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HVAC Design and Operation for Green School Building

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ABSTRACT: This paper examines the design and operations of school's HVAC. These systems are liable for a main component of overall institutional energy consumption. The right size HVAC handles space and equipment heating and cooling loads, and adjusts the air supply technology to stand the exact forecast heating and cooling loads of the school building. This paper discusses full details of designing an air supply technique to convey the right amount of air into space. HVAC design depends on the location, view and construction of the building. It also explains the social implications and hoped that HVAC designers and those involved in the construction industry will have a best knowledge of green school buildings and use efficient approaches and technologies for this purpose.

KEYWORDS: HVAC, Design and operation, Green Building, Heating and Cooling, Air conditioning

I. INTRODUCTION

Green buildings are very relevant in this age of declining natural resources. The fundamental job of warming, ventilation, and cooling hardware in schools is to control the temperature and the nature of indoor air [1]. These systems are responsible for maintaining a comfortable temperature for teachers, staff and students, and for minimizing exposure to air pollutants [2]. A solid school climate advances understudies' learning and profitability in the study hall and upgrades their accomplishment and execution all through life. HVAC (Heating, ventilation, and air conditioning) frameworks include energy use in schools. As a result, energy effectiveness is an objective for schools HVAC frameworks. The other two aims are to reduce water consumption and promote a conducive listening environment for students and teachers [3].

The goal of the school's HVAC framework is to keep students and staff effective and efficient, while actually "53 million children and 6 million adults pass through their 120,000 private and public spaces every day. This is based on the fact that a large portion of these older and needed buildings may expose workers to environmental hazards such as carbon monoxide or mold" [4]. In fact, the "Center for Green Schools in the U.S. Green Building Council" found that many schools in the country were in a state of disrepair. The association's 2013 schools report showed that \$ 542 billion is needed to move schools in line with current welfare, well - being and guidelines [5].

This presents an extraordinary chance for HVAC experts. Many are now assisting with building schools for asset preservation and energy proficiency. A lot more things are expected to update the hardware in more established schools. "Bringing HVAC systems in schools up to date will be a key part of improving student health and performance," said Rachel Gutter, the head of the Center for Green Schools.

The plan, development, or activity of a green building limits or disposes of unfriendly impacts and can deliver constructive outcomes on our environment and regular habitat. Green buildings protect natural resources and improve our personal satisfaction. Its highlights are energy-productive, asset-effective, squander-free, and non-contaminating. Profoundly utilitarian and appropriate for long-haul activity; they are not difficult to work and keep up and support efficiency and representative prosperity. Making a specific building "green" is an extraordinary arrangement that reacts to explicit utilitarian prerequisites and the environment of the building space. A superior plan considers energy and ecological execution over the whole life pattern of the building, including site determination, development, tasks, support, redesign, destruction, and substitution. The life cycle of building as shown in Figure 1.



High performance, and the entire building strategy to deal with configuration looks at how a building communicates with its systems works and the general climate. Since an important part of the green building standard is related to energy performance, environmental performance or responsiveness is an important factor in determining energy issues in general. Complete building plan techniques that coordinate latent sun-powered energy, energy proficiency, and other sustainable power advancements are utilized to diminish building energy utilization. “By advancing the building standard components (site, windows, dividers, floors, HVAC frameworks), building proprietors can essentially lessen energy utilization without expanding development costs. The best green plan is a completely coordinated plan whereby building, HVAC and electrical frameworks all communicate to limit size, squander energy use, and other adverse consequences on the climate” [2].

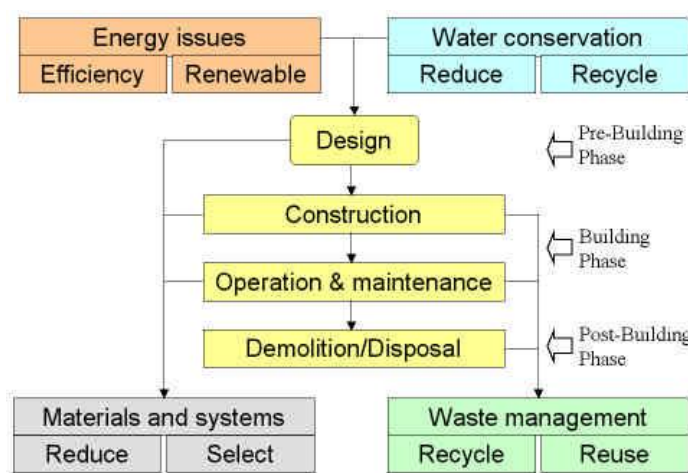


Fig. 1 Life cycle of building construction

This paper depicts the essential ideas of green school assembling and talks about the part of the warming, Ventilating, and cooling (HVAC) to guarantee superior green structures in plan and capacity. The plan methodologies for green HVAC frameworks are clarified and new arising HVAC advances for green structures are portrayed.

