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Design of Air Conditioning System for a Residential Building Using Air Cooled Chillers

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Abstract: The average summer temperatures experienced by most countries are increasing every year and consequently the energy needs to provide air-conditioning is also increasing annually. The HVAC industry has a challenging task of providing energy efficient technologies to satisfy this growing demand with a minimum impact on global warming and ozone depletion.
The chilled water types of central air conditioning plants are installed in the place where whole large buildings, shopping mall, airport, hotel, etc, comprising of several floors are to be air conditioned.
The project consists of how the proposed centralizes air conditioning is designed and its criterion for a new buildings in Hyderabad. It consists of 6 floors having an area of 4,000 sqft. Per floor. The main objective is to create a thermally controlled environment within the space of a building envelope such as kitchen room, master bedroom, dining room etc. The tentative air conditioning load for the system shall be 290 TR approx. Air cooled chillers with pumping system are proposed to make the system energy efficient. The proposed air conditioning plant shall be located on the building terrace.
Keywords: Humidification, Dehumidification, Infiltration, Ventilation, Dry Bulb Temperature, Wet Bulb Temperature, Dew Point temperature, Relative Humidity, Specific Humidity, Indoor-Air-Quality, British-thermal-unit, Ton-of-Refrigeration.

I. INTRODUCTION

Air conditioning application engineering is as much an art as it is a science. Science has evaluated all the factors required to determine a heating or cooling load through years of experimentation, tests, and analysis. It is the application of these factors in determining the building or space load that much care and judgment must be exercised.
It is the purpose of the manual to provide data and procedures for the load calculations for the summer and winter air conditioning in small commercial and public assembly applications. The intent is primarily for the summer, winter, and year-round conditioning systems employing unitary equipment (package or split system, including heat pumps) of all types installed in commercial buildings. This manual does not apply to large buildings employing central systems using built up or central station equipment for air conditioning purposes. For applications where life, safety, or specific processes depend on maintaining specified indoor design conditions, a consulting engineer component in the particular application should be employed. For heating load calculations, it is sufficient to calculate the heat transmission through the various elements of the building without regard to orientation.

II. REFRIGERATION AND AIR CONDITIONING

A. HVAC (Heating Ventilation and Air Conditioning)

It is a system which controls temperature, humidity, air quality of an indoor space according to human comfort condition
HVAC refers to Treatment of air so as to which control temperature, moisture content, quality and circulation, as required by occupants, a process, or products in the space.
There are six main processes required to achieve full air conditioning and they are listed and explained below:

1) Dry-bulb Temperature (Heating & cooling)
2) Moisture (Humidifying & Dehumidifying)
3) Air movement
4) Fresh air (Ventilation)
5) Cleanliness of the air (Filtration)
6) Noise levels

