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ENHANCING HOSPITAL HVAC EFFICIENCY: A COMPREHENSIVE STUDY ON OPTIMIZING SYSTEMS WITH VRF TECHNOLOGY IMPLEMENTATION

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Abstract

This paper is focused on designing HVAC systems that offer optimal thermal comfort while protecting patients, visitors, and staff from infections in hospitals. To achieve this goal, the authors recommend using 'Variable Refrigerant Flow' systems that can control refrigerant flow in indoor units based on demand, enabling multiple indoor units to function efficiently with a single outdoor unit. VRF systems are those efficient HVAC systems which can reduce the energy usage in buildings. The key aspect in the design process includes heat load calculation, in which various parameters of the design space are measured to calculate the required tonnage of refrigeration. The data collected is compiled in a database, and MS Excel is used to perform calculations that enables to select an appropriate HVAC system based on its viability, availability, technical feasibility, and economic feasibility. The piping systems are designed using the single line diagram software. Mc Quay duct sizer software is used to calculate the duct dimensions according to the required CFM. Finally, AutoCAD software is utilized to visualize beam structures, partitions, and optimal placements for the piping system, ductwork, indoor and outdoor units, and other essential supporting accessories. By using these tools, the HVAC system is designed to meet the specific requirements of the hospital and provide optimal thermal comfort.

Keywords: Duct design, Heat load calculation, HVAC system, Piping system, VRF System

INTRODUCTION

Hospital HVAC systems oversee controlling the temperature, humidity, hygiene, and air quality, all of which are essential components of keeping a safe and congenial environment for both employees and patients. Additionally, these systems are important for lowering the danger of infection transmission and contamination, particularly in places that require extreme sensitivity, including operating rooms and intensive care units. Also, it also aids in faster recovery of patients. Catalog By regulating airflow and obstructing the circulation of contaminated air, properly constructed, and maintained HVAC systems can mitigate the spread of infectious diseases. They can also assist in removing contaminants from indoors, such as dust, chemicals, and biohazards which can cause respiratory troubles and other health problems. HVAC systems that are properly constructed not only ensure a healthy interior environment but also help hospitals save money and energy. Studies show that HVAC systems account for hospitals' overall energy use, significantly increasing their carbon footprint [20]. HVAC systems that are energy-efficient can help maintain ideal indoor conditions while consuming less electricity. Evidence from multiple studies indicates that VRF systems can achieve energy savings in HVAC site energy use and in source energy use when compared to traditional HVAC systems. A properly designed system enables reduced refrigerant usage, longer lifespan of equipment and less carbon footprints generated. The quantity and placement of air intake and exhaust vents, the kind of filters utilized, and the temperature and humidity requirements for various spaces are vital design considerations for hospital HVAC systems.

HVAC systems must also be designed to comply with local and national regulations and guidelines, which may vary depending on the type, size, and criticality of the hospital. Challenges that hospitals face with HVAC systems include equipment failures, maintenance issues, cross contamination, and the risk of airborne infection transmission. Regular maintenance and inspections of HVAC systems are necessary to ensure their optimal performance and to minimize the risk of equipment failures and system malfunctions.

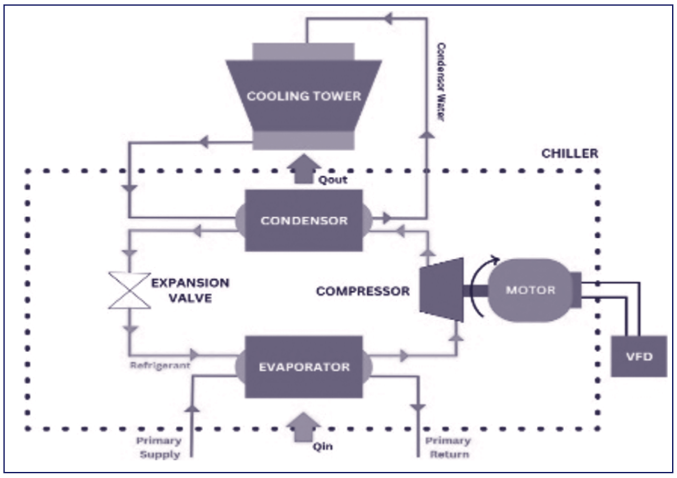
This paper provides us with the insights of the stages involved in the VRF system design which are as follows:

i. Calculation of heat loads.
ii. Computation of tonnage and cfm requirements.
iii. Selection of the necessary auxiliary components.
iv. Determining the piping and ducting layouts.
v. Preparing BOQ and cost estimate.

LITERATURE REVIEW

An HVAC system that uses water as a medium of cooling is a chilled water system. The chilled/cooling water system (CCWS) encompasses a sequence of operations (Figure 1). This system commonly operates in a parallel configuration, running concurrently with heat exchangers (HE) and chiller/cooling towers. In the parallel arrangement of the CCWS, process streams receive cooling utility at the supply temperature. In contrast, a series arrangement facilitates the reuse of returned chilled/cooling water, preventing it from being directly sent to the chiller/cooling tower.[17]. These central chiller produces chilled water, which is subsequently sent throughout a building to air-handling units (AHUs) or fan coil units (FCUs) through efficiently designed ducts The primary function of a chilled water system is to transfer heat from the interior air to the chilled water loop, which is then conveyed by the chilled water to the chiller for further processing. The chiller cools the water and circulates it back to regulate the temperature in the designated spaces. It compresses the refrigerant gas, which then releases the heat through a condenser. The refrigerant evaporates and absorbs heat from the chilled water loop as it passes through an expansion valve. The chilled water is then sent back to the chiller via a closed loop of pipes. The AHUs or FCUs cool the indoor air and distribute it through ductwork or fans.

