An-Najah National University
Faculty of Graduate Studies

Energy Consumption and Economic Comparison between VRF System and Air to Water Chiller for Air Conditioning Systems Case study: An-Najah University Child Institute

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Dedication

To My wife (Sarah)

To My daughter Ameera

To the spirit of my grandfather teacher Taher

Blessings and Peace be upon him

To My big family (Khaleel)

To My teachers

To All friends and colleagues

To All of them,

I dedicate this work

Acknowledgments

First, I would like to thank Allah for this blessing opportunity of contributing to the research community through this research thesis.

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Thanks also to the reviewers of this master thesis.

Finally, I would like to thank my parents for being patient during this time of work on my thesis, also a lot of thanks for my lovely wife Sarah for her giant support.

الإقرار

أنا الموقع أدناه، مقدم الرسالة التي تحمل العنوان:

Energy Consumption and Economic Comparison between VRF System and Air to Water Chiller for Air Conditioning Systems Case study: An-Najah University Child Institute

مقارنة بين نظام VRF ونظام Chiller Air to Water من حيث استهلاك الطاقة ومن الناحية الاقتصادية في أنظمة تكييف الهواء دراسة حالة: مبنى طفولة جامعة النجاح

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Declaration

The work provided in this thesis، unless otherwise referenced، is the researcher's own work، and has not been submitted elsewhere for any other degree or qualification.

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List of Abbreviations

ANCI	: An-Najah Child Institute
AC	: Air Cooled
ASHRAE	: American Society of Heating, Refrigerating, and Air Conditioning Engineers
CAV	: Constant Air Volume
VAV	: Variable Air Volume
DX	: Direct expansion
ECM	: Electronically Commutated Motor
FCU	: Fan Coil Unit
HVAC	: Heating Ventilation and Air conditioning
GHG	: Green House Gases
kWh	: kilo Watt Hour
NIS	: New Israeli Shekel
PCBS	: Palestine Central Bureau of Statistic
PEA	: Palestinian Energy Authority
TR	: Ton of Refrigerant
VRF	: Variable Refrigerant Flow
ESEER	: European Seasonal Energy Efficiency Ratio
DD	**:** Degree Days method

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Energy Consumption and Economic Comparison between VRF System and Air to Water Chiller for Air Conditioning Systems Case study: An-Najah University Child Institute

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Abstract

Air conditioning systems have the major amount of energy consumption in West Bank, with a poor and expansive amount of energy available in West Bank, energy conservation is needed.

In this research; two air conditioning systems: Variable Refrigerant Flow system (VRF) and Air to Water Chiller system were discussed in order to select the system the most feasible option. An-Najah Child Institute (ANCI) was selected to be the case study. Initially, the cooling load for ANCI was calculated using to be equal to 60 Tons.

Energy consumption and economic analysis were performed for the two system based on accurate design. The design of air conditioning system includes selecting the system parts; indoor units, outdoor units, pipes, and pumps based on the cooling load and configuration of the building. Actual pricing based on parts quotations from manufacturing and procuring companies were made.

The economic analysis was based on calculating present worth value for both air conditioning systems. The present worth value for VRF system

was found to be -158,204 $, while it was equal to -182,654.0 $. For Chiller system. The less negative value was for VRF system, in other words, this system is more feasible and can save more money energy.

Chapter One

Introduction

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Introduction

1.1 Energy in West Bank

Energy is the power of life for many sector such as residential, commercial and industrial sectors. In the last few years it was cleared that the electricity needs increasing more and more since the population increases and the increase of electrical equipment dependency.

The Palestinian (West Bank) region energy consumption according to Palestine central bureau of statistic (PCBS 2005) was estimated to be 890 GWh/year, and this is relatively low consumption and it is considered to be the lowest consumption in the region. [1]

Energy sector in west bank mostly depends on imported power supply, mainly from Israel of about 88% and 3% from Jordan and Egypt. As a result; fuel and energy costs considered to be one of the highest in the region. [1]

HVAC systems have the major amount of energy consumption in West Bank, according to (PCBS 2004) ,most of West Bank households used electricity as a main source for air conditioning. In the summer of 2004," 80.7% of families use electricity for air conditioning". Expenditure in energy was estimated to be one third of the consumer monthly budget in winter and two third of consumer monthly budget in summer. [1]

Palestinian energy authority (PEA) put many strategies in order to sustain these disturbing numbers of energy consumptions. In March 2012 the cabinet of the Palestinian Authority approved a strategy specific to energy efficiency called the national energy efficiency action plan (NEEAP). This plan aims at reduce the energy consumption in important sectors in Palestine thus reducing the GHG greenhouse gases emissions. The main goal and target for this plan is to reach an amount of 384GWh cumulative energy electrical savings between 2012 and 2020, thus ramping up this amount of saving over the 9 year period in many west bank energy sectors such as industrial, buildings, and water pumping. Table (1.1) describes the PEA energy saving plan phases. [1]

Table (1.1): Target energy saving (GWh). [1]

Sector	phase I 2012-2014	phase II 2015-2017	phase III 2015-2017
Industrial	5	6	8
Buildings	38	130	195
Water pumping	0	1	1
Total	43	137	204

PEA energy saving plan targeted all sectors but the potential saving not the same of all. Households sector have the best savings potential, on the other hand people can't be convinced easily to use energy retrofits and make some changes in their homes. Industrial sector may have lower potential in energy saving, but unlike the households sector they can respond to polices, and retrofits to save energy. Due to the nature of industrial and services sector and the high energy consumption compared to residential sector any small amount of energy saving will be more effective end can save much more energy than residential sector.

HVAC sector is the most cost effective technology category relating to many studies that PEA made, and relating to figure (1.1) shows the national energy savings potential by technology category.

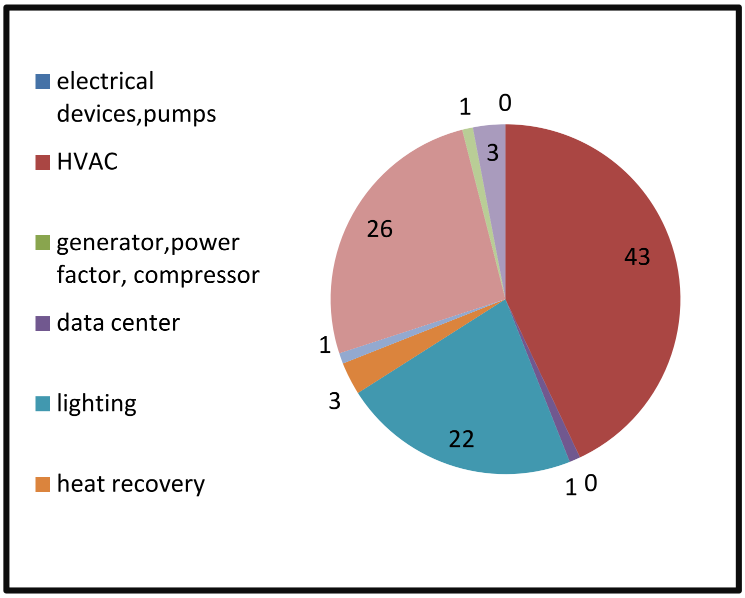

Figure (1.1): National energy savings potential by technology category [1].

National energy savings potential by technology, displayed on a percent basis in year 2015, all these numbers was forecasted if the recommended actions and energy audits in each technology category were implemented. It's clear that the most cost-effective major category is HVAC systems around of 43%, for example at a marginal cost of 19% of the price of the energy consumed, 29GWh equivalent energy could be saved per year in the audited facilities primarily by targeting the HVAC, lighting, and heat recovery categories of energy efficiency actions.

Problem statement

As a conclusion, HVAC systems have the largest amount of energy consumption thus the largest amount of energy saving possibilities at the same time when implementing energy saving audits or opportunities within the system, structure, and surroundings. In the next chapters more details will be discussed about HVAC different systems (Centralized and Decentralizes) every system components and contents, every system energy consumption and installation. Also the energy saving opportunities within each centralized and decentralized air conditioning systems that could save the maximum amount of energy including the parts efficiency improvement or parts replacing will be discussed. In addition to many retrofits studies that may be save energy when conducted to each system.

The next chapters also include case study that show the differences between centralized and decentralized air conditioning systems in a selected building (An-Najah child institute -ANCI) ,this study compares between two air conditioning systems; Variable refrigerant flow system and Air to water chiller system. By using HVAC software design program cooling load for the building was calculated. At the end of the study, comparison was made between the two different air conditioning systems air cooled system and variable refrigerant flow system in order to know which one is better and show more potential in energy saving.

1.2 Heating Ventilation and Air Conditioning Existing Systems at West Bank

Air conditioning systems have many types, each type of them has its own properties, specifications, equipment, parts, way of connection, cost …etc.

In general air conditioning systems can be classified into two categories:

1- Centralized air conditioning systems

2- Decentralized air conditioning systems.

The first category which is central air conditioning systems; multiple spaces can be served and fed from one base location that usually use chilled water and distribute air through a wide sheet metal work (ductwork) inside spaces to be conditioned.

In the second category Decentralized air conditioning systems the service almost for small spaces or multiple small spaces from bases locating within or directly near to the space. Air is cooled directly exchanging heat from the refrigerant. Direct expansion (DX) type most common used in this category.

Selection of most suitable air conditioning system depends on many parameters such as thermal comfort, building architecture, spaces included, performance and energy use, life cycle and cost. Each of these parameters has its own influence on the selection such as the thermal comfort that gives an indication about the internal environment of the building; whether the people are comfortable with the temperature and humidity of the indoor air, a number of variables interact with this comfort such as the activity level (what are the people doing inside ?). The American Society of Heating and Air-Conditioning Engineers (ASHRAE) standard 55-1981 gives the full description of this thermal comfort. [2]

Building Architecture including the purpose of the building, area classification, occupancy, type of building structure, materials and thickness of walls and roofs, all these can influence the selection of air conditioning category.

Spaces included or the available spaces have a big deal in selecting air conditioning category in the way that considerable space is needed for mechanical rooms to house or keep air conditioning equipment.

The most important parameter that influencing our choice is the cost and energy use; because each component from our choice must use as low energy as possible and still meet the performance requirements.

Centralized air conditioning contain a closed circle of water begins as a chilled water generated from a chiller at one base location and distributed to fan coil units (FCU) or air handling units (AHU) located within building spaces, then such a fan can forces air to be heat exchange with this chilled water to be cooled and transferred through duct work.

Figure (1.2) shows the main component of central air conditioning, as we can see the parts are condenser, evaporator, compressor, cooling tower, pumps, and FCU.

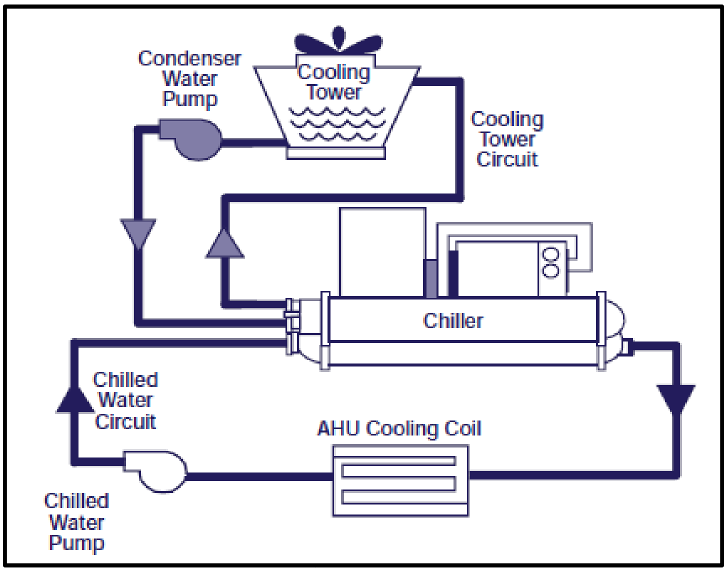

Figure (1.2): Central air conditioning circle. [2]

Chilled water leaving the evaporator section toward the inlet of the FCU to exchange heat with the air supplied by the fan.

Return water leaves the FCU again to the chiller evaporator to close the circuit, the system energized by pump to make sure that the system pressurized. Cooled air leaves the FCU to the indoor space through duct work ending with a supply diffuser and return grill pull out the air inside by return air fan again to the FCU to be cooled again there alone or with mixed with fresh air and then cooled with the fresh air.

The condenser inside the chiller connected to a cooling tower, the hot water leaves the condenser and forced by a pump toward the cooling tower to reject heat there and then back again to the condenser through piping system.

Central system category divided into three main types:

1- Central systems with Constant Air Volume (CAV) air handling units

2- Central systems with Variable Air Volume (VAV) air handling units

3- Central systems with fan coil units (Water systems)

The difference between these types is that CAV system uses all air with constant volume, the VAV uses air also but with variable air volume which supplies different zones, and finally the FCU fan coil unit system uses all water in piping system with ductless system, the water reaches the FCU to make heat exchanging there with air.