II. LITERATURE REVIEW

Modeling and simulation are advancements for taking care of plan issues in many designing fields and different orders. Progressed instruments are accessible in the space of framework execution plan, investigation, and improvement. The plan, testing, activity, and the board of HVAC frameworks continuously rely upon demonstrating and reproduction strategies. Schmidt et al. has implemented control volume models for humid air and desiccant materials, mimicking the performance of the desiccant wheel. Comparison of dynamic and static conditions with open literature, manufacturer data and test results are used to validate the model [6].

Sam C (2001) depicts the essential ideas of green structure and examines the part of HVAC for guaranteeing elite maintainable building plan and activity. The plan methodologies for powerful green HVAC frameworks clarified new arising HVAC innovations for green structures are depicted [7]. In another investigation, a methodical procedure called total recreation-based consecutive quadratic programming (CSB-SQP) was created by J. Sun, a. Reddy (2005) to decide the ideal control of HVAC frameworks [8].N. Zurich (2007) et al. the single-target streamlining calculation that takes care of issues with two goals is applied al on the grounds that the improvement calculation is one unbiased and the issue has two destinations, which are insignificant in general, expense and palatable warm solace [9].In another examination (A. Hasan (2008) et.al) building execution recreation “program IDA ICE combined with GenOpt to discover advanced upsides of five plan boundaries of building and HVAC framework for minimization of life cycle cost. The streamlining brought about a 23-49% decrease in space warming energy”[10].

K. Haddad (2008) et.al, presented reenactment models of a half and half HVAC framework that joins a conventional steam pressure framework and a desiccant cooling framework. Models were utilized to break down the force decrease

capability of the crossbreed framework [11]. K.RatnaKumari (2016) et.al, clarifies the plan and drafting of HVC, a focal cooling framework for a place of business, and different plan methodologies are talked about for energy utilization [12]. It can be seen that the optimization studies of most HVAC systems focused on control procedures or advancement of a particular framework or segment. This work focuses on the design and draft of the green school building and applies effective strategies and techniques to achieve the goal.

III. METHODOLOGY

In this paper, the results of only one school building are presented. Air conditioning is required in many situations where mechanical ventilation is required. The conditions under which air conditioning is required are: 1. Rooms subject to high sunlight-based energy acquire, south-bound rooms, particularly lives with huge spaces of glare. 2. High equipment density rooms such as computer rooms and offices. 3. Rooms that perform environmentally sensitive (temperature, dust or humidity) work like activity theatres and microchip-producing units.

a. Refrigeration cycle

The refrigeration cycle consist of four part compressor, condenser, expansion valve and evaporator. A blower is a gadget that converts excess energy into compact air. A condenser is a device or unit used to accumulate a thing from its gas to a liquid state. Thusly, the inert warmth is moved to the material and moved to the condenser coolant. An augmentation valve is a piece of refrigeration and cooling systems control the proportion of refrigerant stream to the evaporator and in this manner control the superheating of the evaporator outlet. Vaporizer is a condenser utilized to convert the fluid type of substance into vapor form.The fluid either expands into gas or disappears. Figure 2 shows the refrigeration cycle.