Fig 1: Chilled Water System



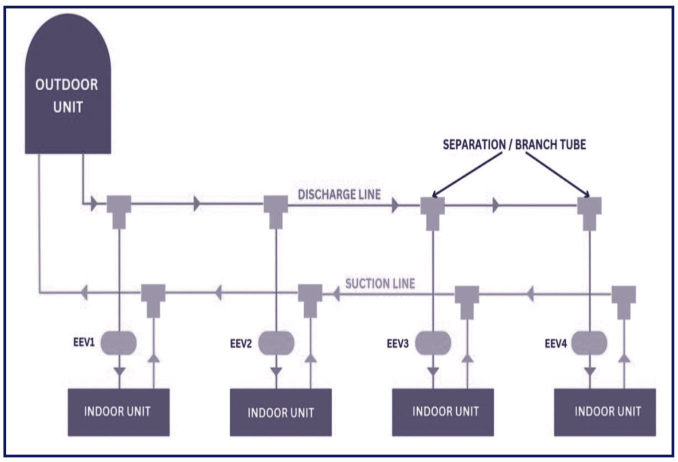
Packaged air-conditioning systems, such as rooftop units (RTUs), are extensively used in small commercial buildings. However, despite new regulations and standards that require multi-speed supply fan operation for new air-conditioning equipment, most of the existing units still rely on fixed-speed supply fans. This leads to high electrical energy consumption, as the supply fans run continuously during occupied periods for ventilation. Additionally, RTU compressors typically have single- or two-stage capacity controls, resulting in frequent unit cycling and reduced energy efficiency performance [12].

The PAC (packaged air conditioning) systems that are currently in use mostly have fixed-speed supply fans and compressors. In pursuit of enhanced operational efficiency, diverse initiatives have been pursued, including retrofitting existing units with improved controls and developing the latest products with complex designs. [10]. HRV units are an effective way to ensure a constant supply of fresh and clean air to indoor living spaces while exhausting stale air from high-moisture areas such as kitchens, laundries, and bathrooms. These air-to-air heat exchangers have in them two fans installed that operate continuously to maintain a consistent flow of air. One fan expels indoor stale air that may contain pollutants, smoke, or other unpleasant odors, while the other fan supplies fresh and filtered outdoor air. The beauty of HRVs is that the fresh air and stale air are kept separate and do not meet each other, and the air is not recycled. In addition to providing a steady supply of fresh air, HRV units are tailored to capture and recycle the heat or cooled energy within the air. The technology behind HRVs ensures that energy is not generated, but instead, it is captured and reused. Accordingly, HRVs can help lower energy consumption and reduce costs. To ensure that the indoor air pressure remains balanced, HRVs are tailored to maintain a nearly equal balance between the incoming and outgoing air. This balanced indoor pressure helps to keep the air quality high, and it can also help to prevent mold growth and other moisture-related problems [11].

IMPLEMENTED SYSTEM

In VRF systems the refrigerant flow is adjusted according to demand for indoor units. The Variable Refrigerant Flow technology is the optimal selection for applications where zoning is necessary or when changing loads are present because it allows users to manage the quantity of refrigerant supplied to indoor units and air handling units spread throughout a building. In situations when concurrent heating and cooling are necessary, VRF systems can be used as heat pump systems or heat recovery systems. VRF systems not only offer improved comfort but also design flexibility, energy savings, and affordable installation. Several indoor units are connected to a single outdoor unit in a VRF system. The speed of the outdoor unit's multiple inverter- driven compressors can be altered by changing the frequency of the power supply to the compressor. The amount of refrigerant that will be delivered by the compressor changes along with the compressor speed. The outdoor unit distributes the amount of refrigerant required to satisfy each indoor unit's specific needs as soon as each indoor unit transmits a demand to it. A VRF-HP system can annually save cooling energy compared to a conventional AHU system based on chillers. These characteristics render the VRF system exceptionally well-suited for applications with part load requirements due to usage, building orientation, as well as applications demanding zoning capabilities.

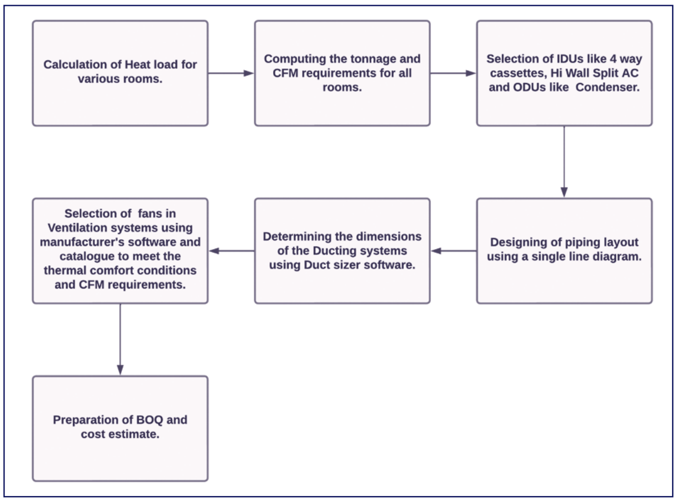
Fig 2: Variable Refrigerant Flow (VRF) System



METHODOLOGY

The process of designing an HVAC system for a hospital involves several steps. The initial stage involves conducting a comprehensive analysis of the design space, taking into consideration factors like the building's orientation, position, climate, and potential sources of heat or humidity. Following this, the subsequent step entails determining and measuring the cooling area, along with calculating the heat load for each zone. This critical information is necessary to accurately size and choose an air conditioning system that aligns with the cooling requirements of the building or space. Refrigeration capacity, CFM requirement, and TFA requisite for each room must be determined, and respective IDU and ODU are selected. The line of piping from outdoor to indoor is a crucial aspect of designing for a HVAC system, which is drafted in AutoCAD. The ducting system is designed, including the Supply Air ducts, Return Air ducts, and Treated Fresh Air Duct, using Static Regain Method. The next step involves selection of AHUs, including the fans used to push air through the supply air duct. Ventilation systems must also be selected for supply and exhaust ventilation in the room to maintain the required amount of pressure and meet the CFM requirement. Finally, a bill of quantities is created that lists all the equipment needed for the HVAC system, as well as the total quantities required. BOM is useful for cost estimation and the total disbursement for the system.