Decentralized air conditioning system do not uses chilled water as an intermediate cooling medium. Direct expansion (DX) one of many generic names of Decentralized air conditioning systems that directly heat exchanging heat with refrigerant type inside cooling coil to deliver cooling into single room or spaces rather than building. Individual systems, floor by floor systems, unitary systems also commonly names of this category.

Decentralized systems contains many parts that all assembled into package, these parts are cooling coil, refrigerant coils, controllers, fans, filters, compressor, and condenser. Heat rejection and cooling happen inside this package.

There are plenty types of Decentralized system such as VRF systems, packaged air conditioners, split air conditioning systems, and window air conditioner Somehow they have the same principle of work. We will focus in VRF air conditioning systems principles and specifications in this research.

VRF air conditioning system (Variable Refrigerant Flow); unique system that can serve multiple spaces from an individual basis, it can automatically change refrigerant flow depending on the heating/cooling load of the building.

Figure (1.3) shows the main principle and schematic for VRF system. First in the outdoor unit a compressor increases the refrigerant pressure, then the condenser make the refrigerant reject heat out to reach the expansion valve with high pressure liquid, after that the refrigerant leaves the expansion valve with low pressure and temperature. VRF system come in two system formats, the simple one with two pipes that makes all the zones either in cooling or in heating mode. The other type is the heat recovery (HR) systems that have three pipes design which gives this system the ability to heat some zones and cool others at the same time. All this can be done with microprocessor based electronics. [3]

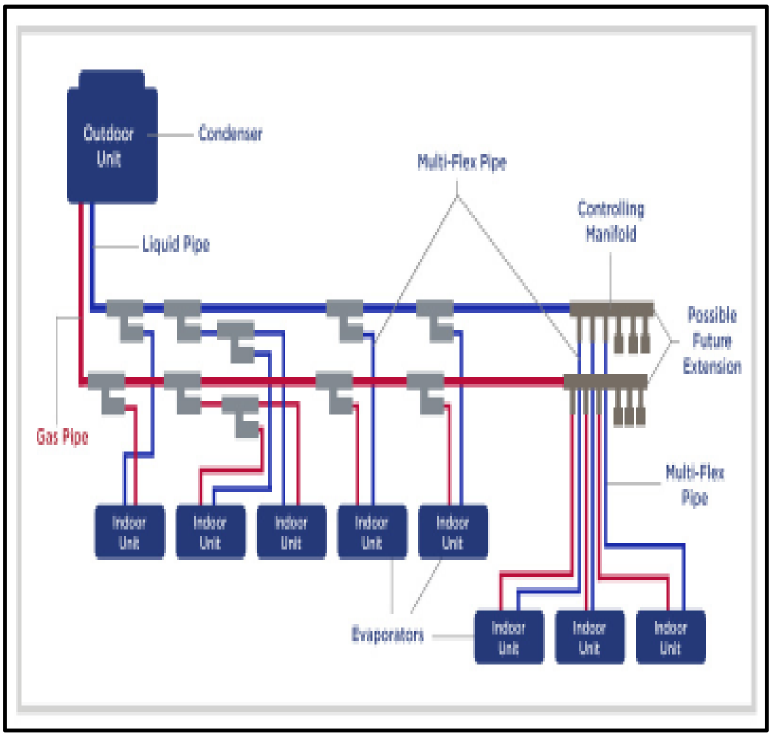

Figure (1.3): VRF air conditioning schematic. [3]

1.3 Case study: An-Najah Child Institute (ANCI)

An-Najah child institute is special place for modern teaching method dealing with all the kids talented groups and people with special needs and deals based on international scientific standards installed via the clinics that provides diagnosis and assessment and rehabilitation services. [4]

An-Najah child institute located in Nablus city west-south side beside An-Najah national university with latitude 32.2^o and longitude 35.2^o. ANCI consists of four floors ground, first, second, and third floor with total area of (1600 m^2) and 3.5m high for each.

(First, second, third, and fourth floor drawings are given in Appendix 12).

Providing comfort conditions at ANCI building needs suitable air conditioning system, so Cooling and heating loads should be considered in all floors to set an accurate air conditioning system.

All necessary data was collected and tabulated in all building floors.

The ground floor contains 4 clinics rooms, one multisensory room, and one intervention room with different areas, the details are listed in table (1.2).

Table (1.2): Ground floor details at ANCI building

	Ground Floor		
Space	**Area m^2**	**Windows**	**Doors**
Clinic Room1	14.6	2	1
Clinic Room2	15	3	1
Clinic Room3	12.25	3	1
Clinic Room4	12.25	1	1
Multisensory Room	40.4	0	1
Intervention Room	45.3	4	1
Waiting Room	28	4	1
Lobby	4.6	0	0

First floor contains 3 class rooms, 1 Staff room, 1 Meeting room, 1 administration room, 1 secretary and waiting area, and 1 Pantry. Every space have its own area and details are given in Table (1.3) show below.

Table (1.3): First floor details at ANCI building

	First Floor		
Space	**Area m^2**	**Windows**	**Doors**
Class1	23	4	1
Class2	26.1	6	1
Class3	24.6	3	1
Staff Room	35.4	6	1
Meeting Room	21.6	3	1
Administration	17.4	3	1
Secretary and waiting area	17.5	2	2
Pantry	4.6	1	1
Lobby	63	0	0

Second floor spaces are listed in Table (1.4), Music room, LD room, Art room, Library, Resource and service, and Pantry. All these spaces contain persons inside.

Table (1.4): Second floor details at ANCI building

	Second Floor		
Space	**Area m^2**	**Windows**	**Doors**
Music Room	23	4	1
LD Room	31.9	6	1
Art Room	31.7	3	1
Library	20.6	4	1
Resource and Service	19.4	1	1
Lobby	63	0	0
Pantry	4.6	1	1

Finally third floor that contains meeting room, 4 admin offices, research room, and pantry with different areas and details as given in table (1.5).

Table (1.5): Third floor details at ANCI building

	Third Floor		
Space	**Area m^2**	**Windows**	**Doors**
Meeting Room	28.4	4	1
Admin Office1	19.6	1	1
Admin Office2	17.5	1	1
Admin Office3	17.5	1	1
Admin Office4	19.4	1	1
Research Room	16.3	4	1
Lobby	63	0	0
Pantry	4.6	1	1

1.4 Cooling load

Cooling load was calculated at ANCI building using HAP 4.6 air conditioning design program so that any air conditioning system can be evaluated and designed including indoor units, outdoor units, piping systems, and pumps. Cooling load variables considered at ANCI building are spaces area, space orientation, doors detail, windows detail, partitions detail, lighting, people occupancy, and electrical devices.

ANCI building was divided into many spaces, every space contain one zone or more. Every zone was covered by HAP program as figure (1.4) shows.

Cooling load depends on many variables, so that every zone can be unique depends on covered area, number of people inside zone, number and areas of windows and doors, orientation of the zone and many other variables.

HAP4.6 assumptions during cooling load calculation:

-Building weight 341.8 kg/m^2 [Med].

-Latitude = 32.2^o, Longitude = 35.2^o.

-Summer design DB Temp = 40 c^o.

-Daylight saving = [Yes].

-Avg ceiling high = 3.5 m

-People/Activity level = office work

-Overhead lighting = Free hanging.

-Door U-Value = 1.7 W/m^2.K

-Wall Assembly: 13mm gypsum plaster + 102mm common brick + 13 mm gypsum plaster + Air space

-Window Assembly/ Glass details: 3mm clear + 3mm clear + Air space.

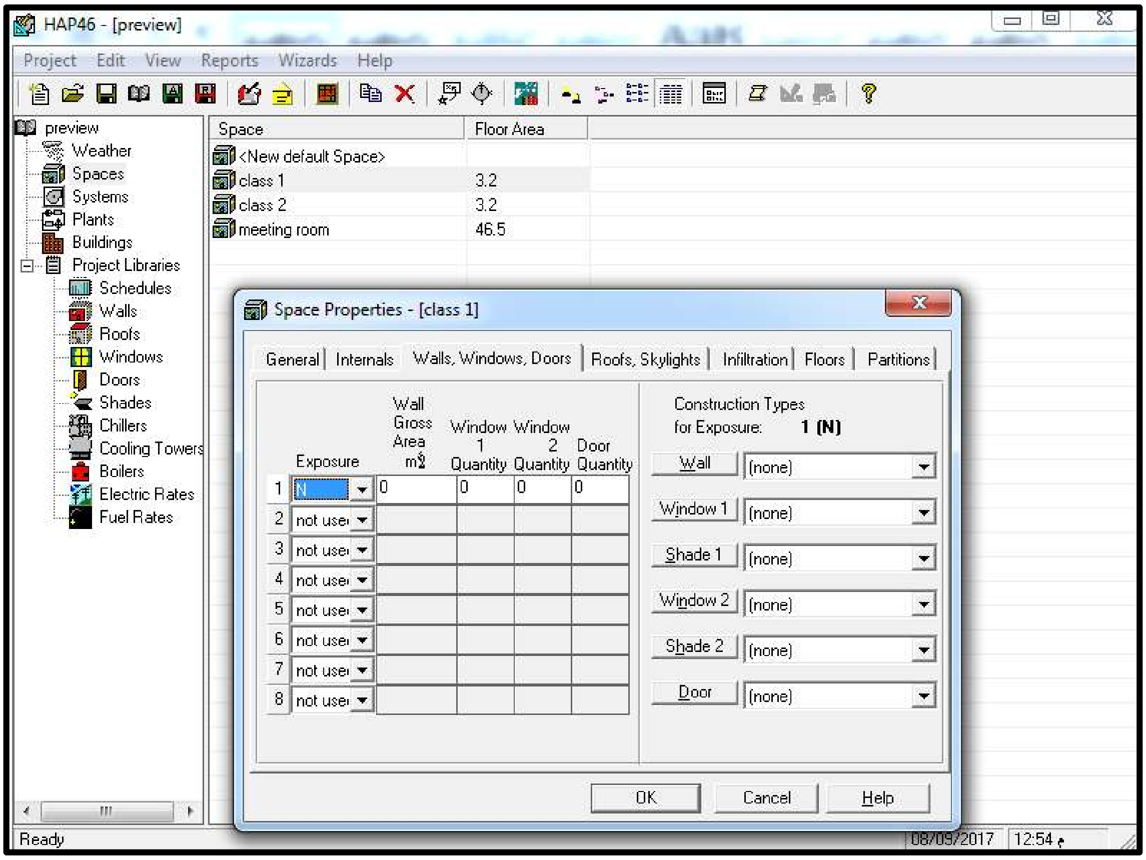

Figure (1.4): HAP 4.6 program parameters.[Appendix 11]

After making all zones details and interring them to HAP 4.6, this software offer final report that include all details about all desired zones and there cooling load beside the final cooling load for ANCI building which was **60 TR**, and this cooling load will be used in designing each of the two air conditioning systems in the next chapters.

Note: HAP4.6 cooling load calculations final report available at the appendix 11.

1.5 Objectives

The main objectives of this research:

1- comparing between centralized and decentralized air conditioning systems in terms of economically, energy consumption, controlling, and zoning including chillers and variable refrigerant flow air conditioning systems.

2- Redesigning variable refrigerant flow air conditioning system at An-Najah child institute based on cooling load and heating load calculations, the design include outdoor units, indoor units, piping system, and duct works.

3- Designing chilled (water to air) system at ANCI based on the same cooling and heating loads calculations used in designing VRF air conditioning system, this new design contains outdoor units, indoor units, piping system, duct work, and necessary pumps.

4- Calculating the energy consumption of chiller (water to air) and also for variable refrigerant flow system.

5- Calculating the fixed cost and running cost for both air conditioning systems chiller (water to air) and variable refrigerant flow.

6- Comparing between both air conditioning systems chiller (water to air) and variable refrigerant flow economically using present worth value.

Summary

West bank nowadays suffering from electricity problems. High population creates high electrical consumption, this high consumption led to Low voltage and high demand of electricity.

HVAC systems have the major amount of energy consumption in west bank, related to (PCBS 2004) statistics most of west bank households use electricity as a main energy source for air conditioning system. So that any conservation on these air conditioning systems will help in decreasing the demand of electricity. [1]

This research contain an important comparison between two local air conditioning systems; VRF and air cooled systems. Every system has its own properties and components that was selected.

The comparison will be made to choose the most economic system. So that every system will be studied alone then a comparison will be made between them based on present worth values.

Chapter Two

Decentralized and Centralized Air Conditioning Systems

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2.1 Decentralized Air Conditioning System Design

Decentralized systems are more efficient in low to medium demanding, it show high efficiency at low rise buildings such as office buildings and residences building. It is recommended when initial cost is effective for such a project budget. [3]

These systems provide cooled air to single spaces instead of the buildings. With many different market names such as floor by floor systems, unitary systems, and individual systems Decentralized system designed and manufactured as one package that includes all parts in one envelop including fans, filters, cooling coils, refrigerant side, heating source, controls, and condenser. Each part within this envelop is assembled to provide specific responsibilities and specifications.

Decentralized systems have many types, and each type has its own specifications and design. These types are:

Window air conditioner

Split air conditioning systems

Variable refrigerant flow (VRF) split system

Packaged air conditioners

2.1.1 Window air conditioner

In window air conditioner type, all components designed and manufactured to be inside one envelop namely the condenser, expansion valve or coil, evaporator, compressor, and cooling coil all are enclosed inside a single box.