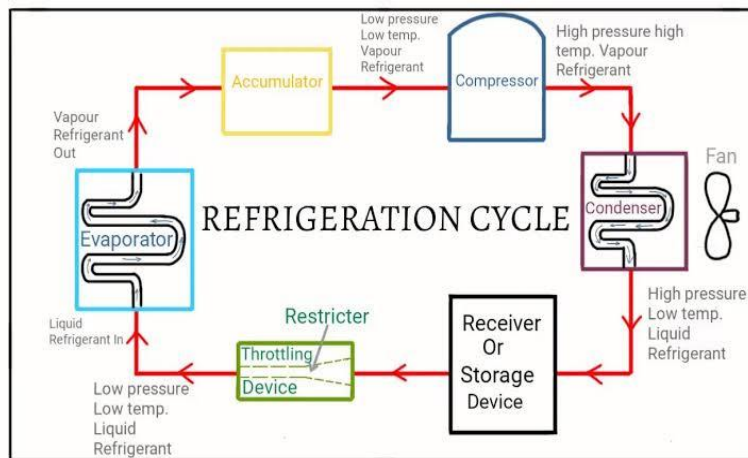


Fig. 2 Refrigeration cycle

b. Air Handling Unit (AHU)

It was utilized to control and circle air as a segment of warming, ventilation, and cooling frameworks. This controller is typically a huge metal box that contains a blower, warming and cooling parts channel chambers, sound attenuators, and dampers. The air controller associates with the ventilation work, which conveys adapted (warmed or cooled) air all through the structure prior to getting back to the AHU. There are a few units that remove air straightforwardly all through the structure without the requirement for ventilation work. Figure 3 represent the air handling unit. The AHU divided into five parts they are box enclosure, cooling coil, ducts, fan or blower, air filter.

Box enclosure is included in the air handling unit box type enclosure. This guarantees the smallness of unit and the assurance of parts inside it. The box is protected to forestall heat misfortune from the unit. The cooling coil is the primary piece of the air dealing with units. It is covered with wings with copper holders of two turns to add glow movement ability to the cooling coil. Air channels also provide air managing inventory related to air. The stock air channel unit distributes cold air to different rooms, while the hot air returns from different rooms. The fan returns hot

air from blower over the cooling coil and sends it to the space for cooling. The air channel is a significant piece of any cooling framework. The air channel eliminates residue, smoke, different impurities from the air.

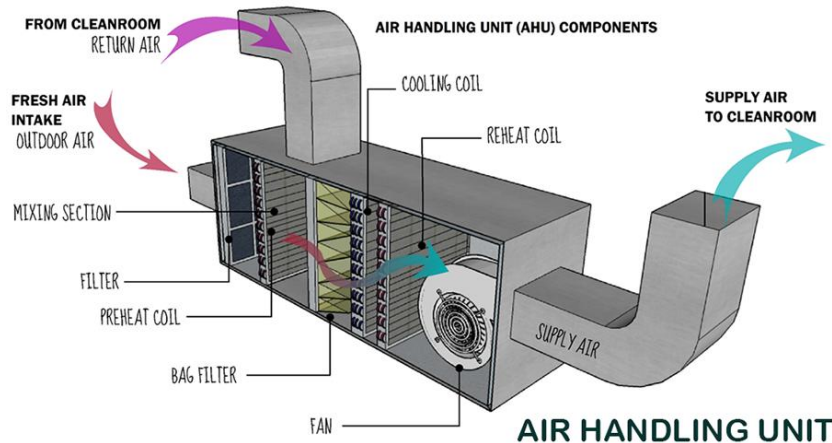


Fig. 3 Air Handling Unit

c. Experimental Analysis

1) Load Estimation, Heat load estimation and Building Survey

Once understand the various heat sources in the building, conduct a building survey for thermal load calculations. The building survey includes measuring the various dimensions of the building, building orientation, and applying various factors to calculate heat load calculations. The importance of an accurate load estimate for the air cooling configuration is never exaggerated. In fact, the accuracy and support applied by the planner in calculating the summer cooling load, winter heating load is seamless, depending on the effective operation of the cooling plant after installation.

2) Heat Gain through Glass, Walls and Roofs

Transparent glass permits daylight to go through. It makes heat spread all through the room. The measure of warmth streaming into the room relies upon the space of the glass in contact with the sun. Thermal gain during the greatest heat flux is usually measured by the external construction (walls and roof). This is because of the way that sun-oriented warmth is consumed by the external surface and temperature contrast among indoor and outside air. Warmth motion through the design can be determined at the same temperature contrast (ETD) utilizing the steady warm condition.

$$Q = U * A * ETD$$

Where, ETD is Equivalent Temperature Difference, A is area of surface, Q is heat flow rate, U is transmission rate.