Fig 3: Methodology Flowchart



DESIGN

1. Heat Load Calculations: HVAC load calculation is a computational process for determining several aspects of a building to determine the best size, application, and style of a HVAC system. The objective is to ensure energy efficiency while also maximizing thermal comfort.

Terminologies used are as follows:

i. Load Estimation: Load estimation in heat load refers to the process of determining the amount of heat energy that a building or a space requires to maintain a comfortable temperature with respect to heating or cooling.

ii. Solar Heat Gain Through Glass: The quantity of solar radiation that enters a structure through its windows and glazed surfaces, which can add to the cooling load of the building, is referred to as solar heat gain through glass.

iii. Solar Heat Gain Through Walls and Roofs: The quantity of solar radiation absorbed by a building's exterior surfaces, which can add to the structure's cooling burden, is referred to as solar heat gain through walls and roofs. gain through walls and roofs.

iv. Transmission Heat Gain Through Glass: The quantity of heat energy that enters a building through windows, skylights, or other glazed surfaces is referred to as transmission heat gain through glass.

v. Transmission Through Partitions and Walls: The amount of heat energy that is moved from one location to another through the walls or partitions separating them is referred to as transmission across partitions and walls.

vi. Occupancy Load: When designing and sizing HVAC systems, the number of people expected to be in a space at any given time must be considered.

vii. Lighting Load: Lights generate sensible heat by the conversion of the electrical power input into light and heat.

viii. Appliance load: Most appliances contribute both sensible and latent heat to a space.

ix. Heat Gain from Outside Air: The quantity of heat energy that enters a structure from the outside environment through infiltration or ventilation is known as heat gain from outside air.

x. Shading coefficient: It is a measure of thermal performance of a glass unit (panel or window) in a building. It is the ratio of solar gain (due to direct sunlight) passing through a glass unit to the solar energy which passes through 3mm Clear Float Glass.

xi. The solar cooling load (SCL) factor: It is employed to approximate the speed at which solar heat energy directly radiates into a space, warming surfaces and furnishings. Subsequently, this accumulated heat is later released into space as sensible heat gain.

xii. Sensible heat: It is the amount of thermal energy that is required to change the temperature of an object.

xiii. Sensible heat load: When there is direct addition of heat to an enclosed space without phase change.

xiv. Latent heat: It is defined as the heat or energy that is absorbed or released during a phase change of a substance. It could either be from a gas to a liquid or liquid to solid and vice versa.

xv. Latent heat load: When there is an addition of water vapours to air of enclosed space, it is latent heat gain.

xvi. Bypass factor: The inability of a coil to cool or heat the air to its temperature is indicated by a factor called bypass factor (BPF).

xvii. Heat gain: It is the amount of heat energy to be removed from a room by the HVAC equipment to maintain the indoor design temperature.

xviii. Δw: Difference between outside and inside humidity

xix. CFM: Cubic feet/ min. It is a standard unit of airflow volume. It tells you the volume of air that is being moved by an HVAC device every minute.

xx. Air change: It is the number of times that the total air volume in a room or space is completely removed and replaced in an hour.

1.1 Theoretical Calculations

A) Solar heat gain for wall and floor: Q= u*A*ΔT, Where, Q = heat flow, U= Overall heat transfer coefficient of the material A= Area of surface in sq. ft, ΔT = Outside temperature – inside temperature °F

B) Solar heat gain by Glass :Q= A*sc*scl, Where, Q= heat gain by solar radiation through glass A= Area of surface in sq. ft, sc= Shading coefficient of window, scl= Solar cooling load factor (BTU/hr/sq. ft)

C) Effective room sensible heat load (ERSHL): Outside air= (Volume of room (ft^3) ×No. of air changes)/60 Sensible heat Qs = CFM* ΔT* bf* 1.08 BTU/hr, Internal heat = No. of people * sensible heat gain/person = BTU/hr Light load = Total area (sq. Ft) * lighting load* 3.41 BTU/hr Equipment load = No. of equipment* equipment load* 3.41 BTU/hr, Total sensible heat load = BTU/hr, Effective sensible heat load = 5-15% safety factor

D) Effective room latent heat load (ERLHL): Latent Heat Ql = Outside air CFM * Δw* bf * 0.68 BTU/hr Internal load = No. of people * latent heat gain = BTU/hr Total latent heat load = BTU/hr, Effective latent heat load = BTU/hr 2.5 – 5% safety factor

E) Effective room total heat load (ERTHL) ERSHL + ERLHL = BTU/hr

F) TR of AC required: ERTHL/12000

Fig 4: Recovery Room

HVAC LOAD CALCULATION

PROJECT	SUVARNA HOSPITAL
LOCATION	Borivali
FLOOR	Third Floor
SPACE REFERENCE	Recovery Room
AREA (SqFt) (WxL)	500.00
Falce Ceiling Height (Ft)	9.00
Volume (CuFt)	4,500.00
Estimate for	Summer

Design Conditions	DB (°F)	WB (°F)	RH (%)	HR (Gr/Lb)
Ambient(Out Side)	95.00	72.00	70.00	74.00
Room (InDoor)	75.00	63.00	55.00	68.00
Difference Δ	20.00	9.00	15.00	6.00