As shown in figure (2.1), this unit box can be direct in a slot in the wall or fitted in a window shelf since its flexibility in structure and design.

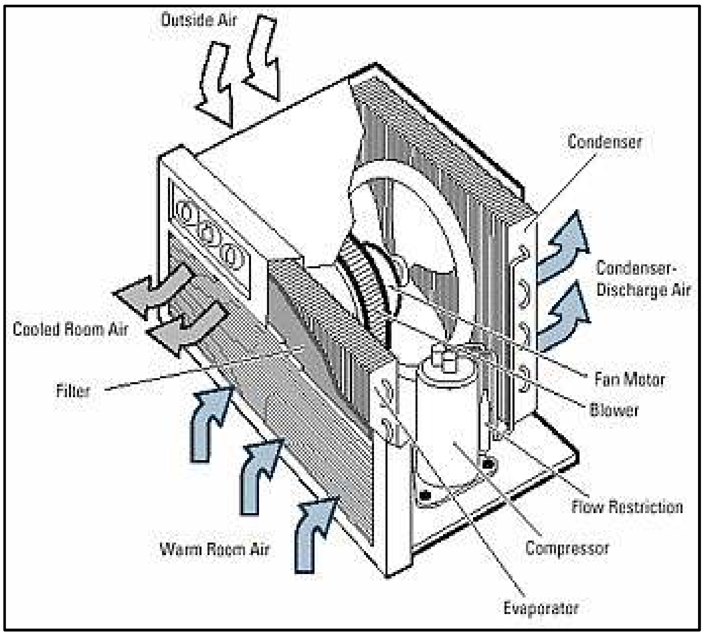


Figure (2.1): Window air conditioner type assembly. [3]

This type of decentralized system can serves cooling only where and when needed. It is available with capacities varying within a range of about 0.5 – 3.0 TR.

2.1.2 Split air conditioning systems

This type basically has two parts working together to sustain the requirement demanding. These two parts are indoor unit and outdoor unit, the indoor unit contains cooling coil, cooling fan, and the evaporator while the outdoor unit has the compressor, expansion valve, and the condenser.

The outdoor unit responsible for providing cooled refrigerant to the indoor unit through refrigerant pipes, while the indoor unit responsible for heat exchanging between the air and the cooled refrigerant, then supplying cooled air to the space.

As we can see in figure (2.2), outdoor unit and indoor unit connected with each other by refrigerant pipe. This pipe distance is critical and shouldn’t be more than 30m.

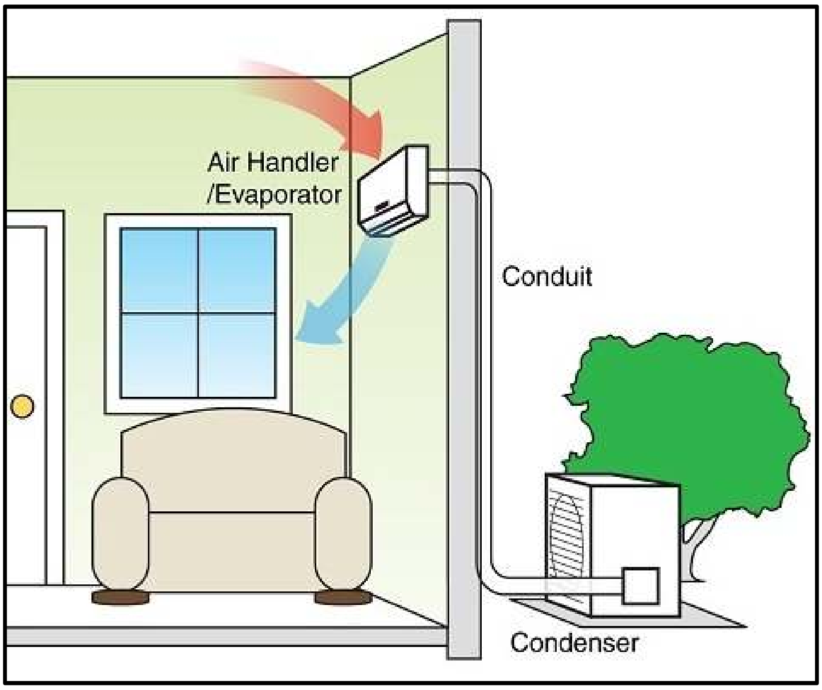


Figure (2.2): Split air conditioner arrangement. [3]

It is very clear that this type of decentralized system easy to install so it gives an engineer that flexibility in maintaining the architectural and physical requirements.

2.1.3 Variable refrigerant flow (VRF)

Modern type of decentralized air conditioning system is variable refrigerant flow system (VRF) which is complex and efficient. It can serve multiple indoor units connected with refrigerant piping system to a single outdoor VRF condensing unit. [3]

Among these systems; VRF system can provide both heating and cooling simultaneously by control system. Control system has the ability to automatically control refrigerant flow to meet the cooling or heating load of the spaces needs by hand held control or the use of wall mounted key pads.

Figure (2.3) shows the main principle and schematic for VRF system first in the outdoor unit a compressor increases the refrigerant pressure, then the condenser make the refrigerant reject heat out to reach the expansion valve with high pressure liquid, after that the refrigerant leaves the expansion valve with low pressure and temperature. VRF system come in two system formats, the simple one with two pipes that makes all the zones either in cooling or in heating mode. The other format is the heat recovery (HR) systems that have three pipes design which gives this system the ability to heat some zones and cool others at the same time. All this can be done with microprocessor based electronics.

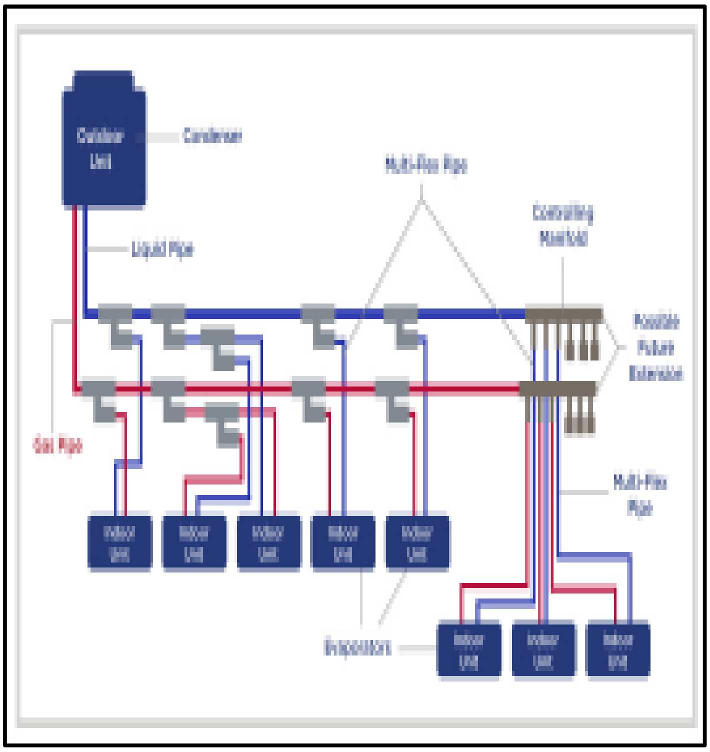


Figure (2.3): VRF air conditioning schematic. [3]

2.1.4 Packaged air conditioners

Packaged air conditioners most suitable for cooling capacities arranged between split air conditioners and central air conditioning systems. It is available in fixed rated capacities of 3, 5, 7, 10, and 15 tons. [3]

Packaged systems contain all important parts inside one house including compressor, cooling coil, air handling unit, and the air filter. According to the type of the cooling system used with packaged air conditioners it can be divided into two types: ones with air cooled condenser and ones with water cooled condenser.

In air cooled system the outdoor unit should be kept in a place where the atmospheric air is available to cool the condenser of the refrigeration system. While in water cooled system the condenser of the refrigeration system cooled by water, so that water must be continuously available to maintain functioning of air conditioning system.

As shown in figure (2.4) packaged system can serve two rooms or more at the same time. Its available capacities ranging from about 5 TR up to about 100 TR, so it is more efficient to use in large spaces or offices.

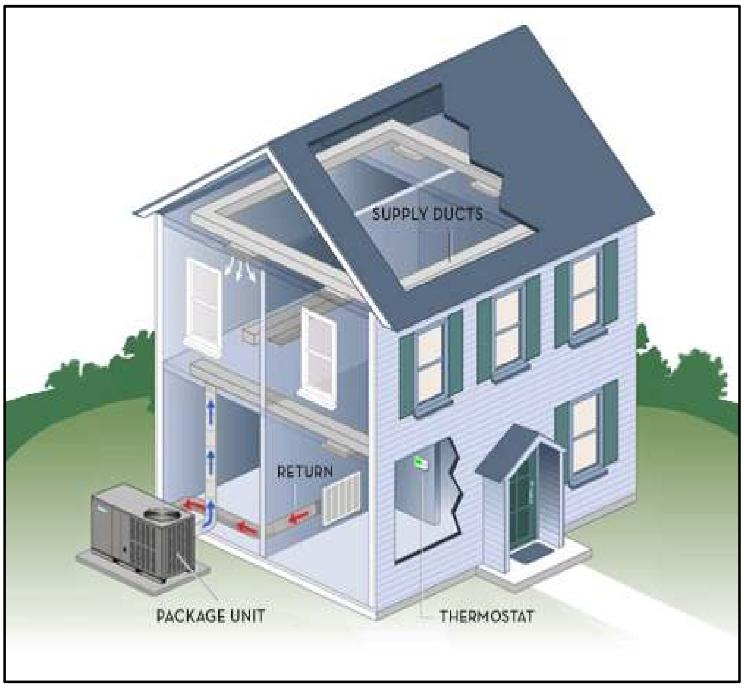


Figure (2.4): Packaged air conditioners installation. [3]

But it should be noted that the larger of tonnage in packaged system the larger air flow will be, so that we will need duct work to cover all spaces and reduce noise.

2.2 Centralized air conditioning system design

Centralized air conditioning system uses one base location to serve single or multiple zones with cooled air, these system are most efficient in mid to high rise buildings that include five to seven and more floors. Centralized systems can be divided into three categories as the following:

Central systems with Constant Air Volume (CAV) air handling units

Central systems with Variable Air Volume (VAV) air handling units

Central systems with fan coil units (All-Water systems).

Constant air volume system (CAV) category is an all air system which maintains comfortable temperature and humidity (comfort conditions) in served zones by constant air volume supply and variable air temperature.

Variable air volume system (VAV) is an all air system which can serve multiple zones by supplying air at a constant temperature from the base central plant to one or many VAV units in each zone. But the amount of air flow to each zone can be adjusted to meet each zone cooling load requirements. And this is the main advantage of this system over the constant air volume system is the flexibility of air flow control that can serve any number of zones within the building at the same time.

Central system with fan coil unit is an all water system with FCU units. Outdoor unit produces chilled water to be passing through insulated pipes then pumped to the fan coil unit (FCU) placed inside the conditioned space, heat exchanging with air made there to produce cooled air, then cooled air transferred to the zones and back again to the FCU to be cooled again by cooling coils to make a close loop.

Basically central systems design broken down into three major subsystems: the chilled water plant, the air delivery system, and the condenser water system (or heat rejection system). Every subsystem responsible for a private job, as we can see in figure (2.5) we have central system water to air divided into three subsystems shown in the figure below.

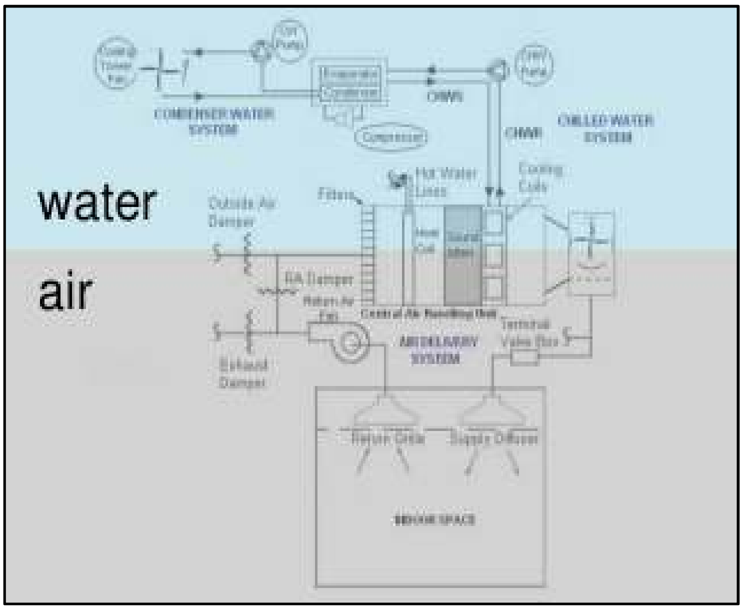


Figure (2.5): Centralized air conditioning system schematic. [4]

Chilled water substation begins its circle inside the chiller body evaporator section. Pumps make the system pressurized supplying the inlet of evaporator with water to be chilled there and then leaves the evaporator through piping system to supply chilled water to air handling units cooling coils to be heat exchanged with air supplied by fans. The system may have primary and secondary chilled water pumps, primary water pump sustain the system pressurized and ensure constant water flow through the chiller, while the secondary water pump serve chilled water to AHUs with quantities needed only.