B. Methods of Refrigeration and Air Conditioning

Refrigeration or Air Conditioning can be done using following cycles

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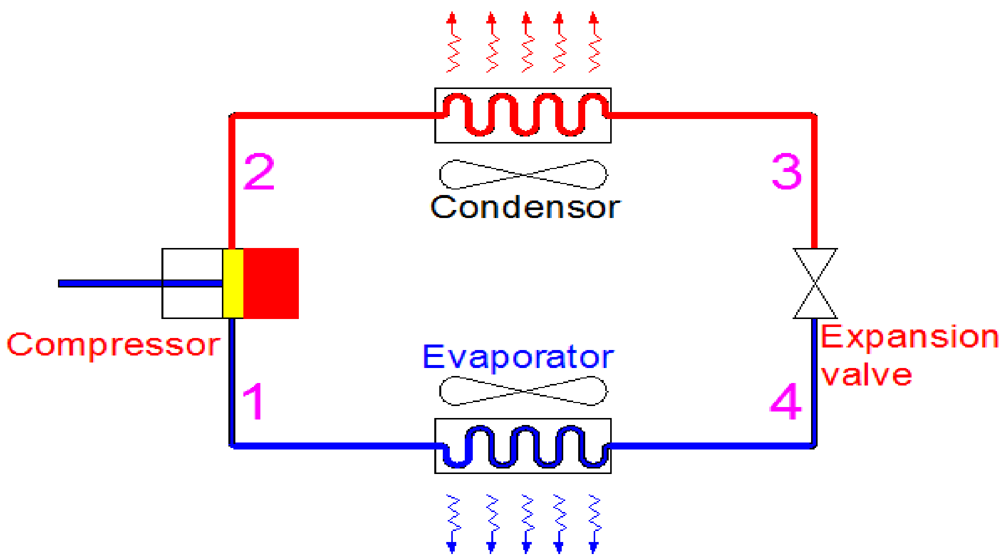
1) *Non-cyclic refrigeration:* In This method of refrigeration cooling to a contained area is given by melting ice, or by sublimating dry ice. Perhaps the simple example of this type of cooing is a portable cooler, where items are put in it, and then ice is poured over the top. Continuously ice can maintain temperatures near, but not below the freezing point, unless salt is used to cool the ice down further (as in a traditional ice-cream maker). Dry ice is used to maintain the temperature well below freezing.
2) *Cyclic refrigeration:* In this system of refrigeration cycle, heat is extracted from a low-temperature side or source or area and is supplied to a high-temperature side or sink with the help of external work, and the inverse of this cycle is, the thermodynamic power cycle. In the power cycle, heat is supplied from a high-temperature source to the engine or machine, part of the heat being used to produce work and the some part of heat rejected to a low-temperature sink. This satisfies the second law of thermodynamics.

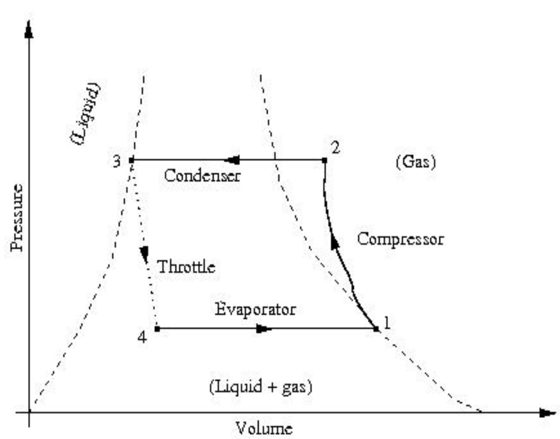
Cyclic refrigeration can be classified as

C. Vapour cycle

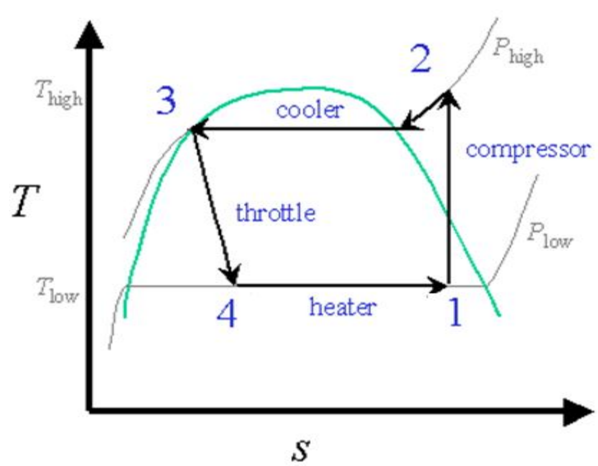
1) *Vapour Compression Refrigeration Cycle:* In many cases the mostly used refrigeration system is the vapour-compression refrigeration cycle, although vapour absorption refrigeration heat pump cycle are used in a minority of applications.