Item	Area or Quantity			Sun Gain or Temp. Diff.			Factor (U)	Btu/Hour	Watts
	ROOM HEAT				Q= U*A*ΔT				
ROOM SENSIBLE HEAT									
Solar Gain - Glass	Area			ΔT			U		
Glass - N	36.00	SqFt	x	20.00		x	1.15	828.00	
Glass - NE		SqFt	x			x		0.00	
Glass - E	72.00	SqFt	x	20.00		x	1.15	1,656.00	
Glass - SE		SqFt	x			x		0.00	
Glass - S		SqFt	x			x		0.00	
Glass - SW		SqFt	x			x		0.00	
Glass - W		SqFt	x			x		0.00	
Glass - NW		SqFt	x			x		0.00	
Skylight		SqFt	x			x		0.00	
Solar & Transmission Gain - Walls & Roof									
Wall - N	453.00	SqFt	x	20.00		x	0.30	2,718.00	
Wall - NE		SqFt	x			x		0.00	
Wall - E	813.00	SqFt	x	20.00		x	0.30	4,878.00	
Wall - SE		SqFt	x			x		0.00	
Wall - S		SqFt	x			x		0.00	
Wall - SW		SqFt	x			x		0.00	
Wall - W		SqFt	x			x		0.00	
Wall - NW		SqFt	x			x		0.00	
Roof	500.00	SqFt	x	45.50		x	0.50	11,375.00	
Transmission Gain - Except Walls & Roof									
All Glass	27.10	SqFt	x	20.00		x	0.30	162.60	
Partition	46.15	SqFt	x	15.00		x	0.50	346.13	
Ceiling		SqFt	x			x		0.00	
Floor	321.35	SqFt	x	15.00		x	0.30	1,446.08	
INFILTRATION AND BY PASSED AIR									
Infiltration		CFM	x	20.00	T.Diff	x	1.08	0.00	
Outside Air	340.00	CFM	x	20.00		x		881.28	
Internal Heat									
People	25.00	Nos.	x	230.00	Btu/Hour Per Person			5,750.00	
Lighting	500.00	SqFt	x	1.00	W/SqFt	x	3.41	1,705.00	
Equipments	1.00			200.00	Watts	x	3.41	682.00	
Power		kW/Hp	x					0.00	
Sub Total								32,428.08	
Factor							5-15%	4,864.21	
Effective Room Sensible Heat								37,292.29	1.00
ROOM LATENT HEAT									
Infiltration	0.00	CFM	x	6.00	Gr/Lb	x	0.68	0.00	
Outside Air	340.00	CFM	x	6.00	Gr/Lb	x	BFx0.68	166.46	
People	25.00	Nos.	x	120.00	Btu/Hour Per Person			3,000.00	
Sub Total								3,166.46	
Factor							2.5 - 5%	158.32	
Effective Room Latent Heat								3,324.79	2.00
EFFECTIVE ROOM TOTAL HEAT								40,617.08	
		OUTSIDE AIR HEAT							
Sensible	340.00	CFM	x	20.00	F(TD)	x	CF x 1.08	6,462.72	3.00
Latent	340.00	CFM	x	6.00	Gr/Lb	x	CF x 0.68	1,220.74	4.00
OUTSIDE AIR TOTAL HEAT								7,683.46	
GRAND SUB-TOTAL HEAT								48,300.54	
Factor							1 - 3%	1,449.02	
GRAND TOTAL HEAT								49,749.55	
							TMBH	49.75	
							TKW	14.43	
							TSMBH	43,755.01	
							TSKW	12,688.95	
TONS=GRAND TOTAL HEAT/12000								4.15	

By Pass Factor (BF)					=	0.12
Contact Factor (CF = 1 - BF)					=	0.88
CFM Ventilation						
CFM Per Person	10.00	No	=	25.00	=	250.00
CFM Per SqFt	0.18	Sqft	x	500.00	=	90.00
Air Change Per Hour (CFM)			=	5.00		
CFM Cu.ft	4,500.00 x	5.00		x1/60	=	375.00
CFM Infiltration						
Swinging		x		cfm/door	=	0.00
Revolving Doors (People)		x		cfm/door	=	0.00
Open Doors		x	2.00	cfm/door	=	0.00
Crack (feet)		x		cfm/ft	=	0.00
						0.00
Supply CFM from Machine						
Effective Room Sensible Heat Factor =						
Effective Room Sensible Heat/Eff Room Total Heat					=	0.92
Apparatus Dew Point (ADP)						
Indicated ADP (°F)					=	
Selected ADP (°F)					=	54.60
Dehumidified Rise						
(Room DB - ADP) x CF					=	17.95

DEHUMIDIFIED AIR QUANTITY			
Effective Room Sensible Heat / Dehumidified Rise x 1.08	=	1,923.46	CFM
	=	904.02	L/s
TOTAL HEAT CAPACITY			
Grand Total Heat	=	4.15	TR
SENSIBLE HEAT CAPACITY			
Grand Sensible Heat / 12,000.00	=	4.15	TR
Notes:			