Chillers have three most common options; centrifugal compressors (200 to 2000 TR), screw compressors (100 to 750 TR), and reciprocating compressors (up to 200 TR). Each one has its own restrictions, properties, and peak load efficiency.

Air delivery subsystem responsible for delivering cooled air to spaces through duct system and registers to maintain the cooling load standards.

In most building cases air is back again to the AHU by return air system to be mixed with supply air with an amount to be recommended.

Return air system can be ducted returns or plenum returns. In ducted returns air is collected from each zone using return air devices attached to the ceiling or walls which supply air to AHU by direct duct work. Plenum returns collect the air from all zones through return air devices as in ducted returns to the space between drop ceiling and the real ceiling, then the air returned to the AHU by duct work or structural channels and conduits.

Before heat exchanging air should be filtered to remove particular matter (mold, dust, and allergens).

As any refrigeration system heat rejection must occur. Condenser water system is responsible for this part by two option of heat rejecting: 1- water cooled 2- air cooled.

Water cooled units are common used in large buildings such as hotels and airports, these units reject heat which absorbed from spaces or zones to water that with the same way can reject this heat via cooling towers or fluid coolers.

Air cooled option is the most common used in residential and light commercial applications. Heat absorbed from spaces or zones can be rejected to the ambient air.

2.3 Comparison between Centralized and Decentralized air conditioning systems

Every building type has its own regulations, specifications, and restrictions that affect Selecting HVAC system, and every HVAC system also has its own design and properties that influence the decision of type selected. So to make a decision and select the suitable type of HVAC system that fit our case we should first take a look at every type and summarize every type design, specification , properties, and limitations.

Centralized and Decentralized air conditioning systems have many differences parameters which at the end make one better than another in such a case, these parameters are:

Applications, usage patterns, and zoning

Control views, Structural design and costs

2.3.1 Applications, usage patterns, and zoning comparison

Central systems are used widely for completely air conditioning in large buildings, airports, hotels, shopping malls, theaters…etc. one base chiller or multiple chillers can be used to offer the desired load capacity and sometime a hybrid system is preferred which is a combination between centralized and decentralized system in such a couple of central plant and packaged split units that the central plant serve corridors and lobby, and the packaged system serves individual rooms such as guests rooms, meeting rooms.

Centralized systems like chillers are available in the market with maximum capacity 2000 tons, so these systems are best fit with cases that requires high usage time and consistent.

Multiple zones can be served with one central plant and can have many different control points since every zone contain its own control (thermostat) that provides signals to the main central plant to monitor the flow of chilled water.

Decentralized systems are more suitable for buildings which have unoccupied spaces at any given time to provide potential energy saving since every single space has its own air conditioning unit that can be shut off alone without influencing the others. Decentralized systems also preferred in low to mid rise buildings and low to intermittent air conditioning requirements such as small residential buildings and offices. But for large buildings, multiple package units can cover the desire loads.

For cases of that spaces which may have expansion or addition of more equipment, decentralized system can give the solution.

Decentralized systems such as split units (DX) are only recommended to serve single zone applications since split units can't respond to many sensors (thermostat) signals and do not provide modulating control, every zone has its own thermostat connected with the single base unit that's due to the assembly of its content namely the compressor which only works with ON – OFF response to the signals coming from a thermostat, it can be either totally shut off or totally shut on. For multiple zones application it is required multiple units to cover them.

Decentralized air conditioning systems are available in the market with capacities range from 0.5 ton to 130 tons (for roof top package units).

2.3.2 Control views

Control is very important in all systems for energy saving such as capacity control. Central systems (chilled water type) show a good capacity control by modulating the chilled water flow rate through the cooling coils generally within the air handling unit or the fan coil unit, so every zone thermal load can be covered without influencing the control of any other zones in the other hand decentralized systems that do not provide modulating control since they have fixed coil temperature during the cooling mode, the only control available in decentralized systems like (DX) systems is by cycling the compressor ON and OFF depending on the sensor (thermostat) signals.

In air quality control, centralized systems offer high quality of air conditioning so that it can be used for applications demanding precise control and sensitive for environmental conditions. In decentralized systems the air quality less than that in central systems.

Decentralized air conditioning systems do not show that accuracy in temperature control since there is only two positions of control ON or OFF which makes the temperature and relative humidity swings. This might be happened in central systems when it balanced and it won’t be hot spots in targeted zones due to the high level of control between the base unit and the indoor units (as an example FCUs).

In controlling fresh air and ventilation, central system gives good control in fresh air quantities allowing for fixed or varying quantities while decentralized system do not provide much flexibility in fresh air control.

We saw most of control views are better in centralized systems that in decentralized systems for energy saving opportunities. But in individualized control decentralized system are better due to capability to offer room by room control providing heating for space that needs heat and at the same time can provide cooling to adjacent that needs cooling without influencing each other as clear in figure (2.6).

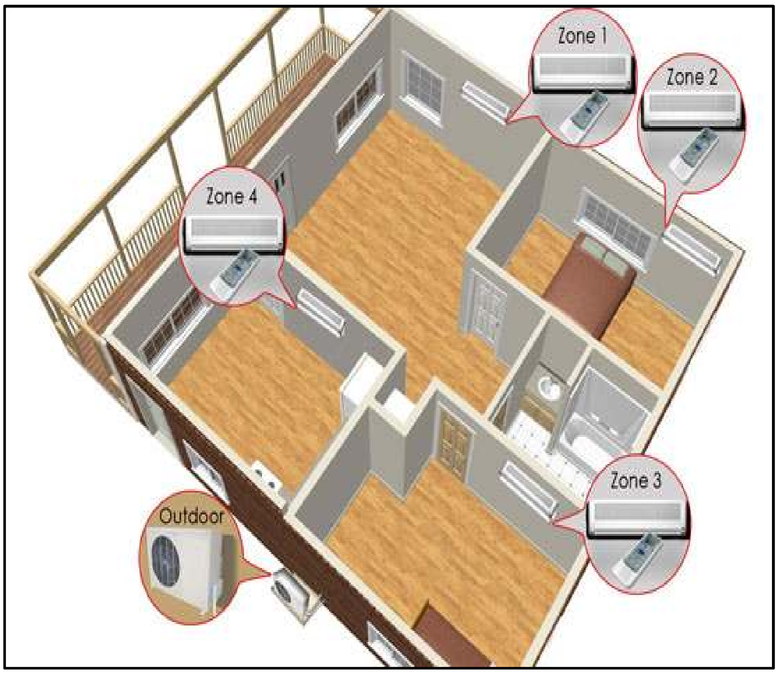


Figure (2.6): Individualized control in decentralized air conditioning (split type).[4]

Central systems can't always provide individual control as flexibility as in decentralized systems. But in (VAV) central system figure (2.7) individual control is available by monitoring the air delivery rates to the spaces while keeping the coils as fixed temperature.

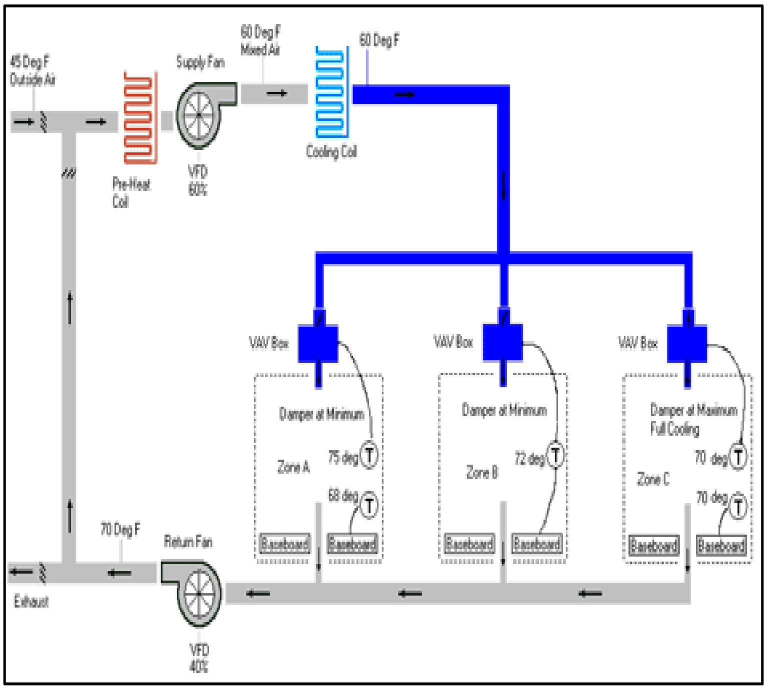


Figure (2.7): Individualized control in centralized air condition systems(VAV type). [4]

In central air conditioning systems (CAV) type also can provide individual control by keeping the air delivery constant and altering the coils temperature, this type not recommended due to huge quantities of energy wasted by simultaneous cooling and heating.

2.3.3 structural design and costs

Centralized systems have huge and heavy equipment that required large space to handle them called mechanical room that must be available in every building used in.

Central systems should contain plumping structure and drainage system arrangement in the mechanical rooms where air handling units or fan coil units are located there with their cooling coils, also in plant room where cooling water pumps available there.

In decentralized systems the situation is more simple cause of their simplicity which is smaller in size, so there is no need for mechanical rooms to handle the equipment and this can offer large free areas in the building. The plumping structure also simple since most of decentralized air conditioning systems evaporators are located inside or at the boundaries, the plumping need to be carried out in the indoor spaces connected with the zone drainage system itself and no need for a new special drainage line.

Capital costs for centralizes systems are much higher than decentralized systems. Capital costs can vary depending in the type of equipment used in the system, centrifugal chiller for example is most expensive then screw packaged chiller and the cheapest is reciprocating packaged chiller, but the cost can vary depending on the size of chillers such as centrifugal chiller under 200 tons is more expensive than reciprocating but becomes competitive in the larger sizes.

In another way central air cooled machines are much cheaper in capital costs than the water cooled machines about 10% - 15%, at the same time energy or power saving will be caught (running costs), so engineers should work out the pay pack period and make visibility studies before selecting which system to be chosen finally.[3]

Decentralized air conditioning systems mostly have lower capital costs than central systems paid for an equivalent custom system. These systems have fewer materials to install and so lower installation costs that make decentralized systems more preferable.

In engineering costs view decentralized systems also show a good cost saving since they are standard size units readily available so that installation is faster and simple that save time and installation operation costs. Central systems are much higher in installation costs since equipment and parts are heavy lifting and larger in size that make them require more costs for handling facility at site. Also central systems ductwork, piping system, insulation, and false ceiling give extra engineering costs.

For maintenance cost, central air conditioning systems can take much expensive and time consuming than decentralized air conditioning systems. All these costs depend on the type used and the capacity also, so costs vary in values and time.

Maintenance can be done directly in occupied spaces in most decentralized systems while it can be done within mechanical rooms or outdoors in central systems.

2.4 Energy Saving Opportunities in Centralized Air Conditioning Systems

Institutional and commercial organizations concentrate in energy efficiency nowadays to catch as much amount of energy saved as they can which lead for electricity saving thus money saving.

Managers in most projects looking for opportunities that may do this savings and recommended strongly to those whose responsible about structural and designs to do the best they can to maintain the most efficient behavior with less electricity consumption.

Since energy saving became a top priority in most projects, engineers concentrations have to be on finding more and best opportunities in energy saving within the projects related to heating ventilation and air conditioning systems (HVAC) including, boilers, chillers, and air handling units components since air conditioning makes as much as 60% of the total consumption of a building in a season.

In centralized air conditioning systems there is a big chance of energy saving, since they are used widely and with huge cooling or heating capacities. By the nature of these systems components and the big sizes any saving amount even its small will play a good role and will be more effective than decentralized air conditioning systems.

Energy saving opportunities in centralized air conditioning systems can be within the equipment (Internal opportunities category) or the surrounding (External opportunities category). Every category has its own cost and reliability and dependency.

The first step of energy saving is making an energy audit by plan the work, then work the plan. Such a plan need some data collection before going forward such as equipment logs, weather data, and structural data within the building.

Working the plan might be starting with opportunities easy to apply and with less cost going to more complex opportunities with more cost.

As air temperature increases the electricity consumption in air conditioning increases substantially. In addition to this process the cooling of air conditioning units decreases the same will happen if the air temperature decreases in winter season, this lead to consume more electricity also and heating of air conditioning units increases substantially. With this two cases engineers have to find the opportunities that can faces this increasing in electricity consumption.

Some of those opportunities are as following:

1- Variable air volume system and constant air volume system

2- Scheduling

3- regular motors, high efficient motors and variable frequency drives

Most of centralized air conditioning systems have issues with energy consumption that call for energy conservation and energy saving opportunities to solve these issues. Allot of these issues are within the design of the system or selection and equipment's installed, these opportunities are classified as internal energy saving opportunities and we will introduce and discuss some of most important of them.