3) Transmission Heat Gain through Glass, Partitions and Walls

The warm increase because of the contrast between outside and interior conditions. The ratio of warmth passing via the glass to the room depends on area of glass, intensity of temperature, and transmission coefficient of the glass. The all-out glass territory is determined paying little heed to bear. Here again, the temperature gain depends on the heat contrast among external and internal situations, the transmission coefficient, the divider region or the segment divider region. Here the all-out space of the divider is taken paying little mind to its bearing. The taken temperature is typically 2°C lower than the current temperature slope. In these computations, the same temperature distinction is determined.

4) Occupancy Load and Lighting

Warmth passes through the individual body through oxidation without being called metabolic rate. Metabolic rate contrasts relying on individual and his degree of action. The magnitude of the warmth provided by the individual body through radiation and convection coordinates the heat contrast among outside of the body and its normal parts. Metabolic rate is 85% for men and 75% for young people. The additional warmth and dampness created by individuals will expand the warmth acquire from individuals getting diminutive term work by up to 10%. Lights produce reasonable warmth by changing over electrical force contribution to light and warmth. Warmth scatters as



radiation to encompassing surfaces enters close by articles and escapes into the encompassing air. Fluorescent = absolute light watts * 1.25 radiant = all-out light watts.

5)Appliances, Electric Motors

Most applications include to nonsensical and covered-up heat in one spot. Electric machines add to the dormant warmth because of the work they do, for example drying and cooking. Gas-consuming apparatuses give additional dampness because of burning. Appropriately planned hood with a positive exhaust framework fundamentally eliminates warmth and dampness created by most kinds of gear. Electric engines give legitimate warmth in space by warming and changing over electric force input. A portion of this force disperses as warmth in the engine outline, which can be determined as input * (1-engine effectiveness).

6)System Heat Gain and Heat Gain from Outside Air

Framework heat acquire is determined as the expansion or loss of warmth to framework segments like conduits, channeling, cooling fan, and pump. This warm increase ought to be determined and remembered for the heap gauge, however must be precisely determined once the framework has been planned. To quantify the penetration of air into the molded territory, the breaking technique is all the more precisely determined. Pneumatic stress is the capacity of the gaseous tension distinction, which is dictated by the condition:

$$dp = 0.00470c^2$$

Local wind speed in dp and C Km / hr in centimeters of WP. Tables are available for different DP values for m / hr / m crack infiltration. After considering these factors of room loads, the sensible temperature of the room and the hidden heat in the room are determined.

IV. EXPERIMENTAL RESULTS

a. Determination of U factor

Conductive warmth move through dividers or rooftops relies upon its thickness and the warm conductivity of the materials utilized. Likewise, convection and radiation can happen from outer and inward surfaces. Along these lines, the consistent state heat move is characterized as the general warmth move coefficient U and the general contrast in temperature inside and outside. A divider comprises a few areas of various developments and protecting substance. For this reason, all layers of various substances of various thicknesses 'X', warm conductivity 'K' should be considered. Cross-segment of divider is viewed as the thickest of the structure.

Table 1:Densities and Thermal Conductivities

Materials (Kg/Cu.m)	Thickness(M)	Thermal Conductivity (K)	Density(W/MK)
Brick	0.2286	1.32	2000
Cement Plaster	0.0127	11.77	1885
RCC Slab	0.2	9	1920
Asbestos	0.04	0.154	470-570

Table 1 shows the densities and thermal conductivities. The coefficients of air determined from the following equation.

$$U \text{ value} = \frac{1}{(R_{so}+R_{si}+R_1+R_2\dots)}$$

Where R_{so} is a fixed external resistance, R_{si} is the fixed internal resistance, $R_1, R_2\dots$ are resistivity of all elements within the application. The U factor for wall, partition wall, and roof are 0.357, 0.309, and 0.469 respectively.

b. Designs inside Air-conditioned Area (Psychrometric Calculations)

It presents the calculation technique for different conditions in the area of clean rooms. Also presents heat load estimations for rooms that require convenient conditions. Normal clean room load estimation, which vary in particle size, only discuss the quantity of cleaning needful and the class to be conserved. The area where convenient condition is required is also discussed.

