4.5}$$

$$\frac{\triangle P_f}{L} = 1 mm of water guage per meter \tag{4.6}$$

$$W_{fan} = Q_{air} * \triangle p/\eta_{fan} \tag{4.7}$$

pressure drop per unit length is taken as $1N/m^2$per meter selected room ducting design is shown in 4.1

Table 4.1: Selected room ducting design

Sys no.	Room name	Fresh air CFM	Return air CFM	AHU Exhaust	Supply fan capacity
AHU-GF-01	2.0 M WIDE PASSAGE	350	2623		
AHU-GF-01	2.0 M WIDE PASSAGE	274	2055		
AHU-GF-01	2.0 M WIDE PASSAGE	280	2099		
AHU-GF-01	2.0 M WIDE PASSAGE	242	1816		
AHU-GF-01	A/L	122	435		
AHU-GF-01	A/L	122	435		
AHU-GF-01	A/L	122	435		
AHU-GF-01	A/L	122	435		
AHU-GF-01	OFFICE	26	303		
AHU-GF-01	SPARE ROOM	18	291		
AHU-GF-01	SPARE ROOM	29	306		
SYSTEM TOTAL		1706	11233	1707	12940

4.3 Air Handling Unit Design

By calculating required TR,Reheat,supply CFM,fresh air CFM,supply fan CFM Air Handling Unit Design is completed

It is sent to vendor which in return creates General arrangement drawing which is checked and approved