2.4.1 Variable air volume system and constant air volume system

The first internal energy saving opportunity that could save energy within the air central air conditioning systems is that when we have such a system of constant air volume (CAV) designed to be serving out building. It's recommended to replace this current design with a new one that called variable air volume (VAV) when our case suitable for both systems according to reference [1].

Figure (2.8), and figure (2.9) show a schematic plans of CAV and VAV distribution within a multiple zones.

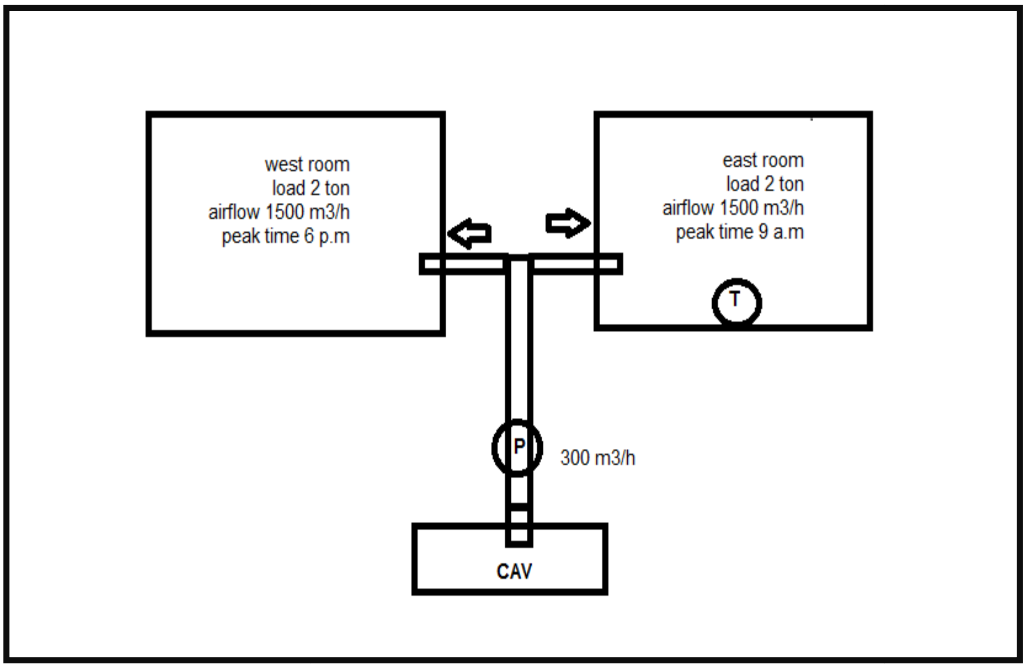


Figure (2.8): Schematic plan of CAV distribution within a multiple zones.

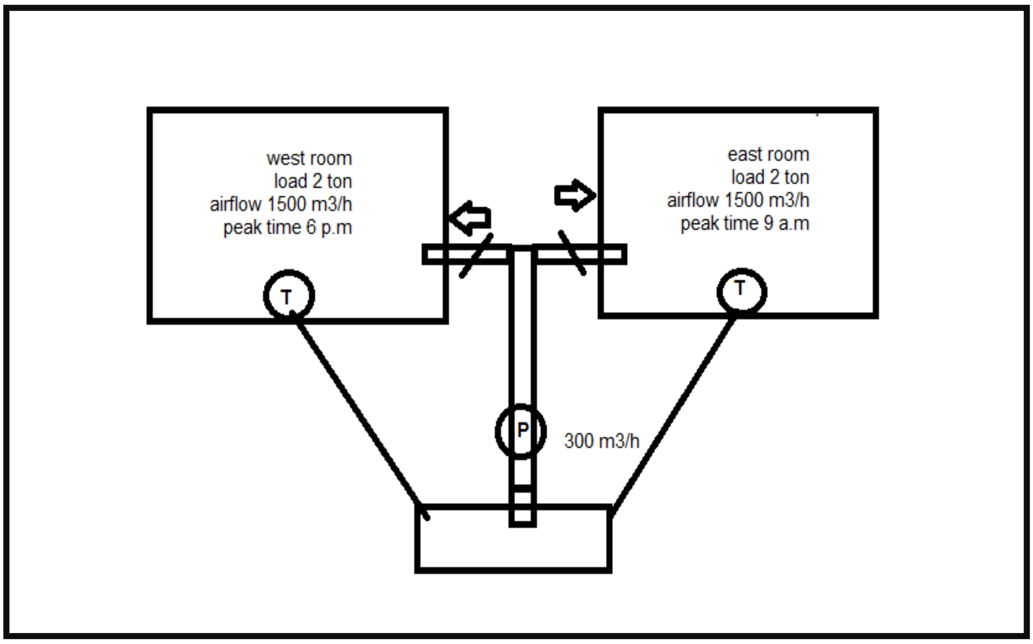


Figure (2.9): Schematic plan of VAV distribution within a multiple zones.

The two plans show the same case that include two zones one is west and the other is east direction, with the same load and air flow and with different peak time, they are connected with CAV system once and with VAV once again.

In the 1st case with CAV connection the east room contains thermostat inside while the west room doesn't. when the system goes on and start pumping cooled air toward the two rooms through duct work system, at time 9 A.M and around this time the east room needs the big load while the west room doesn't , that means the west room will reach its design temperature (assume 24^{o} C). At the same time the east room still receiving more cooling air, this mean that the system will remain ON and pushing more and more cooled air toward two rooms till east room reached its design temperature.

As a result; when east room reach its design temperature, the west room temperature will be lower than the design temperature due to of non-stopping cooling so that all these cooling are waste, and become an extra load for the system that consume and cost an addition energy to the system.

This issue can be avoided by using VAV air conditioning system which can serve the two rooms individually without wasting extra energy. With the same case at 9 A.M the east room will reach its design temperature while the west one doesn't, but unlike the CAV system, VAV system will shut off the cooling toward the west room by a mean of (servo motor and damper system). When the thermostat send such a signal to the VAV system that the desire temperature was reached, the servo will make the damper to partially close so that decreasing the amount of cooled air delivered to the room.

As a result; VAV system conserve energy and prevent wasting energy when the desire temperature reached and save money. These systems are easy to install and cost less. In addition VAV systems can save as much as 30% in energy costs comparing to other conventional systems.

2.4.2 Scheduling

Most buildings that contain an air conditioning system it will shut on the system at the first moment it start working or occupied with people. So energy consumption starts till the last moment of that working day.

In our case study An-Najah child institute building, the working hours schedule is as following:

7 AM: Cleaners and guards

8 AM –11:30 AM: Employees, officers, and students

11:30 AM – 12:30 PM: Break

12:30 PM – 3 PM: Employees, officers, and students

When designing an air conditioning system especially in centralized air conditioning systems like chillers it is better to keep in mind the above working schedule distribution to have an accurate cooling and heating loads as a result and so sizing of the air conditioning system equipment's. Figure (2.10) and figure (2.11) describes schedule of people used in calculating and designing the air conditioning system via designing program HAP 4.6. [1]

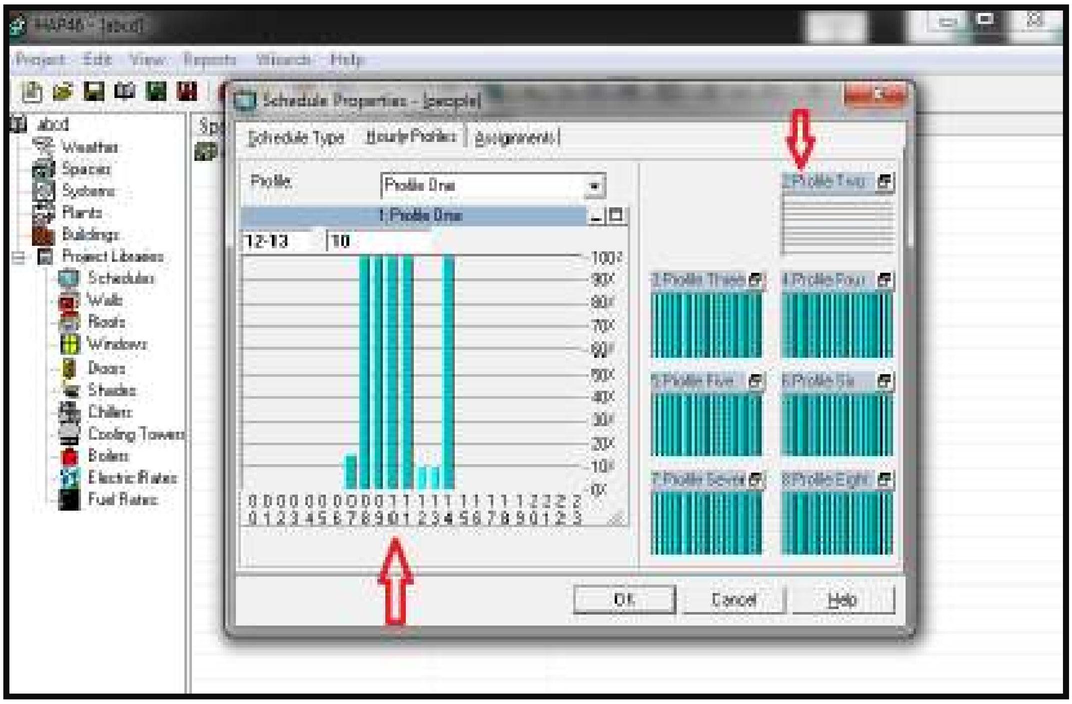


Figure (2.10): Hourly people schedule using HAP 4.6 program

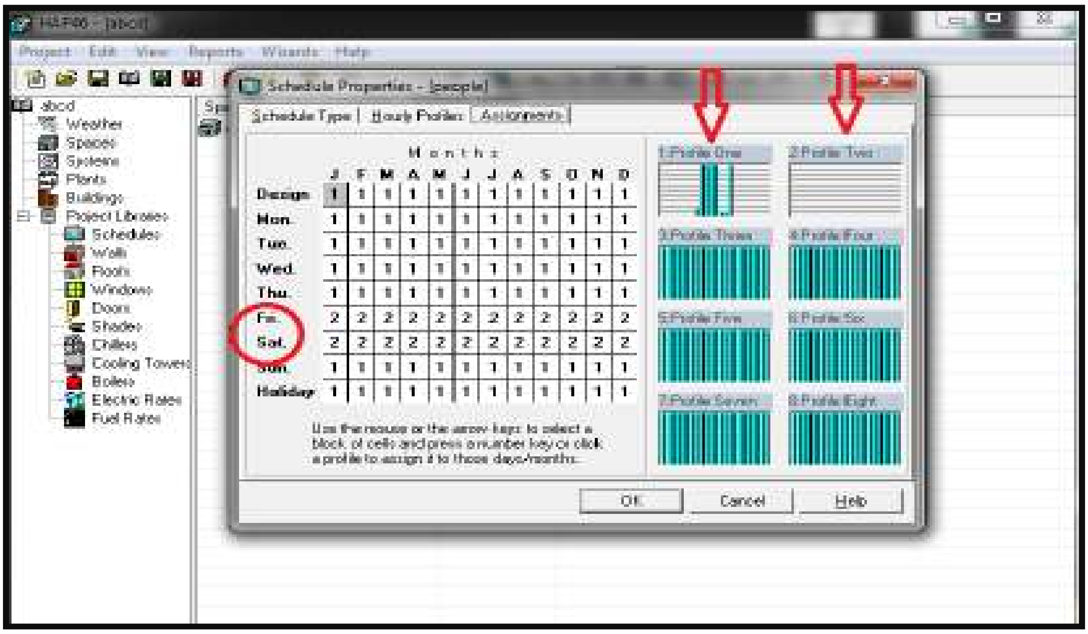


Figure (2.11): People schedule profile description using HAP 4.6 program.

Figure (2.10) give working hours distribution Vs the load distribution relating to the building working hours table. It is clear that the load between 7AM till 8AM have about 15% of total capacity, while between 8AM till 11:30 AM the capacity is 100%, and between 11:30 and

12:30 there is only about 10% cooling capacity of full load, and finally at 12:30 till the end of that working day the system will work with full load capacity 100%.

This schedule will huge amount of energy cause of the rest intervals that could be in many hours with less load capacity and for sure will increase the life time of the system equipment's. Also if we applied this schedule to ventilation design we will harvest another energy saving since ventilation causes an extra cooling load to the system and make the system consume more energy to cooling that air coming from outside.

Relating to figure (2.11) the people schedule can be more accurate and be applied to the days of the week or the days of the months and so on. This strategy saves more and more energy since the cooling load will decreases as we exclude many hours and 2 days a week from our cooling load calculations. So that the system equipment's will be smaller and cost less money as a capital cost and cost less in running cost as an electricity bill during the months.