Fig 5: Lobby Wide

HVAC LOAD CALCULATION

PROJECT	SUVARNA HOSPITAL								
LOCATION	Borivali								
Item	Area or Quantity			Sun Gain or Temp. Diff.			Factor (U)	Btu/Hour	Watts
	ROOM HEAT				Q= U*A*ΔT				
ROOM SENSIBLE HEAT									
Solar Gain - Glass	Area			ΔT			U		
Glass - N		SqFt	x			x		0.00	
Glass - NE		SqFt	x			x		0.00	
Glass - E		SqFt	x			x		0.00	
Glass - SE		SqFt	x			x		0.00	
Glass - S		SqFt	x			x		0.00	
Glass - SW		SqFt	x			x		0.00	
Glass - W		SqFt	x			x		0.00	
Glass - NW		SqFt	x			x		0.00	
Skylight		SqFt	x			x		0.00	
Solar & Transmission Gain - Walls & Roof									
Wall - N		SqFt	x			x		0.00	
Wall - NE		SqFt	x			x		0.00	
Wall - E		SqFt	x			x		0.00	
Wall - SE		SqFt	x			x		0.00	
Wall - S		SqFt	x			x		0.00	
Wall - SW		SqFt	x			x		0.00	
Wall - W		SqFt	x			x		0.00	
Wall - NW		SqFt	x			x		0.00	
Roof	138.51	SqFt	x	45.50		x	0.50	3,151.10	
Transmission Gain - Except Walls & Roof									
All Glass	27.10	SqFt	x	20.00		x	0.30	162.60	
Partition	46.15	SqFt	x	15.00		x	0.50	346.13	
Ceiling		SqFt	x			x		0.00	
Floor	321.35	SqFt	x	15.00		x	0.30	1,446.08	
INFILTRATION AND BY PASSED AIR									
Infiltration		CFM	x	20.00	T.Diff	x	1.08	0.00	
Outside Air	174.93	CFM	x	20.00		x		453.42	
Internal Heat									
People	15.00	Nos.	x	230.00	Btu/Hour Per Person			3,450.00	
Lighting	138.51	SqFt	x	1.00	W/SqFt	x	3.41	472.32	
Equipments	1.00			200.00	Watts	x	3.41	682.00	
Power		kW/Hp	x					0.00	
Sub Total								10,163.64	
Factor							5-15%	1,524.55	
Effective Room Sensible Heat								11,688.19	1.00
ROOM LATENT HEAT									
Infiltration	0.00	CFM	x	6.00	Gr/Lb	x	0.68	0.00	
Outside Air	174.93	CFM	x	6.00	Gr/Lb	x	BFx0.68	85.65	
People	15.00	Nos.	x	120.00	Btu/Hour Per Person			1,800.00	
Sub Total								1,885.65	
Factor							2.5 - 5%	94.28	
Effective Room Latent Heat								1,979.93	2.00
EFFECTIVE ROOM TOTAL HEAT								13,668.12	
		OUTSIDE AIR HEAT							
Sensible	174.93	CFM	x	20.00	F(TD)	x	CF x 1.08	3,325.10	3.00
Latent	174.93	CFM	x	6.00	Gr/Lb	x	CF x 0.68	628.08	4.00
OUTSIDE AIR TOTAL HEAT								3,953.18	
GRAND SUB-TOTAL HEAT								17,621.30	
Factor							1 - 3%	528.64	
GRAND TOTAL HEAT								18,149.94	
							TMBH	18.15	
							TKW	5.26	
							TSMBH	15,013.30	
							TSKW	4,353.86	
TONS=GRAND TOTAL HEAT/12000								1.51	

FLOOR	Third Floor					
SPACE REFERENCE	Lobby wide					
AREA (SqFt) (WxL)	138.51					
Falce Ceiling Height (Ft)	9.00					
Volume (CuFt)	1,246.59					
Estimate for	Summer					
Design Conditions	DB (°F)	WB (°F)	RH (%)	HR (Gr/Lb)		
Ambient(Out Side)	95.00	72.00	70.00	74.00		
Room (InDoor)	75.00	63.00	55.00	68.00		
Difference Δ	20.00	9.00	15.00	6.00		
By Pass Factor (BF)					=	0.12
Contact Factor (CF = 1 - BF)					=	0.88
CFM Ventilation						
CFM Per Person	10.00	No	=	15.00	=	150.00
CFM Per SqFt	0.18	Sqft	x	138.51	=	24.93
Air Change Per Hour (CFM)			=	5.00		
CFM Cu.ft	1,246.59 x		5.00	x1/60	=	103.88
CFM Infiltration						
Swinging		x		cfm/door	=	0.00
Revolving Doors (People)		x		cfm/door	=	0.00
Open Doors		x	2.00	cfm/door	=	0.00
Crack (feet)		x		cfm/ft	=	0.00
						0.00
Supply CFM from Machine						
Effective Room Sensible Heat Factor =						
Effective Room Sensible Heat/Eff Room Total Heat					=	0.86
Apparatus Dew Point (ADP)						
Indicated ADP (°F)					=	
Selected ADP (°F)					=	54.60
Dehumidified Rise						
(Room DB - ADP) x CF					=	17.95
DEHUMIDIFIED AIR QUANTITY						
Effective Room Sensible Heat			=	602.85	CFM	
Dehumidified Rise x 1.08						
			=	283.34	L/s	
TOTAL HEAT CAPACITY						
Grand Total Heat			=	1.51	TR	
SENSIBLE HEAT CAPACITY						
Grand Sensible Heat			=	1.51	TR	
12,000.00						
Notes:						