Vapour Compression Refrigeration Cycle



P-V diagram of vapour compression Refrigeration cycle



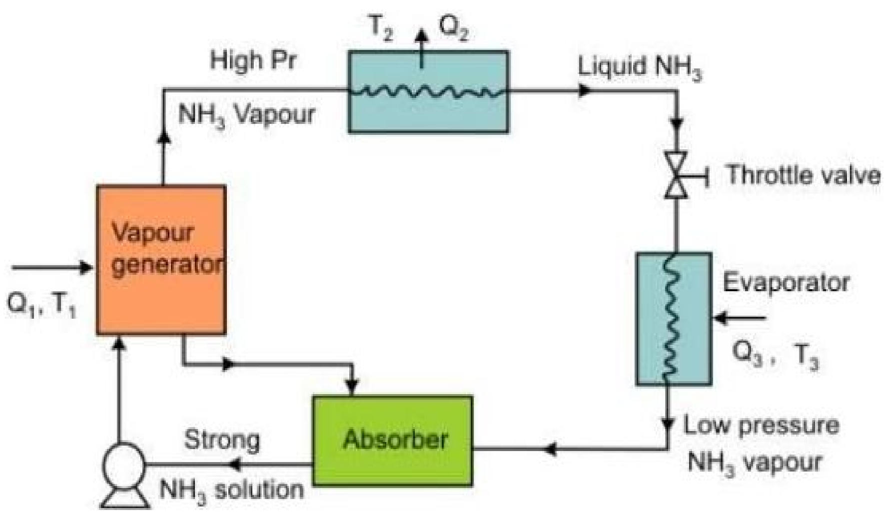
T-S diagram of vapour compression Refrigeration cycle *a)* Process 1-2: The refrigerant first enters into the compressor as a low-pressure and low temperature gas, it is compressed by the compressor and then moves out of the compressor as a high-pressure and high temperature gas.

b) Process 2-3: The high-pressure and high temperature gas then flows to the condenser coil. In condenser coil the gas condenses to a liquid, and gives off its heat to the outside air. That is change of phase takes place from gas to liquid by removal of heat. This moderate temperature and moderate pressure refrigerants liquid enters into the expansion valve.

c) Process 3-4: The liquid moderate temperature refrigerants liquid enters into the expansion valve high pressure. This expansion valve works as a metering device and restricts the flow of the fluid, and lowers its pressure and temperature as refrigerant fluid leaves the expansion valve.

d) Process 4-1: This low-pressure and low temperature liquid then moves to the evaporator coil, where heat from the inside air is taken by the refrigerant and changes its phase from a liquid to a gas. As a hot low-pressure refrigerant gas leaves evaporator coil, this refrigerant again moves to the compressor where the entire cycle is repeated.

2) *Vapour absorption refrigeration cycle:* In the early years of the twentieth century, the vapour absorption refrigeration cycle using water and ammonia mixture systems was popular and widely used. After the development of the vapour compression refrigeration cycle, the vapour absorption refrigeration cycle lost much of its importance due to its low coefficient of performance (about 1/5th of that of the vapour compression refrigeration cycle). Now a day, the vapour absorption refrigeration cycle system is used mainly where fuel is available but electricity availability is less, such as recreational vehicles. It is also used in commercial and industrial environments where plentiful waste heat overcomes its inefficiency.