2.4.3 Regular motors, high efficient motors and variable frequency drives

The highest energy consumers in both residential and commercial sectors are motor-driven components. In residential sector HVAC applications represent around 63% of motor driven energy use, and refrigeration represents around 28% .In commercial sector, the HVAC and refrigeration categories together represent 93% of motor driven energy use, while electric motor-driven systems and their components in appliances and equipment account for more than 25% of the primary consumption in both commercial and residential sectors [4].

This huge energy consumption of motors used in air conditioning systems (fan motors and compressor motors) can be reduced by using high efficient motors instead of regular motors or by installing variable frequency drives VSD especially in variable load applications plus other non- energy benefits such as reducing the noise and the ability to reach higher rotational speeds. These retrofits have capital costs first and that the major problem, but nowadays and regarding to new semiconductors and electronics modern technologies the high efficient motors costs decayed and the payback period became more realistic and feasible.

The International Electro technical commission (IEC) has published an international standard that defines three distinct energy efficiency classes for single speed and three phase motors (IE1, IE2 ,IE3) figure (2.13) related to reference [3], IE1 with standard efficiency, IE2 with high efficiency and IE3 with premium efficiency. Figure (2.12) show conclude these standards with their capital cost, maintenance cost, and energy cost with two cases, one with 8000 operating hours per year and the other one with 2000 operating hours per year.[5]

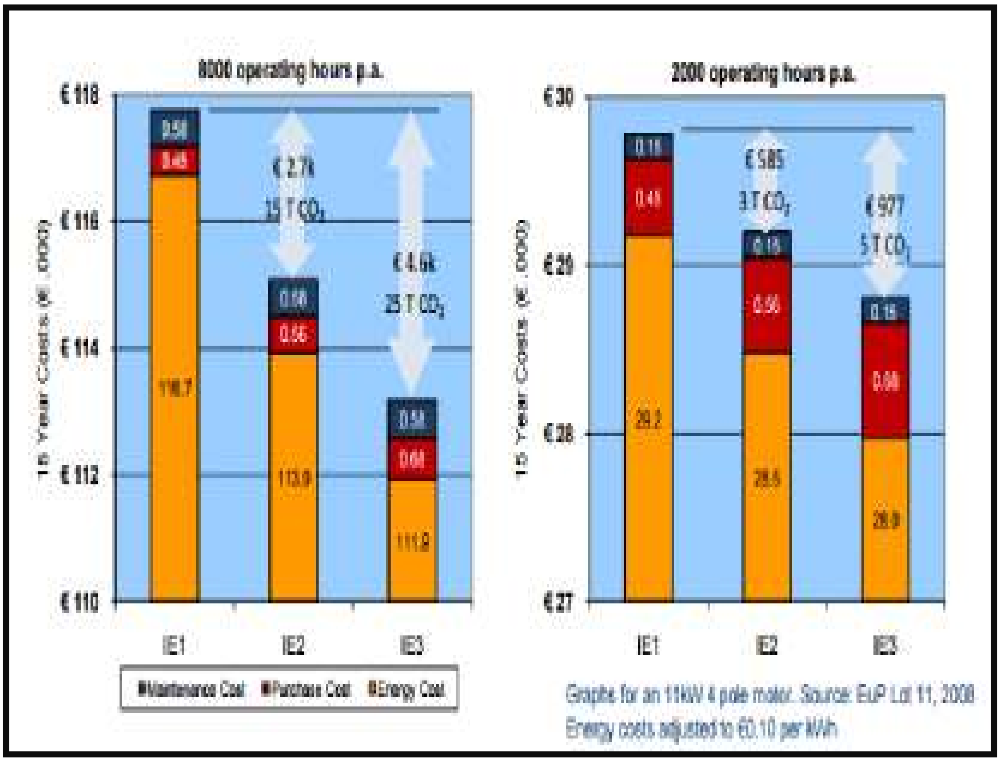


Figure (2.12): Three different motor classes' energy analyzing with 8000 and 2000 operating hours per year graphs. [5]

According to table (2.1) we can see the potential of energy saving between three motor standard types, when using motor type IE2 the payback period will be about 7 months in 8000 operating hour's case. While in 2000 operating hours case we will get our investment by energy saving within 3 years. We can also use equations below to calculate energy saving:

$\Delta P\ saving = Pout\left(\left(\frac{1}{\gamma 1}\right) - \left(\frac{1}{\gamma 2}\right)\right)$ … Eq (2.1)

Table (2.1): Motors specification and their energy efficiency potential. [6]

Motor type		IE1	IE2	IE3	IE4	IE5
Three-phase cage-rotor induction motors (ASM)	Random wound windings; IP2x (open motors)	Yes	Yes	Yes	Difficult	No
	Form wound windings; IP2x (open motors)	Yes	Yes	Difficult	No	No
	Random wound windings; IP4x and above (enclosed motors greater than 0.75 kW)	Yes	Yes	Yes	Difficult	No
	Random wound windings; IP4x and above (enclosed motors less than or equal to 0.75 kW)	Yes	Yes	Yes	Difficult	No
	Form wound windings; IP4x and above	Yes	Yes	Yes	Difficult	No
Three-phase wound-rotor induction motors		Yes	Yes	Yes	Difficult	No
Single-phase induction motors	Start capacitor	Difficult	No	No	No	No
	Run capacitor	Yes	Difficult	No	No	No
	Start/run capacitor	Yes	Difficult	No	No	No
	Split-phase	Difficult	No	No	No	No
Synchronous motors	Line-start permanent-magnet (LSPM[a])	Yes	Yes	Yes	Difficult	No

[a] Line-start permanent-magnet motors have limitations on their line-start capabilities with respect to torque and external inertia and may not be suitable for all types of applications.

Energy saving not excluded only in improvement of motor efficiencies, it is also can be achieved by using variable frequency drives VFDs especially on those systems which spend the majority of their operational life at a part load.

VFDs used to control the speed of an HVAC fan or pump motor (like a throttle on a car) depending on the demand. VFDs can make the fans or motors work under 100% full load when the system don’t need a full load demand while the regular fans and pumps without VFDs can only working with 100% load or 100% off load, so that VFDs can conserve energy and save money.

VFDs adjusting the frequency to control and change the speed of a fan or motor, typical frequency adjustment range can vary from 10-60 Hz. At the same time they system has VFDs it is recommended to have also a Bypass to keep the system running when VFDs interrupted or under servicing.

VFDs can save energy as much as 30-70% when it's connected to fans and motors (centrifugal fans and pumps only). [6]

2.5 Energy saving opportunities in Decentralized air conditioning systems

Decentralized air conditioning systems have many shapes and structures differ from those in centralized air conditioning systems thus they differ when using energy saving opportunities. So when using such energy saving opportunities we should go deeply and understand the system structure and principles to use the suitable opportunities for suitable system and gain more energy conservation.

Many researches were done for energy saving among these air conditioning systems, some effective and some are not and others under study.

In this section we will introduce some of these opportunities that might be best fit or somehow effective. These opportunities are as following:

1– Components shading

2– Evaporative cooling

3– Cleaning air conditioning system filters

2.5.1 Component Shading

Decentralized air conditioning systems specially split air conditioners contain an outside box that include compressor and condenser unit within, condenser component is responsible for heat dropping the heat coming from inside spaces toward outside air surrounding (heat exchanger), in different words it dropping hot air to hotter air. As we know natural air moves from cold to hot, so the heat will moves from hot to hotter naturally. Figure (2.13) shows outside box that contain condenser unit within.

Figure (2.13): Outside box split unit

As we can see the air flow in this outside unit is vertical, and sometimes the air flow may be horizontally and this is an important note in this case when using shading to keep the outdoor unit away from the direct sunlight.

Shading can reduce the direct solar gain toward condenser body so that its efficiency will improve and capability of dropping hot air to surrounding will increases, and that can make the return air temperature deceases. Since the temperature difference became less between the return air and inside space air, cooling capacity will be reduced and energy consumption also reduced.

This energy saving opportunity is sensitive to the shading structure we used, it should be noted the direction of the fan exhaust first and the structure of the shading in the other side. Figure (2.8) showing the perfect shading structure in an outdoor unit.

Figure (2.14): Shading structure in outdoor split unit. [7]

Related to the previous figure (2.14) the suitable and perfect shading should not interrupt the air flow between the fan and the air surrounding (heat exchanging), and it should not be totally closed so air still circulates around.

This shading strategy is more effective in long time term to gain more saving and be feasible for about 10% energy saving to install relating to study done by FSEC [7]

2.5.2 Evaporative cooling

Evaporative cooling is similar to our bodies sweating, when skin sense of hot condition it sweat and producing liquid water to be changed into vapor water, this process keep make our skin rejecting heat by the evaporation of the liquid water produced, this phase changing from liquid to vapor need heat to be done, so heat will be rejected from our skins and that the main principle of evaporative cooling. Figure (2.15) describes the evaporative cooling schematic.

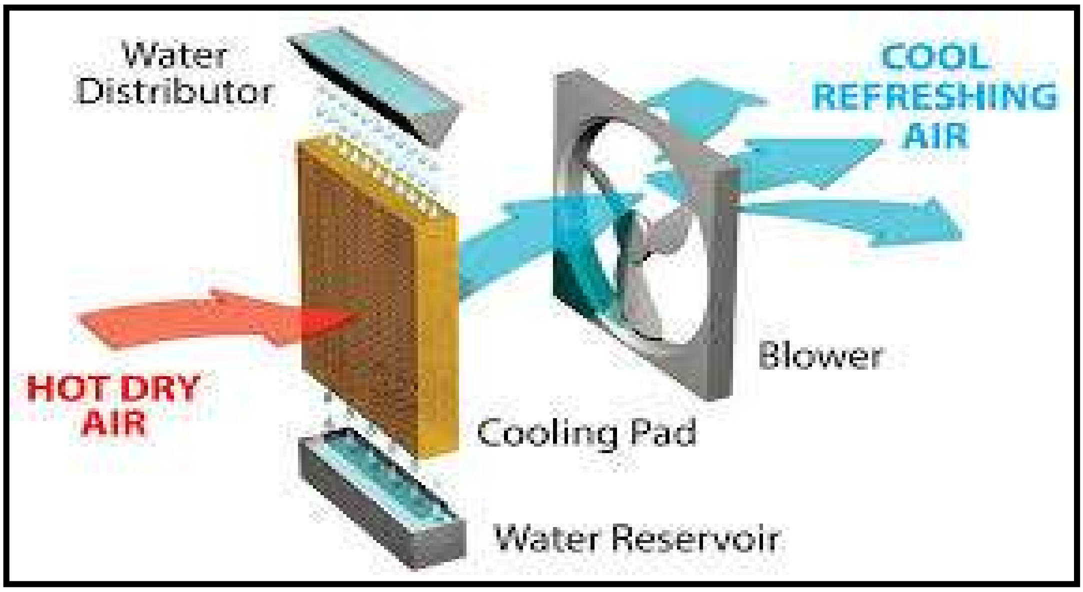


Figure (2.15): Evaporative cooling schematic. [7]

Evaporative cooling is most feasible in system with dry conditions it used a water distributer to spread the water into the condenser body to make the tiny water droplets evaporates taking heat out to the surrounding, so the temperature of the air decrease and thus increases the cooling capacity.

This opportunity make air conditioning system more efficient and save energy. We can use this strategy in centralized air conditioning.

2.5.3 Cleaning air conditioning system filters

Filters very important in air conditioning systems to keep the air inside spaces with high quality and meet the standards ASHRAE. The return air line should contain filters since the air inside contain many harmful particles and must be removed before recycling. [1]

Almost these filters got blocked due to the accumulation of harmful particles within and make the air hard to pass through.

Figure (2.16) shows a split unit filter.

Figure (2.16): Split unit filter. [7]

Air conditioning system filters blockage is almost a serious problem because it reduced the air quality inside spaces and can spread many diseases and illnesses. Addition to that filters blockage can increases the consumption of energy since the air will be hard to circulate cause increasing in pressure.

In decentralized ducted air conditioning systems almost there is a blower which is the heart of the system that is responsible for pulling out the air from spaces to the ducts to be conditioned again in AHU, the blower is powered by an electronically commutated motor (ECM) that controlling the speed depending on varying conditions, and sometimes connected to permanent split capacitor (PSC) which is not as ECM (not a variable speed motor).

When the filter gets too dirty and somehow blocked the blower will fight against an extra pressure above the maximum (typically 0.5 inches of water column iwc). In this case high pressure will make the ECM motor will ramp up in an attempt to maintain proper air flow and fight against high pressure and make it dissipating more heat thus more cooling load causing an extra energy consumption also causing damage on the motor in long term and loss in efficiency.

Figure (2.17) shows two different filters, one is clean and other in dirty. Changing air conditioning filters constantly will save energy as much as 20- 30%. [7]

Figure (2.17): Two air conditioning filters one is clean and other is dirty.. [7]

Chapter Three

Variable Refrigerant Flow (VRF) Design for ANCI

Chapter Three
Variable Refrigerant Flow (VRF) Design for ANCI

Variable refrigerant flow system is a modern air conditioning system that use refrigerant as the cooling and heating medium, VRF system consists of outdoor units, indoor units, and piping system.

Compressed refrigerant lift the outdoor unit through pipes to reach indoor units and have heat exchanging there with air. No ducts for this type of air conditioning.