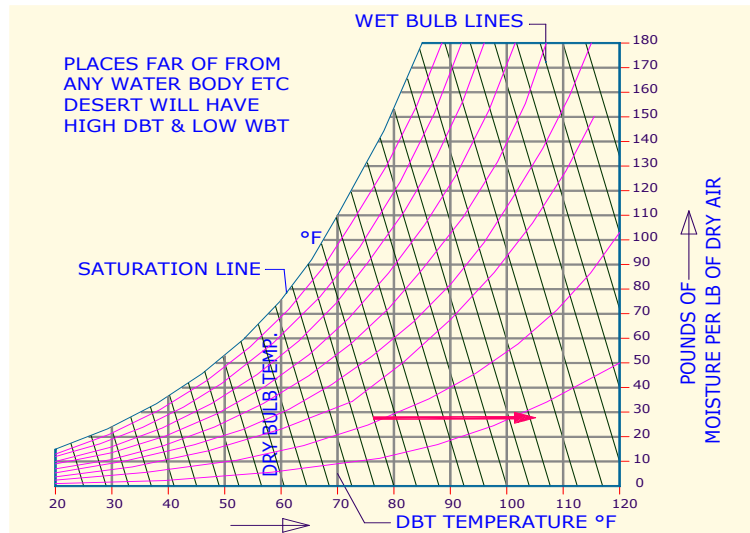


Figure 4.Psychrometric chart for DBT and WBT

Figure 4 shows the psychrometric chart for DBT and WBT. Dry Bulb Temperature (DBT) Temperature of air, water vapor mixture shielded from direct radiation, as registered by a normal thermometer. Vertical lines are lines of constant DBT. The Wet Bulb Temperature (WBT) is the temperature registered by a thermometer, which is covered by a damp wick and exposes to the current of a fast moving sky. Wet bulb temperature lines close to the sloping lines are constant. Areas that are connected to the water body and areas with high rainfall will be high wet bulb.

Figure 5 shows the psychrometric graph for relative moistness. Relative dampness is the proportion of the genuine halfway pressing factor of water fume noticeable all around combination to its immersion pressure at a similar DBT. Specific air (humidity ratio) the weight of water fume in a mixture of dry air expressed in grains of dry air water. These are determined by the horizontal lines. Table 1 shows the outdoor weather and Table 3 shows the psychrometric process.

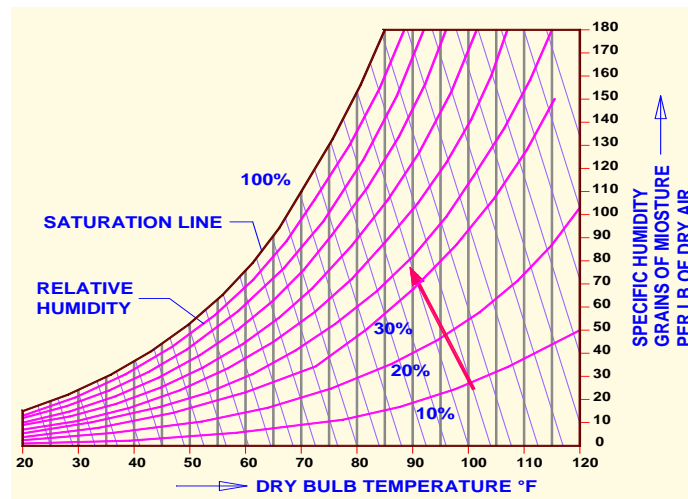


Figure 5.Psychrometric chart for relative humidity



Table 2 Outdoor weather

	DBT	WBT	%RH	SPECIFIC HUMIDITY Grain/LB
Summer	110 F	78 F	24	92
monsoon	95 F	83 F	61	150
Winter	45 F	43 F	88	38

7000 Grains = 1 LB of moisture

Table 3 Psychrometric process

Process	DBT	%RH	Grains
Sensible cooling	Reduces	Increases	Grains level is same
Sensible Heating	Increases	Reduces	Grains level is same
Cooling and Dehumidification	Reduces	Increases	Grains level is reduces
Cooling and Humidification	Reduces	Increases	Grain level is increases
Heating and Humidification	Increases	Increases	Grain level is increases
Heating and Dehumidification	Increases	Reduces	Grain level is reduces

The figure 6 shows the total heat and cooling capacity. The Figure 7 shows the school building layout.