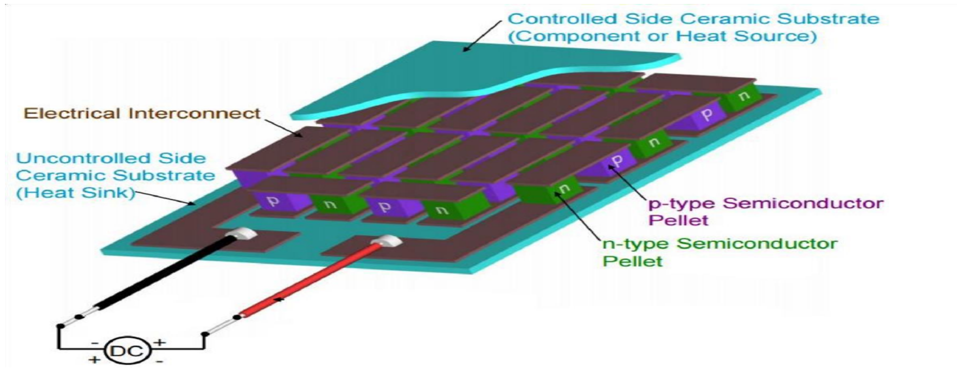
Vapour Absorption Refrigeration Cycle

The absorption refrigeration cycle is similar to the compression refrigeration cycle, except for the method of raising the pressure and temperature of the refrigerant vapour. In the absorption refrigeration system, the compressor is replaced by an absorber which dissolves the refrigerant in a suitable liquid; a liquid then pumped which raises the pressure then the generator which, on heat addition, pumps the refrigerant vapour from the high pressure liquid. Some work is needed by the liquid pump but, for a given quantity of refrigerant, it is much smaller than needed by the compressor in the vapour compression cycle. In an absorption refrigeration cycle, a suitable combination of refrigerant like Li-Br and water mixture absorbent is used. The most common combinations are ammonia (refrigerant) with water (absorbent), and water (refrigerant) with lithium bromide (absorbent).

D. Gas cycle

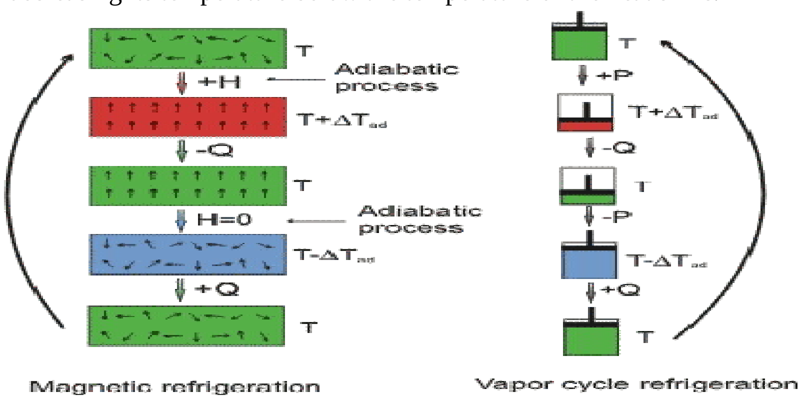
The refrigerant which is used for refrigeration is gas then that refrigeration cycle is called as Gas Cycle. In this cycle the working fluid is a gas that is compressed and expanded but it doesn't change phase, the refrigeration cycle is called a gas cycle. Air is mostly used for this type of system. In this system there is no condensation process and evaporation process, components corresponding to the condenser and evaporator in a vapour compression cycle is the hot and cold gas-to-gas heat exchangers in gas cycles.

1) *Thermoelectric refrigeration:* Thermoelectric cooling uses the thermoelectric effect (peltier effect) to create a heat difference in temperature between the junctions of two types of material. This type of system is commonly used in camping and portable coolers and for cooling electronic components and small instruments.



Thermo Electric Refrigeration System

2) *Magnetic refrigeration*: Magnetic refrigeration system, or adiabatic demagnetization system of cooling, is a cooling technology depends on the magneto caloric effect, an intrinsic property of magnetic solids. The refrigerant is often a paramagnetic salt, such as cerium magnesium nitrate. The active magnetic dipoles in this case are those of the electron shells of the paramagnetic atoms. In this system a strong magnetic field is used. This field is applied to the refrigerant, forcing its various magnetic dipoles to align and putting these degrees of freedom of the refrigerant into a state of lowered entropy. In this system a heat sink is used which then absorbs the heat released by the refrigerant due to its loss of entropy. Then the Thermal contact with the heat sink is broken so that the system is insulated, and simultaneously the magnetic field is switched off. Due to this the heat capacity of the refrigerant increases, thus decreasing its temperature below the temperature of the heat sinks.



Magnetic Refrigeration System

Because some materials only exhibit the required properties at room temperature, applications have so far been limited to cryogenics and research.

E. Types Of Air Conditioning Systems

1) Window air-conditioning system
2) Split air-conditioning system
3) Centralized air-conditioning system
4) Package air-conditioning system
5) Variable Refrigerant Flow or VRF System

For the given Project Centralized air-conditioning system is used with Air Cooled Chillers.

F. Heat load Calculation

It is a Mathematical procedure of calculating the amount of heat generated inside the building space through external and internal sources of Heat.

This Heat has to be removed from the Building space to maintain a set of cooling condition or to maintain the indoor Conditions.