3.1 Selection and Design of Variable Refrigerant Flow (VRF) System Components

All components selection based on **Toshiba** air conditioning catalogues. As in appendix 1, and appendix 2.

- Selection of outdoor units

Outdoor units was divided into two parts, one for ground floor, and first floor and the other one for second floor and third floor.

With total area of 550 m^2 for ground and first floors, the outdoor unit selected was 42HP with code name of (MMY-AP4216HT8P-E) The second floor and third floor with total area of 380 m^2, the outdoor unit selected with capacity of 32HP with code name of (MMY-AP3216HT8P-E)

- Selection of Indoor units

Indoor units was selected to cover target zones in all floors as following:

Ground and first floor contain 17 indoor units, 3 are ducted models and 14 wall mounted models. As in Table (3.1)

Second and third floors contains 16 indoor units. Two are ducted models and 14 are wall mounted models. As in Table (3.2)

Table (3.1): Ground and first floors indoor unit specifications.

Model Name	Unit Name & Room	Capacity Code	Fan Speed	Mode	Capacity (Total/Sensible) [kW] Rated	Corrected	Required
MMD-AP0366BHP-E		4.0HP	High	Cooling	11.20/8.80	9.56/7.65	
				Heating	12.50	8.93	
MMD-AP0566BHP-E		6.0HP	High	Cooling	16.00/11.50	13.74/10.05	
				Heating	18.00	12.87	
MMD-AP0566BHP-E		6.0HP	High	Cooling	16.00/11.50	13.94/10.20	
				Heating	18.00	12.93	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.93/2.84	
				Heating	5.00	3.59	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.78/2.73	
				Heating	5.00	3.55	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.78/2.73	
				Heating	5.00	3.55	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.80/2.75	
				Heating	5.00	3.55	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.83/2.77	
				Heating	5.00	3.57	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.80/3.40	
				Heating	6.30	4.50	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.79/3.39	
				Heating	6.30	4.50	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.83/3.42	
				Heating	6.30	4.51	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.89/3.46	
				Heating	6.30	4.53	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.83/3.42	
				Heating	6.30	4.51	

Table (3.2): Second and third floors indoor unit specifications.

Model Name	Unit Name & Room	Capacity Code	Fan Speed	Mode	Capacity (Total/Sensible) [kW] Rated	Corrected	Required
MMD-AP0366BHP-E		4.0HP	High	Cooling	11.20/8.80	9.53/7.62	
				Heating	12.50	9.25	
MMD-AP0366BHP-E		4.0HP	High	Cooling	11.20/8.80	9.49/7.58	
				Heating	12.50	9.23	
MMK-AP0123H		1.25HP	High	Cooling	3.60/2.60	3.08/2.26	
				Heating	4.00	2.96	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.83/2.77	
				Heating	5.00	3.70	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.82/2.76	
				Heating	5.00	3.70	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.82/2.77	
				Heating	5.00	3.70	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.91/2.83	
				Heating	5.00	3.72	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.91/2.83	
				Heating	5.00	3.72	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.83/2.77	
				Heating	5.00	3.70	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.81/3.41	
				Heating	6.30	4.68	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.85/3.44	
				Heating	6.30	4.69	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.91/3.48	
				Heating	6.30	4.70	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.97/3.52	
				Heating	6.30	4.72	

- Piping length calculations

Ground and first floors piping lengths and diameters are given in table (3.3).

Table (3.3): Ground and first floors piping system quantities

Pipe Diameter	Gas side (m)	Discharge side (m)	Liquid side (m)	Total Length (m)
¼"	0	0	17.5	17.5
⅜"	0	0	31.5	31.5
½"	17.5	0	12.5	30
⅝"	31.5	0	5	36.5
¾"	0	0	7.5	7.5
⅞"	12.5	0	13	25.5
1⅛"	8	0	0	8
1⅜"	4.5	0	0	4.5
1⅝"	13	0	0	13

Second and third floors piping lengths and diameters as shown in table (3.4).

Table (3.4): Second and third floors piping system quantities.

Pipe Diameter	Gas side (m)	Discharge side (m)	Liquid side (m)	Total Length (m)
¼"	0	0	33	33
⅜"	7	0	12	19
½"	26	0	16	42
⅝"	12	0	12	24
¾"	0	0	11	11
⅞"	16	0	0	16
1⅛"	12	0	0	12
1⅜"	11	0	0	11

- Indoor units distribution for ground floor

8 indoor units were distributed in all targeted zones at ground floor, as figure (3.1) gives, there are 8 indoor units distributed as following:

1- Wall mounted 4.50 kW (Clinic1- 14.60 m^2)

2- Wall mounted 4.50 kW (Clinic 2- 15.00 m^2)

3- Wall mounted 4.50 kW (Clinic 3- 12.25 m^2)

4- Wall mounted 4.50 kW (Clinic 4- 12.25 m^2)

5- Wall mounted 5.60 kW (Intervention north- 45.30 m^2)

6- Wall mounted 5.60 kW (Intervention east- 45.30 m^2)

7- Ducted unit 16.00 kW (Lobby west)

8- Ducted unit 16.00 kW (Lobby east)

- Indoor units distribution for first floor

9 indoor units were distributed in all targeted zones at first floor, as we can see in figure (3.2) there are 9 indoor units distributed as following:

1- Wall mounted 6.30 kW (secrtaria1- 16.00 m^2)

2- Wall mounted 6.30 kW (administration- 17.40 m^2)

3- Wall mounted 6.30 kW (Offic1- 20.00 m^2)

4- Wall mounted 5.00 kW (Offic2 west – 38.00 m^2)

5- Wall mounted 5.00 kW (Offic2 north- 38.00 m^2)

6- Wall mounted 8.00 kW (Class 1- 23.00 m^2)

7- Wall mounted 8.00 kW (Class 2- 23.00 m^2)

8- Wall mounted 8.00 kW (Class 3- 23.00 m^2)

9- Ducted unit 12.50 kW (Lobby)

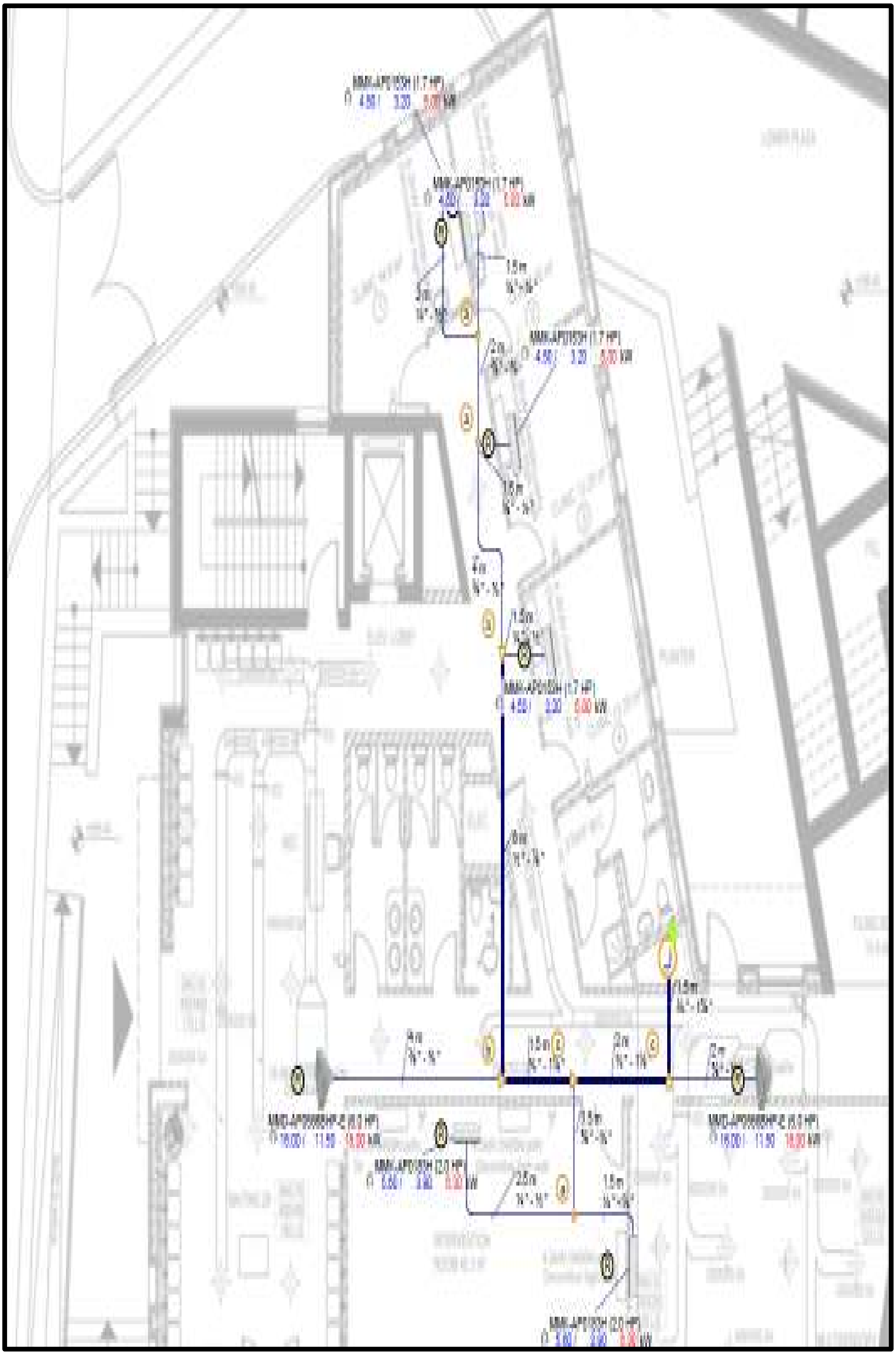


Figure (3.1): Ground floor indoor units distribution

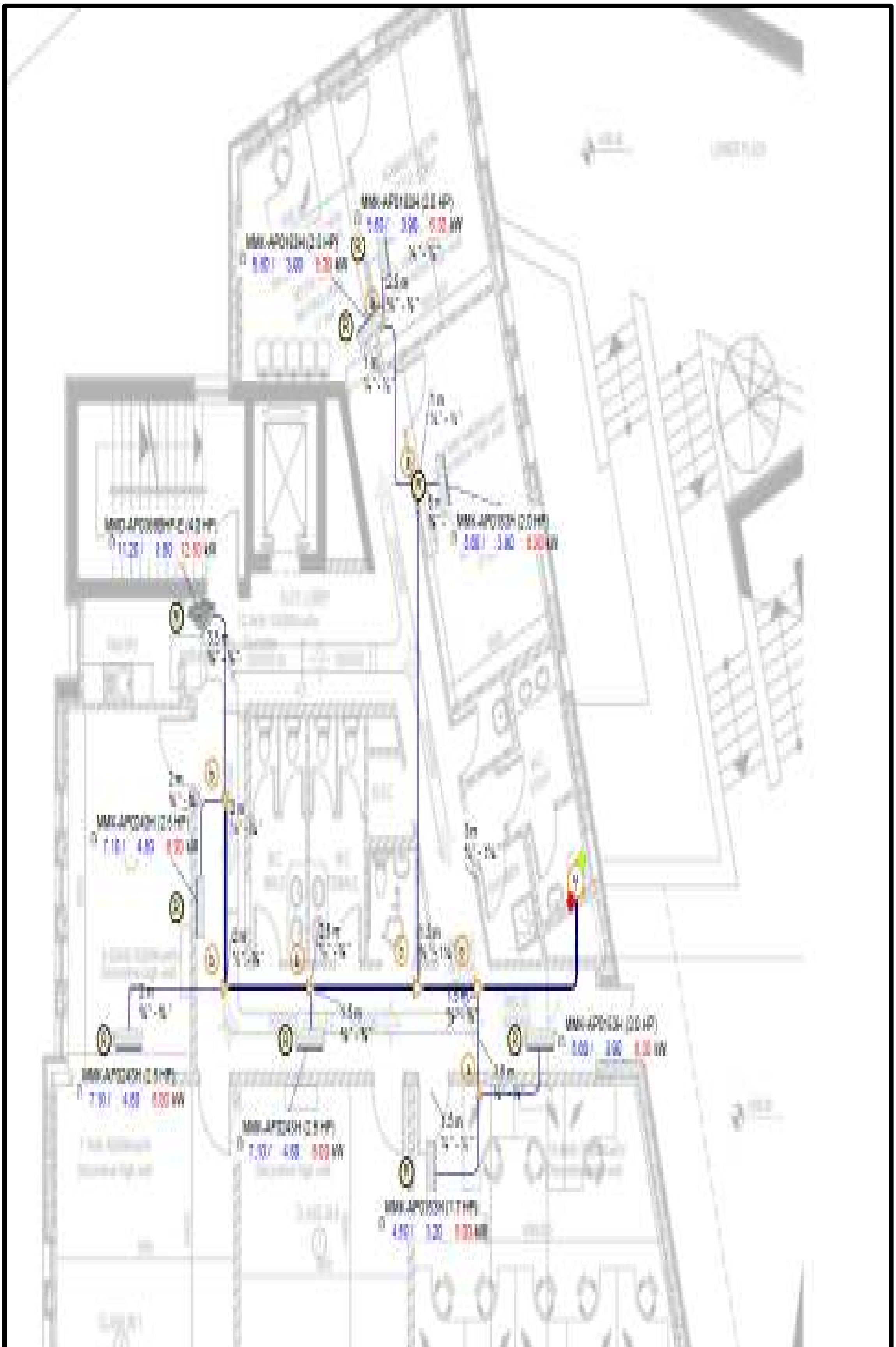


Figure (3.2): First floor indoor units distribution

- Indoor units distribution for second floor

8 indoor units were distributed in all targeted zones at ground floor, as can be see in figure (3.3) there are 8 indoor units distributed as following:

1- Wall mounted 4.00 kW (Resource and Service- 10.0 m^2)

2- Wall mounted 6.30 kW (Library- 20.60 $m^{\wedge 2}$)

3- Wall mounted 5.00 kW (Art room north- 31.70 m^2)

4- Wall mounted 5.00 kW (Art room west- 31.70 m^2)

5- Wall mounted 5.00 kW (LD-room west- 31.90 m^2)

6- Wall mounted 5.00 kW (LD-room north- 31.90 m^2)

7- Wall mounted 6.30 kW (Music room- 23.00 m^2)

8- Ducted unit 12.50 kW (Lobby).