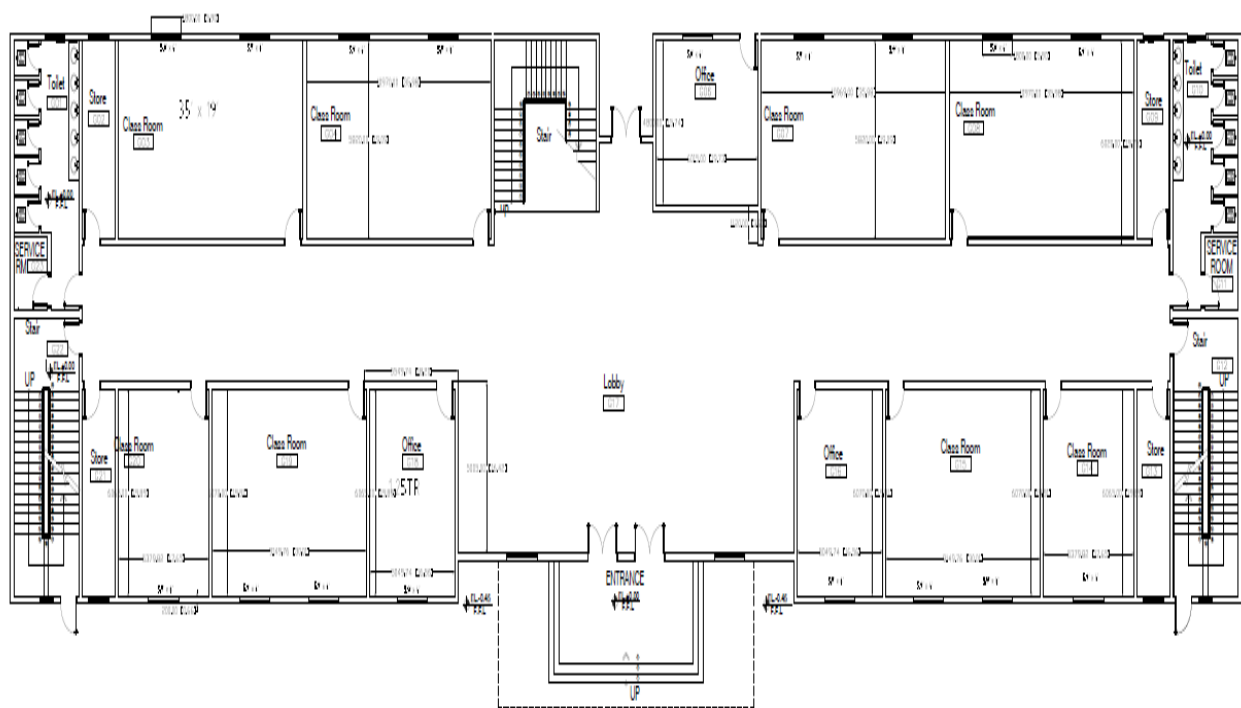


Fig. 6 School building layout



Estimated by :	JACOB ANTONY				1
Checked by:					Ref : abc/xyz/0001
Job Name:	A/C for classroom G03				Date: 25/08/2020
Address:	Bangalore				Estimated for: XYZ
Space Used For:	Class room				
SPACE SIZE					
Length (ft)	Width (ft)	Area (sq.ft)	Height (ft)	Size (cu.ft)	CONDITIONS
35.98	19.09	687	9.91	6807	Outside 93.2 67.3 25 59
					Room 75 62.5 50 65
					Difference 18.2 4.8
SOLAR GAIN-GLASS					
ITEM	Area (sq.ft)	Temp. Difference	Solar Factor	BTU / HR	VENTILATION (OUTSIDE AIR, OA)
N Glass	86.55	50	1	4327.5	65 People 5 CFM/Person 325
NE Glass					687 sq.ft 0.06 CFM/ sq.ft 41
E Glass			1	0	
SE Glass				0	
S Glass				0	* No of Fersh Air Charges per Hour
SW Glass				0	CFM VENTILATION (OUTSIDE AIR OA) 366
W Glass			1	0.0	INFILTRATION
NW Glass				0	Swinging /Revolving Doors 0 People 0 CFM/Per 0
Skylight				0	Open Door Door 0 CFM/Door 0
					Crack 113.45 Vol/60 1 Air.ch/Hr 113.45
SOLAR & TRANS GAIN WALLS & ROOF					
ITEM	Area (sq.ft)	Temp. Difference	Factor (U)		CFM infiltration 113.45
Wall - North	397.38	2	0.103	81.86	
Wall - West				0.00	CFM OUTSIDE AIR THROUGH APPARATUS
Wall - East			0.103	0	EFFECTIVE SENSIBLE HEAT FACTOR & APPARATUS DEWPOINT
Wall - South				0	Room Sense, Ht 38306.33
Roof Sun			0.35	0.00	Room total heat 53279.97
Roof Shaded					Indicated ADP °F Selected ADP 53
TRANS GAIN - EXCEPT WALLS & ROOF					
ITEM	Area (sq.ft)	Temp. Difference	U value		(1-BF) °RM Temp. °ADP Dehumidified Air Rise
All Glass	86.55	18.2	1.27	2000.5187	0.9 75 53 19.8
Partition				0	38306.33 = 1779.89 Dehum air CFM
Ceiling				0	1.08 19.8
Floor		0	0	0	Total Air CFM 1780
INFILTRATION AND OUTSIDE AIR					
ITEM	Infiltration(CFM)	Temp. Difference		Factor	
Infiltration	113.45	18.2		1.08	2229.9732
ITEM	Outside Air(CFM)	Temp. Difference	BF	Factor	
Outside Air	366	18.2	0.1	1.08	719.41
INTERNAL HEAT					
ITEM	No. of People	Internal heat Sensible (btu/hr/person)			
People	65	250			16250
ITEM	Total hp	Internal heat			
hp					0
ITEM	Area (sq.ft)Lights	watts/sq ft	B.F	Factor	
Light	687	1.4	1.25	3.41	4099.67
ITEM	Total usage factor				
Appliances etc	1500	1		3.41	5115.000
					34823.93
Duct Heat Gain	Duct Leak Loss	Fan H.P	Safety Factor	10%	3482.39
Room Sensible heat					38306.33
ROOM LATENT HEAT					
ITEM	CFM	gr/lb(gains diff)		Factor	
Infiltration	113.5	6		0.68	463.08
Out Side Air	366	6	0.1	0.68	149.33