4.4shows GA drawing of AHU

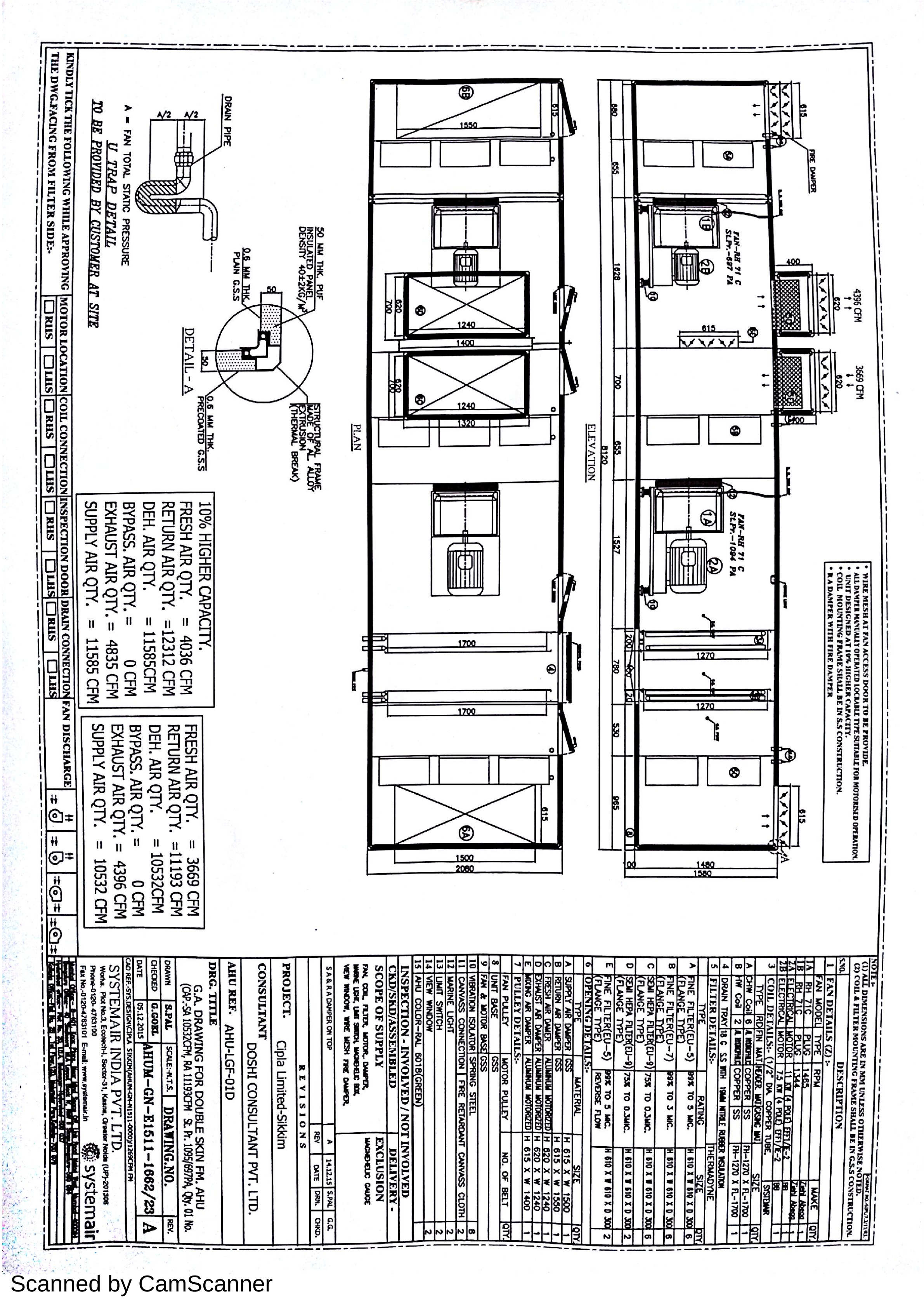


Figure 4.4: Air Handling Unit General Arrangement Drawing

4.5shows ducting drawing in which duct parameters are shown

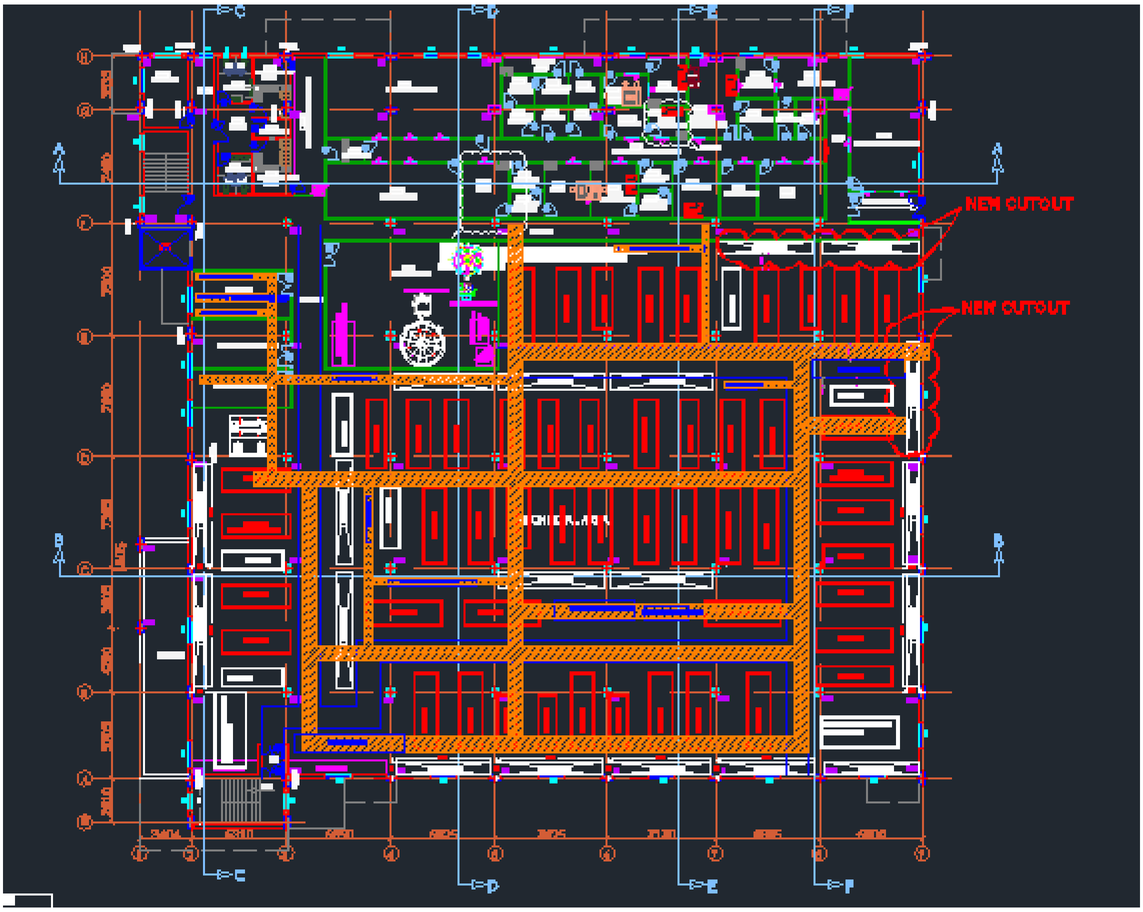


Figure 4.5: Ducting drawing

4.3.1 Filters Unit

To provide fresh air, free from all types of contaminants, different types of filters of different micron size are provided with graded filters $(10\mu 10\mu 3\mu 0.3\mu)$. The graded filters are used to minimize the pressure on less micron Filters. Selected outlets are also specified