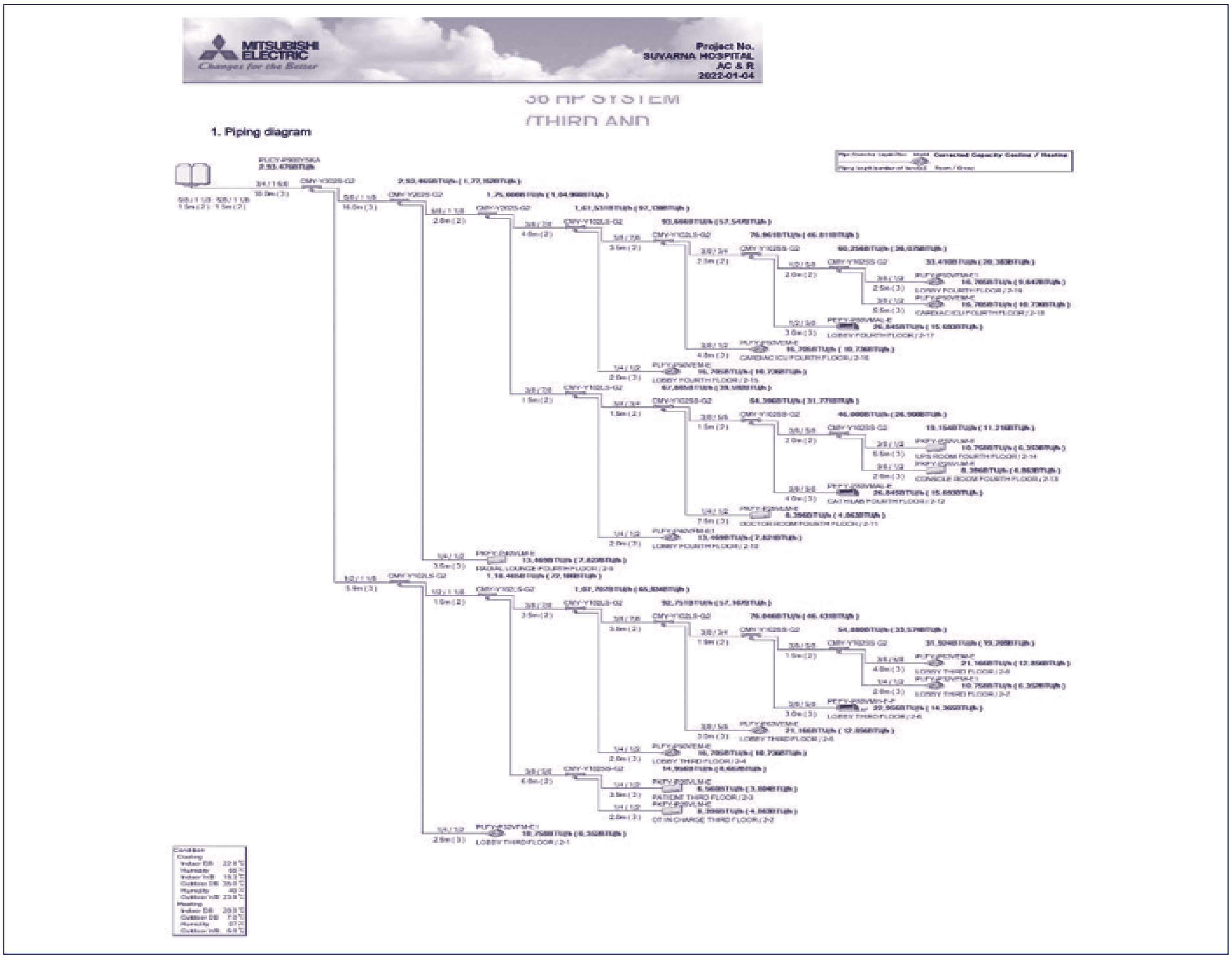
2. Piping System Design

A refrigerant pipe serves as a conduit for the flow of refrigerant between various system components and functions to confine the refrigerant, preventing its release into the atmosphere. Copper pipes are one of the components that is needed in air conditioning and refrigerant system. A piping diagram in HVAC is a schematic representation of the system's piping layout. It shows the connections between various components, such as chillers, boilers, air handlers, pumps, valves, and other equipment. A well-designed piping diagram can help ensure that the HVAC system operates efficiently, safely, and reliably. A single line diagram.is a basic representation of the HVAC piping system that shows the components, connections, and flow direction of the system.

Preparing a single line diagram for refrigerant piping involves the following steps:

1. Before creating a Single Line Diagram (SLD), it is essential to establish the system requirements, including capacity, operating temperature, and refrigerant type.
2. The essential elements of the refrigeration system, including but not limited to the compressor, condenser, evaporator, expansion valve, and other requisite components, are identified.
3. The piping layout and the location of each component will be finalized to estimate the pipe sizes and lengths needed for each section.
4. Using a manufacturer's software, the single line diagram is prepared, showing the piping and the location of each component. The symbols and labels are used to indicate the type of component and the direction of flow.
5. Details, such as pipe sizes, Refnet, lengths, materials, as well as any necessary valves, fittings, and insulation are added to the diagram.
6. The design is verified with the manufacturer's catalogues to ensure that the system is safe, efficient, and meets all requirements.

Fig 6: Single line diagram



3. Duct Design

Establish the necessary heating loads for the room that needs air conditioning.

ii. Determine the location and type of air handling unit (AHU).

iii. Based on the required airflow and air diffusion, select the proper supply air outlet types, and choose their placement and size.

iv. To ensure proper air circulation, filtration and ventilation, choose the position and size of return air inlets.

v. Based on the needed CFM, pressure drop, and noise level, choose the right duct material and shape.

vi. Consider any fittings or obstacles in the duct system when calculating the duct size based on the required airflow and pressure drop.

vii. Plan the duct system layout, including how ducts, branches, and fittings will be routed.

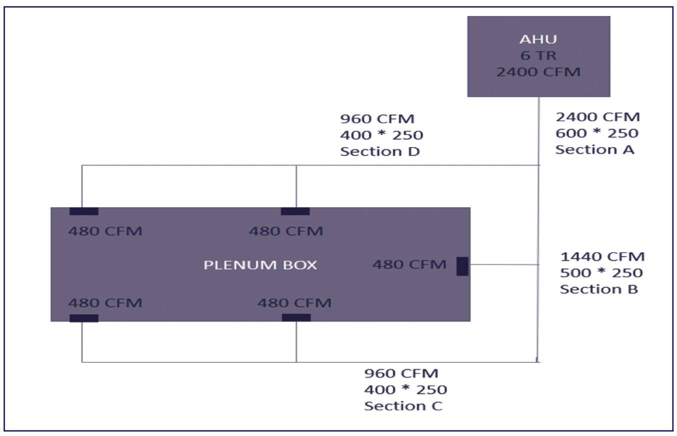
viii. Determine the pressure drop in the duct system and size the air ducts appropriately to guarantee sufficient airflow.

ix. To achieve proper airflow and pressure drop, design, and choose the fans and dampers.

x. To avoid heat loss, air leakage, and noise transmission, provide insulation and sealing.

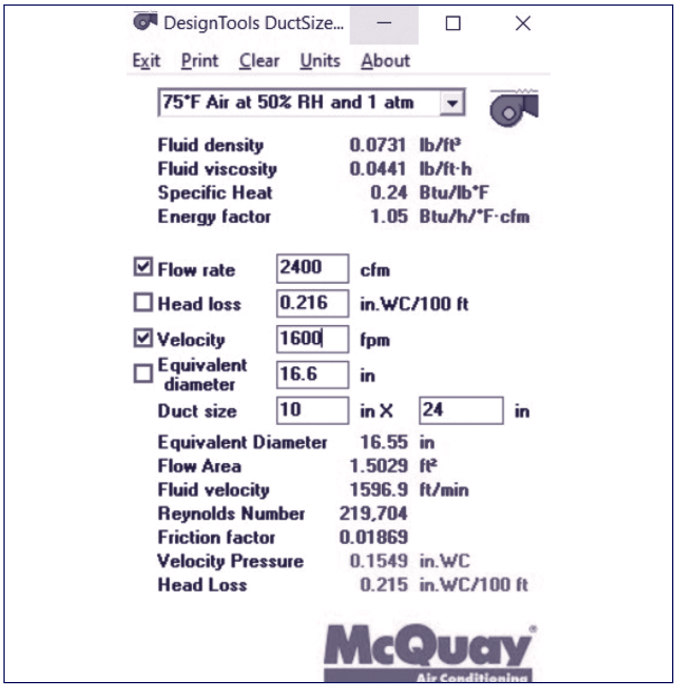
xi. To install UV lamps in ducts that will kill any viruses, bacteria, and micro-organisms from spreading into the HVAC system.