1) Unit of Refrigeration: This Generated heat is measured in BTU/hr. Typically, commercial and industrial refrigeration or air conditioning systems are rated in BTU/hr (British Thermal Unit/Hour) or in TR (Tons of Refrigeration).

2) BTU/hr: The BTU/hr is defined as the amount of heat required to raise the temperature of 1 pond of water by 1O C.
3) One TR: One TR is defined as the amount of cooling given by the 1 ton of ice kept in a room of dimension 10’x10’x10’ in the next 24 hrs. This was very important because many early refrigeration systems were in ice houses.

The unit's value as historically defined was approximately 11,958 BTU/hr (3.505 kW), and has now been conventionally redefined as exactly 12,000 BTU/hr (3.517 kW).

1 TR = 11,958 BTU/hr = 12,000 BTU/hr approximately

Heat Load Calculation Methods

1) Manual Calculation.
2) HAP Calculation (Software).
3) E-20 Sheet (Excel).

III. RESULT AND DISCUSSION

A. *Heat Load Calculation of Building*

Basic Formulae to Find Heat Load Calculation

Q = U A ΔT

Here

Q = Quantity/Rate of Heat Transfer (BTU/hr)

U = Coefficient of Heat Transfer (BTU/hr ft^2 ^{o}F)

ΔT = Temperature difference (^{o}F)

The Total Heat Load Calculation for the Entire Building was done by E-20 Sheet (Excel).

HEAT LOAD ESTIMATE

PROJECT	Residential Project								
LOCATION	Hyderabad								
CLIENT									
CONSULTANT									
Date	29/03/2017								
Item	Area or Quantity			Sun Gain or Temp. Diff.			Factor	Btu/Hour	W
	ROOM HEAT								
ROOM SENSIBLE HEAT									
Solar Gain - Glass									
Glass - N	24	SqFt	x	23	F	x	0.59	326	
Glass - NE		SqFt	x	138	F	x	0.59	0	
Glass - E	24	SqFt	x	163	F	x	0.59	2308	
Glass - SE		SqFt	x	85	F	x	0.59	0	
Glass - S		SqFt	x	14	F	x	0.59	0	
Glass - SW		SqFt	x	85	F	x	0.59	0	
Glass - W		SqFt	x	163	F	x	0.59	0	
Glass - NW		SqFt	x	138	F	x	0.59	0	
Skylight		SqFt	x	251	F	x	0.59	0	
Solar & Transmission Gain - Walls & Roof									
Wall - N	134	SqFt	x	15	F	x	0.38	764	
Wall - NE		SqFt	x	27	F	x	0.38	0	
Wall - E	183	SqFt	x	36	F	x	0.38	2503	
Wall - SE		SqFt	x	30	F	x	0.38	0	
Wall - S		SqFt	x	27	F	x	0.38	0	
Wall - SW		SqFt	x	25	F	x	0.38	0	
Wall - W		SqFt	x	23	F	x	0.38	0	
Wall - NW		SqFt	x	17	F	x	0.38	0	
Roof		SqFt	x	49	F	x	0.38	0	
Transmission Gain - Except Walls & Roof									
All Glass	48	SqFt	x	30	F	x	0.59	850	
Partition	366	SqFt	x	25	F	x	0.54	4941	
Ceiling		SqFt	x		F	x		0	
Floor		SqFt	x		F	x		0	
INFILTRATION AND BY PASSED AIR									
Infiltration	21	CFM	x	30	T.Diff	x	1.08	687	
Ventillation	76	CFM	x	30	T.Diff	x	BF x 1.08	491	
Internal Heat									
People	2	Nos.	x	245	Btu/Hour Per Person			490	
Lighting	230	SqFt	x	2.5	W/SqFt	x	3.41	1957	
Lighting & S. P.		SqFt	x		W/SqFt	x	3.41		
Equipment	0.70	kW	x	3410				2387	
			Sub Total					17704	
			Factor				5-10%	1770	
			Effective Room Sensible Heat					19474	
ROOM LATENT HEAT									
Infiltration	21	CFM	x	32	Gr/Lb	x	0.68	461	
Outside Air	76	CFM	x	32	Gr/Lb	x	BFx0.68	330	
People	2	Nos.	x	205	Btu/Hour Per Person			410	
			Sub Total					1201	
			Factor				2.5 - 5%	60	
			Effective Room Latent Heat					1261	
EFFECTIVE ROOM TOTAL HEAT								20735	
		OUTSIDE AIR HEAT							
Sensible	76	CFM	x	30	F(TD)	x	CF x 1.08	1964	
Latent	76	CFM	x	32	Gr/Lb	x	CF x 0.68	1319	
OUTSIDE AIR TOTAL HEAT								3283	
		GRAND TOTAL HEAT						24018	
			Sub Total						
TONS=GRAND TOTAL HEAT/12000								2.00	