Table 4.2: Filter selection

Sr. no.	Sys no.	Class to be maintained	Minimum ACPH
1	AHU-GF-01	CNC	10
2	AHU-GF-01	CNC	10
3	AHU-GF-01	CNC	10
4	AHU-GF-01	CNC	10
5	AHU-GF-01	CNC	10
6	AHU-GF-01	ISO-8	25
7	AHU-GF-01	ISO-8	25
8	AHU-GF-01	ISO-8	25
9	AHU-GF-01	ISO-8	25
10	AHU-GF-01	ISO-8	25
11	AHU-GF-01	ISO-8	25

Table 4.3: Filter selection

Sr. no.	Sys no.	Type of Filter			
		Fresh air	Plenum Mounted	At Terminal	Bleed Air
1	AHU-GF-01	EU-3	EU-4/EU-7	-	EU-7
2	AHU-GF-01	EU-3	EU-4/EU-7	-	EU-7
3	AHU-GF-01	EU-3	EU-4/EU-7	-	EU-7
4	AHU-GF-01	EU-3	EU-4/EU-7	-	EU-7
5	AHU-GF-01	EU-3	EU-4/EU-7	-	EU-7
6	AHU-GF-01	EU-3	EU-4/EU-7	EU-13	EU-13
7	AHU-GF-01	EU-3	EU-4/EU-7	EU-13	EU-13
8	AHU-GF-01	EU-3	EU-4/EU-7	EU-13	EU-13
9	AHU-GF-01	EU-3	EU-4/EU-7	EU-13	EU-13
10	AHU-GF-01	EU-3	EU-4/EU-7	EU-13	EU-13
11	AHU-GF-01	EU-3	EU-4/EU-7	EU-13	EU-13

Table 4.4: Supply air and Return air Riser

Sr. no.	Sys no.	Terminal HEPA/SA Diffuser	RA Riser with EU-4 filter/Diffuser
1	AHU-GF-01	Swirl Diffuser	Perforated Diffuser with plenum
2	AHU-GF-01	Swirl Diffuser	Perforated Diffuser with plenum
3	AHU-GF-01	Swirl Diffuser	Perforated Diffuser with plenum
4	AHU-GF-01	Swirl Diffuser	Perforated Diffuser with plenum
5	AHU-GF-01	Swirl Diffuser	Perforated Diffuser with plenum
6	AHU-GF-01	HEPA BOX WITH CAPSULE PERFORATION	Perforated Diffuser with plenum
7	AHU-GF-01	HEPA BOX WITH CAPSULE PERFORATION	Perforated Diffuser with plenum
8	AHU-GF-01	HEPA BOX WITH CAPSULE PERFORATION	Perforated Diffuser with plenum
9	AHU-GF-01	HEPA BOX WITH CAPSULE PERFORATION	Perforated Diffuser with plenum
10	AHU-GF-01	HEPA BOX WITH CAPSULE PERFORATION	Perforated Diffuser with plenum
11	AHU-GF-01	HEPA BOX WITH CAPSULE PERFORATION	Perforated Diffuser with plenum

4.5 shows filter details

Efficiency is defined as percentage of number of particles less than or equal to size specified

location of filter depends on class usually filters are mounted on terminals as well when higher filtration level is desired

Table 4.5: Filter details

Type	Location	Make	Size(MM)	Efficiency
10+5ţ prefilter	Mix chamber	AAF	610*610*380	95% down to10 μ
10ţ Fresh Air Filter	Fresh Air chamber	AAF	305 *305 * 50	90% down to10μ
0. 3ţ Bleed air filter	Air Handling Unit	AAF	305 *305 * 50	99.97 % down to 0.3μ
0.3ţ Fine filter	Air Handling Unit	AAF	610*610 *300	99 % down to 3μ

Chapter 5

Conclusions and Future Scope

5.1 Conclusions

In the present study, HVAC system is designed for clean room and highly potent drug to control viable and non-viable particles, temperature, relative humidity, hygiene zone for different process area as per drug regulation. Design for peak load is considered along with a suitable diversity factor. The ASHRAE and GMP guidelines were followed in the design. The major conclusions made from the study are as under:

- In the design, the suitable values of diversity factor and bypass factor were found as 70% and 5% respectively.
- The total dehumidified rise was considered for summer and monsoon and was compensated by cooling coil.
- For recirculation system fresh air was considered as per the occupancy.
- When water was moving from the chiller to the cooling coils, 1^0C temperature rise was found and it was compensated by subcooling.
- In the cooling tower, the difference between minimu outlet temperature and the actual temperature (i.e. approach) was found as 4^0C.
- From the design, total reheat capacity and total chilling capacity were found as 384 kW and 542 TR respectively.

5.2 Future Scope

The future scope of the project are as under:

- Automation in HVAC system can be used.

- HVAC design based on Isolated technology can be done.
- Green energy buildings can also be employed in HVAC system.

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