ITEM	lb/hr	Factor			
Steam					0
item	Total	nt heat (btu/hr/person)			
people	65	200			13000
Room latent heat sub total					13612.41
Supply Duct Leakage Loss		Safety Factor %	10%		1361.24
Room latent heat					14973.65
Room Total Heat					53279.97
OUT SIDE AIR HEAT					
Item	CFM	Temp. Difference	(1-BF)	Factor	
Sensible	114	18.2	0.9	1.08	2016.71
Item	CFM	gr/lb		Factor	
Latent	114	6	0.9	0.68	418.61
Tr	4.64	Grand total heat			55715.29

Fig.7Total Heat & Cooling Capacity

V. CONCLUSION

The green development technique allows building owners to reduce building energy exhaustion, enhance workspace, and reduce the natural impact of building exercises. In the event that the building can decrease working expenses, increment representative profitability, lessen wellbeing objections and be ecologically dependable, it is a green structure. A few changes are brought about by propels in innovation, while others are the consequence of impacts past our nearby control. To ensure this, the performance of HVAC systems plays an important role as HVAC systems directly or indirectly affect green building components. Advancing the HVAC plan and usefulness for green structures requires an incorporated extensive plan measure at the beginning of an undertaking.

As designers, we have an obligation to be dynamic in advancing changes that advantage the local area we serve. This will straightforwardly profit our industry and every person. You can be a piece of that positive change by imparting your insight to different specialists through distributions, serving in standard composing associations, and taking an interest in innovative social orders. Plans straightforwardly affect individuals who own buildings. Keep on discovering approaches to lessen the effect on the climate and normal assets and guarantee their prosperity and wellbeing. Changes happen and get better. We can fulfill our vision for our industry while taking action through our contributions to HVAC technology. These advances have been used effectively in certain applications, and execution enhancements reduce framework costs and speed up the integration of new frameworks into traditional HVAC framework. While green methods make residents and solid dwellers happy with rates, increasing productivity owners need to consolidate these developments in order to achieve market gains.

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