Fig 7: Duct Layout



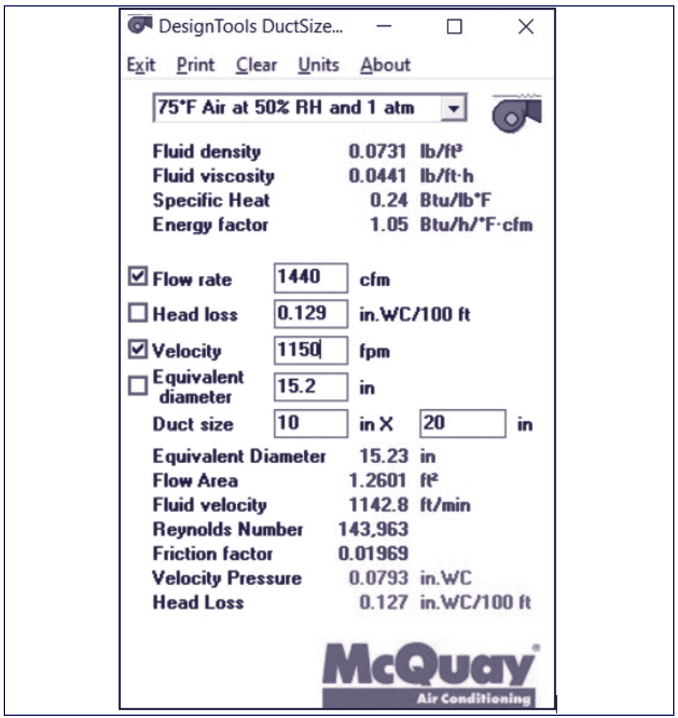
Calculation for Section A Q = 2400 CFM
V = 1600 FPM
Duct Size = 10 * 24 in
Friction Loss = 0.216 inch of wc / 100ft of duct
Equivalent Diameter = 16.6 in

Fig 8: Section A dimensions



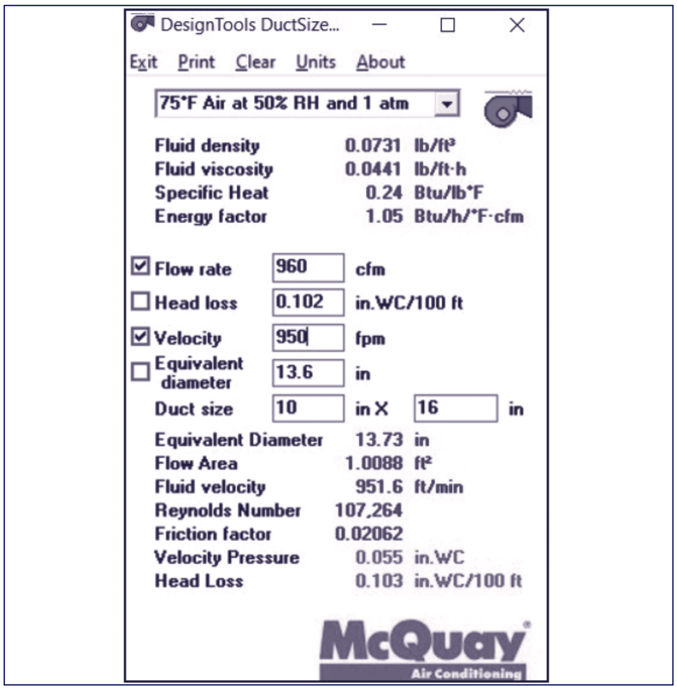
Calculation for Section B Q = 1440 CFM
V = 1150 FPM
Duct Size = 10 * 20 in
Friction Loss = 0.129 inch of wc / 100ft of duct
Equivalent Diameter = 15.2 in

Fig 9: Section B dimensions



Calculation for Section C Q = 960 CFM
V = 950 FPM
Duct Size = 10 * 16 in
Friction Loss = 0.102 inch of wc / 100ft of duct
Equivalent Diameter = 13.6 in

Fig 10: Section C dimensions



Calculation for Section D Q = 960 CFM
V = 950 FPM
Duct Size = 10 * 16 in
Friction Loss = 0.102 inch of wc / 100ft of duct
Equivalent Diameter = 13.6 in