FLOOR	GROUND FLLOR					
SPACE REFERENCE	GF-009					
AREA (SqFt)	230					
Height (Ft)	12.000					
Volume (CuFt)	2755					
Estimate for	Summer					
Design Conditions	DB (F)		WB (F)	RH (%)		SH Gr/Lb
Ambient	106		78	28		100
Room	76		63.5	50		68
Difference	30		14.5	-22		32
By Pass Factor (BF)					=	0.20
Contact Factor (CF = 1 - BF)					=	0.80
CFM Ventilation						
CFM Per Person	2	No	=	20	=	40
CFM Per SqFt	230	Sqft	x	0.33	=	76
Air Change Per Hour (CFM)			=	1.5		
CFM Cu.ft	2,755	x	1.5	x1/60	=	69
CFM Infiltration						
Swinging		x		cfm/door	=	-
Revolving Doors (People)		x		cfm/door	=	-
Open Doors		x		cfm/door	=	-
Crack (feet)	40	x	0.53	cfm/ft	=	21.20
						21.20
Supply CFM from Machine						
Effective Room Sensible Heat Factor =						
Effective Room Sensible Heat/Eff Room Total Heat					=	0.93918
Apparatus Dew Point (ADP)						
Indicated ADP (°F)					=	
Selected ADP (°F)					=	55.0
Dehumidified Rise						
(Room DB - ADP) x CF					=	16.80
DEHUMIDIFIED AIR QUANTITY						
Effective Room Sensible Heat			=	1073		CFM
Dehumidified Rise x 1.08						
			=	504		L/s
TOTAL HEAT CAPACITY						
Grand Total Heat			=	2.00		TR
SENSIBLE HEAT CAPACITY						
Grand Sensible Heat			=	1.62		TR
12000						
			=	19.47		MBH
			=	5.70		kW
Check Figures:						
SqFt Per TR			=	115		
Btu/Hour Per SqFt			=	105		
Dehumidified CFM Per SqFt			=	4.68		
Dehumidified CFM Per TR			=	536		

Heat load calculation e-20 sheet of GF-009

TABLE I: HEAT LOAD OF THE ENTIRE BUILDING

Floor Wise Heat Load		
Floor Reference	TR	L/S
Ground Floor	40.66	8776
First Floor	41.18	8932
Second Floor	41.27	8920
Third Floor	41.38	8850
Fourth Floor	41.25	8726
Fifth Floor	41.22	8945
Roof Deck	43.14	9010
Total	290.10	62159

B. Duct Designing

Duct Designing Basic Formulae is

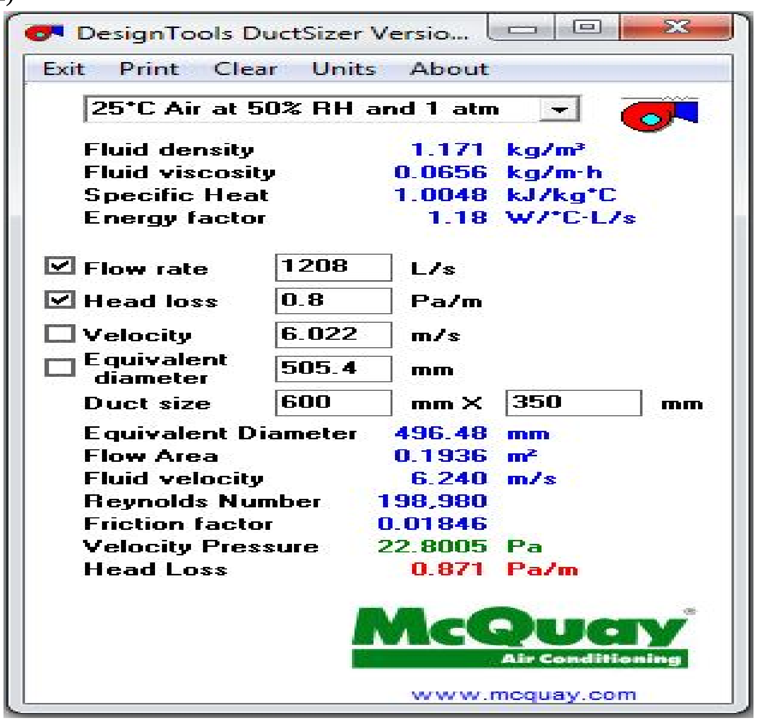
Q = A V

Here

Q = Rate of Air Flow (CFM)

A = Area of Duct (ft^2)

V = Velocity of Air (FPM)



Duct Designing By McQuay Duct Sizer

C. Pipe Designing

Basic Formulae for Pipe Designing is

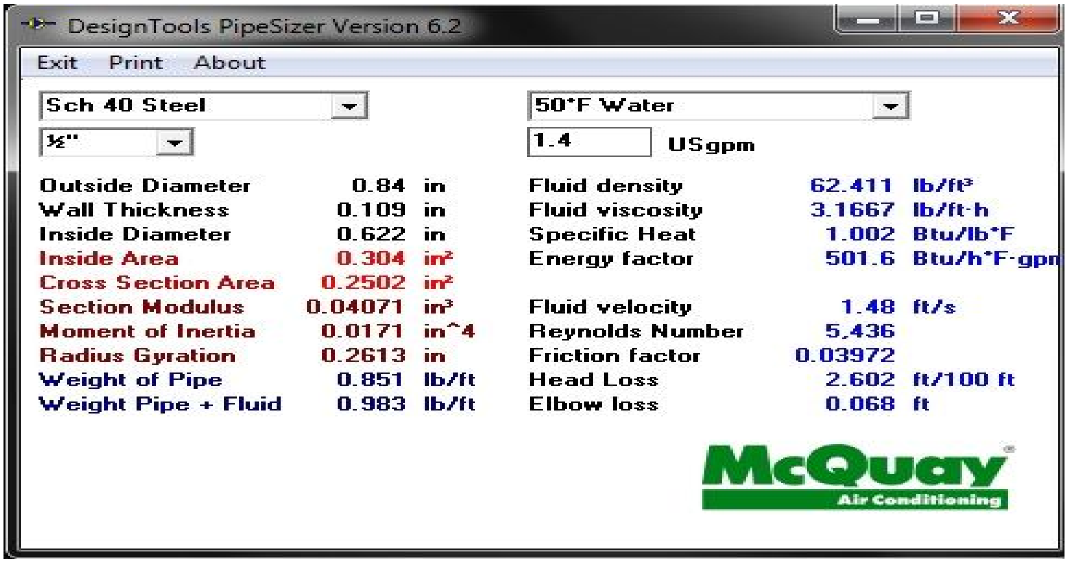
Q = A V

Here

Q = Rate of Flow (GPM)

A = Area of Pipe (ft^2)

V = Velocity of Water (FPS)



Pipe Designing By McQuay Pipe Sizer

IV. CONCLUSIONS

The HVAC System Quality Installation is a datum requirement to align with the standards like ASHRAE to improve the performance of the equipment like Air Cooled Chiller. However, the performance should not just have rated on the installation but also will depend on the design and equipment selection aspects as discussed in the earlier chapter.

The project concludes that, given the right design and equipment for a residential project the quality installation of the equipment will render better performance and will reduce the maintenance cost of the project.

Therefore, the project objective of installation of an Air Cooled Chiller for Residential project is achieved and steps are being taken to further intensify the issues faces in such installation.

V. ACKNOWLEDGMENT

This project has been completed under the guidance and encouragement of many personalities.