Fig 11: Section D dimensions

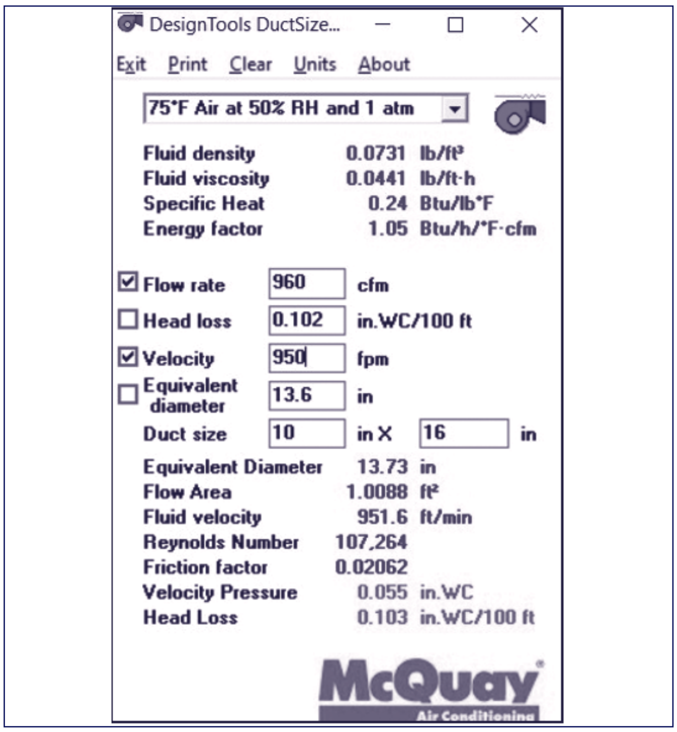
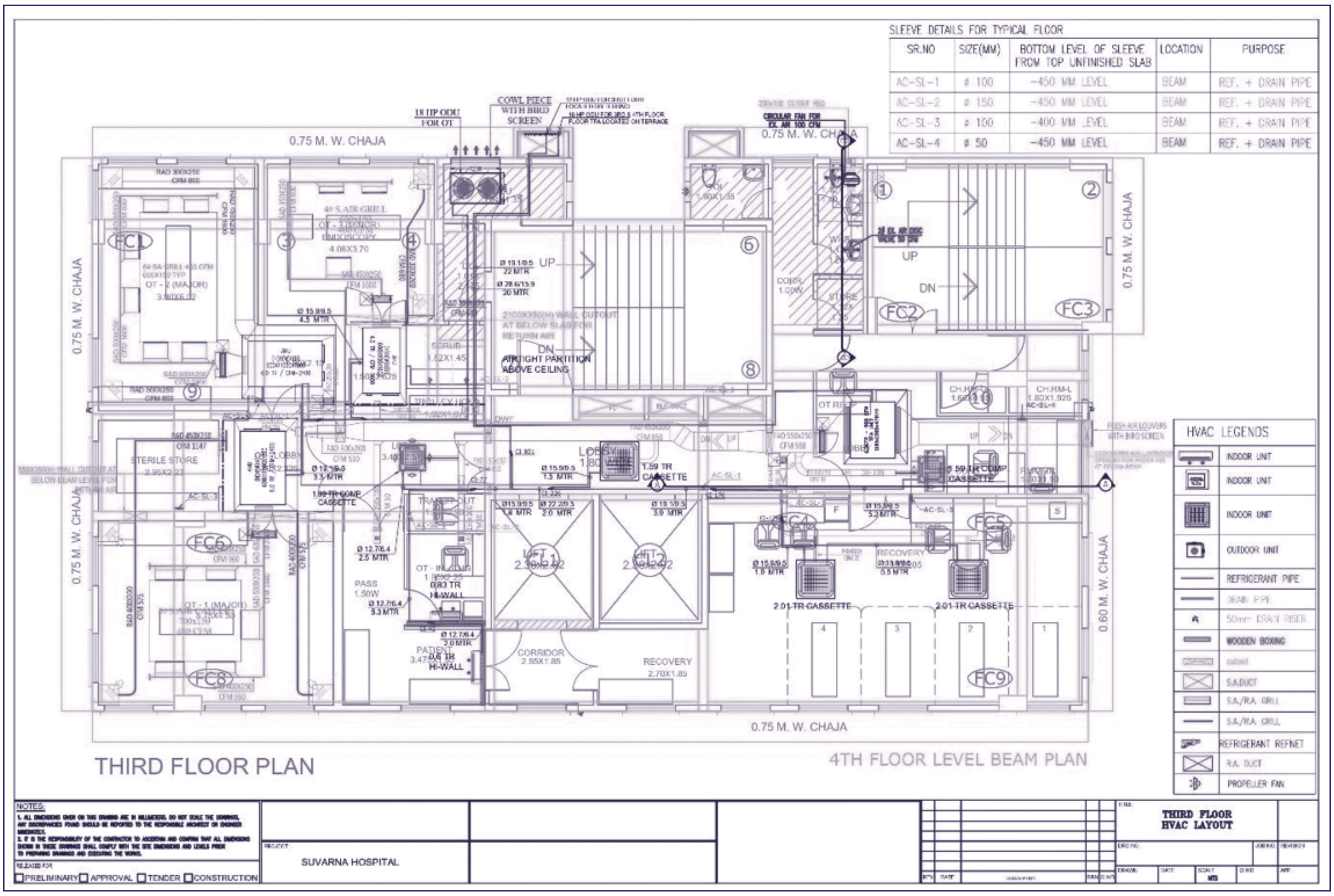


Fig 12: HVAC Layout



RESULTS AND SUMMARY

The layout depicts the various HVAC systems that have been incorporated in rooms in accordance with their respective application. All the HVAC legends denotes the various equipment used in the floor in a tabulated form for ease of understanding. The rooms which have smaller requirement have housed systems such as Cassette and Hi wall type Air conditioners system. Multiple indoor units have been designed to function with respect to a single outdoor unit. The conditioned air is circulated with the help of the duct which have been designed for safe and efficient conditioning and has been installed to account for the beam structures of the design space. Along with the Air conditioning and Ventilation systems, there are multiple accessories which are implemented that are critical in the efficient working of the system.

CONCLUSION

Designing a comfortable, safe, energy efficient and economical HVAC system is critical for any design space especially a hospital. The above paper which incorporates a VRF system is a modernized system that helps fulfil these objectives. While designing, it is important to ensure that the industry standards have been successfully accomplished. Hence, the heat load calculations have been computed referring to the ISHRAE and ASHRAE journals and manuals. Ductwork and piping system have been designed and validated using CAD software with reference to architectural constraints of the hospital. The system has been designed while taking market availability, viability, economic and technical feasibility into consideration. The equipment selection is done after thorough analysis of manufacturer's catalogues. It is therefore safe to conclude that VRF systems are efficient HVAC systems that can reduce energy consumption in buildings.

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