My whole hearted and sincere gratitude to my parents for their tremendous motivation and moral support.

I express my deep sincere thanks and gratitude to chairman Nawab shah alam khan for his motivation and suggestions.

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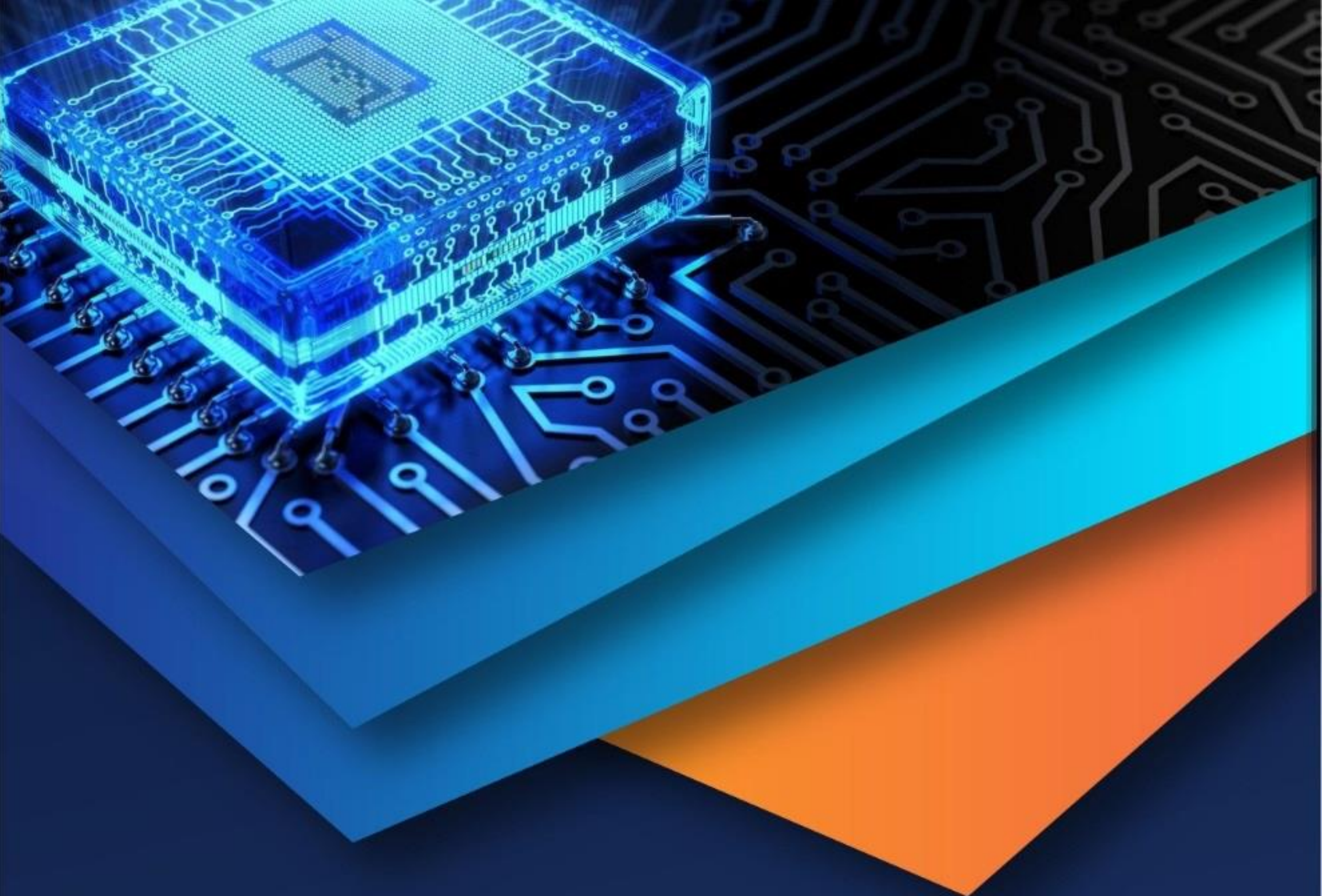

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