- Indoor units distribution for third floor

9 indoor units were distributed in all targeted zones at first floor, as we can see in figure (3.4) there are 9 indoor units distributed as following:

1- Wall mounted 6.30 kW (Research room- 16.30 m^2)

2- Wall mounted 6.30 kW (Admin office1- 19.60 m^2)

3- Wall mounted 6.30 kW (Admin office2- 17.50 m^2)

4- Wall mounted 6.30 kW (Admin office3- 17.50 m^2)

5- Wall mounted 6.30 kW (Admin office4- 19.40 m^2)

6- Wall mounted 5.00 kW (Meeting room north- 28.40 m^2)

7- Wall mounted 5.00 kW (Meeting room west- 28.40 m^2)

8- Ducted unit 12.50 kW (Lobby).

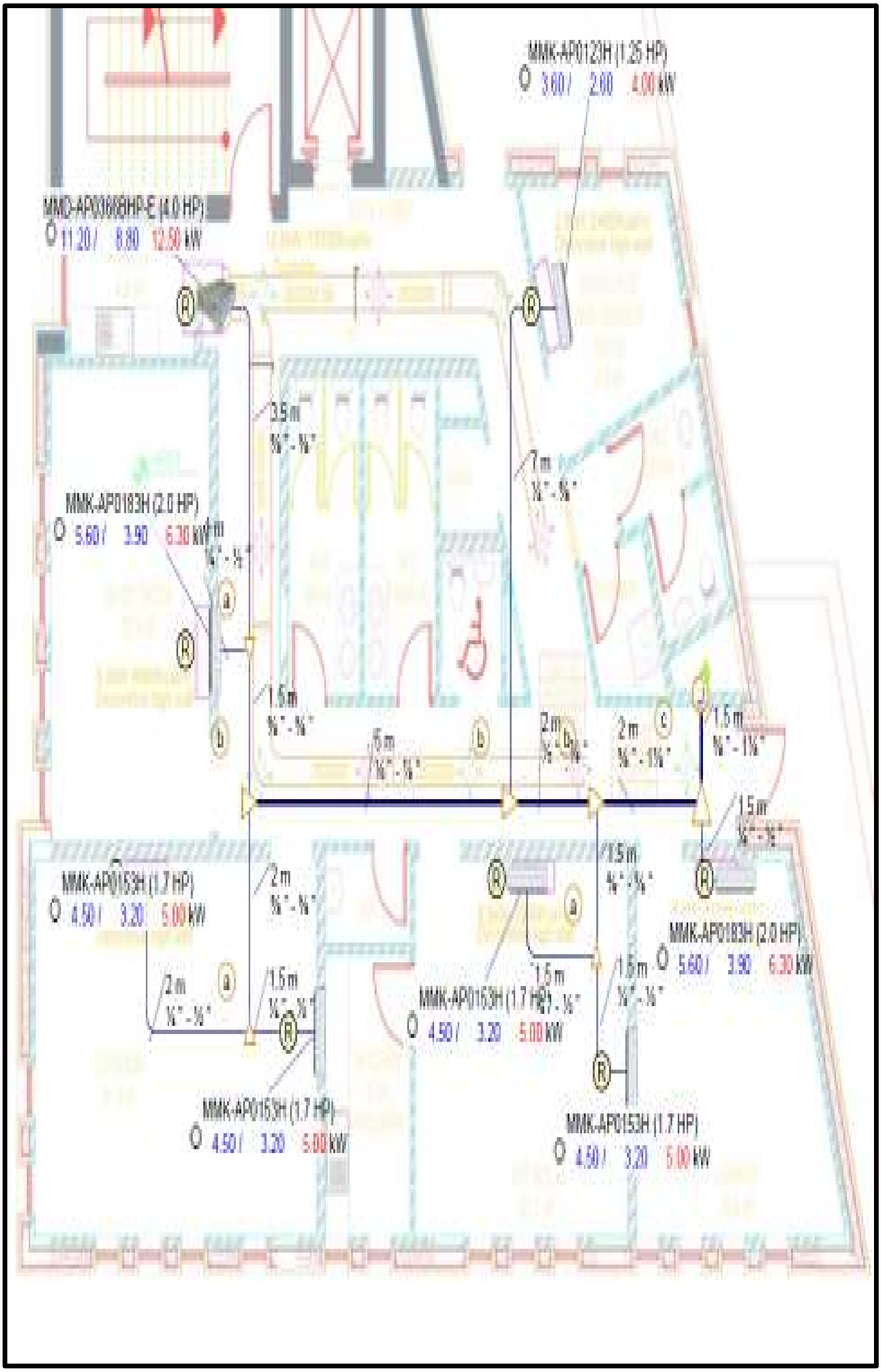


Figure (3.3): Second floor indoor unit's distribution.

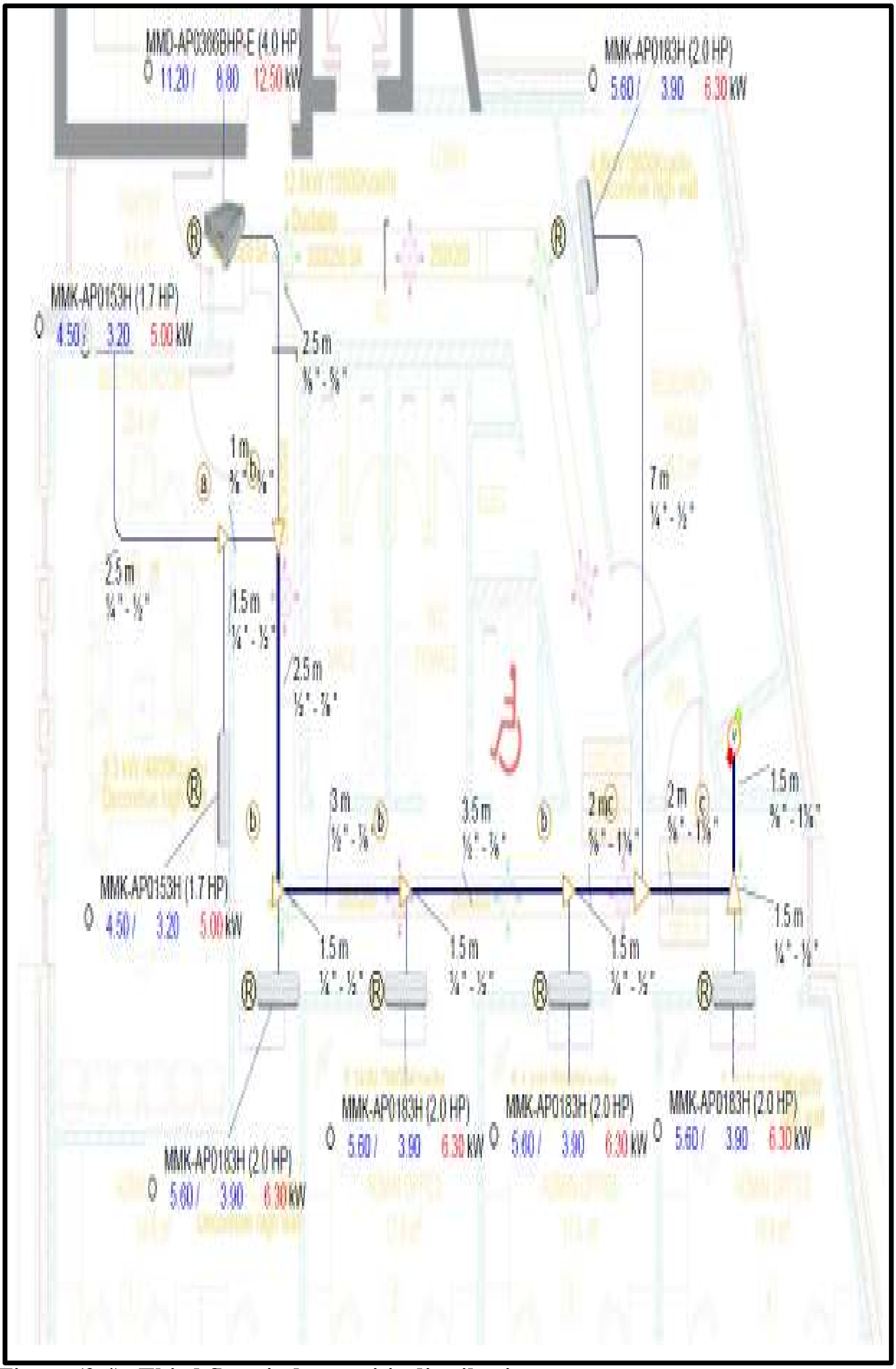


Figure (3.4): Third floor indoor unit's distribution.

3.2 Electrical Consumption in VRF system

(Cooling Mode)

Ground and First floors:

Electrical consumption depends on number of outdoor units capacity, and also depend on number of indoor units and capacity.

Ground floor and first floor contain 1 outdoor unit with 103.70 kW cooling capacity beside of 17 indoor units all contains electrical fans that consume variable Kilo Watts as shown in table (3.5).

According to manufacturer catalogue the outdoor unit used to serve ground and first floors is (MMY-AP4216HT8P-E) power input during cooling mode equals to 40.50 kW. (Appendix1)

Outdoor unit power consumption = 40.50 kW.

Related to manufacturer catalogue for indoor units distributed in both ground and first floors Table (3.5), the power input for all indoor units (1x 0.172 + 2x 0.198 + 5 x 0.043 + 6 x 0.043 + 3 x 0.05 = 1.191 kW.

Table (3.5): GF-1st floors indoor unit's catalogue.

Model name	Description	Quantity
MMD-AP0366BHP-E	4.0HP Standard Concealed Duct	1
MMD-AP0566BHP-E	6.0HP Standard Concealed Duct	2
MMK-AP0153H	1.7HP High Wall Standard (Series 3)	5
MMK-AP0183H	2.0HP High Wall Standard (Series 3)	6
MMK-AP0243H	2.5HP High Wall Standard (Series 3)	3

Electrical consumption (GF + 1st floor) = 1.19 kW

ESEER = 7.13

Using equation (1)

Annual energy consumption = over all electrical consumption X Total operation hours per year …Eq (3.1)

With an assumption of operating hours per year (summer) = 700 hours

Annual energy consumption (1st + GF indoor units) = 1.19 kW X 700 hrs = 833 kWh

Second and Third floors indoor units

Second and third floor contain 1 outdoor unit with 79.30 kW capacity, and also 16 indoor units all contains electrical fans that consume variable kW as shown in table (3.6).

According to manufacturer catalogue the outdoor unit used to serve ground and first floors (MMY-AP3216HT8P-E) the power input in cooling mode equal to 28.60 kW. (Appendix 1)

Outdoor 32HP unit power consumption = 28.60 kW

Related to manufacturer catalogue for indoor units distributed in both second and third floors Table (3.6).

The power input for <u>all indoor units related to appendix (2)</u> 2 indoor units x 0.172 kW + 1 indoor unit x 0.021kW + 6 indoor units x 0.043 kW + 7 indoor unitsx 0.043 kW = 0.924 kW

Table (3.6): 2nd and 3rd floors indoor units' catalogue.

Model name	Description	Quantity
MMD-AP0366BHP-E	4.0HP Standard Concealed Duct	2
MMK-AP0123H	1.25HP High Wall Standard (Series 3)	1
MMK-AP0153H	1.7HP High Wall Standard (Series 3)	6
MMK-AP0183H	2.0HP High Wall Standard (Series 3)	7

ESEER = 7.59

With an assumption of operating hours per year (summer) = 700 hours

Applying equation (3.1): Annual energy consumption (2nd and 3rd indoor units) = 0.924 kW X 700 Hrs = 646 kWh

- Annual overall energy consumption of indoor units (Cooling) = GF-1st energy consumption (Cooling mode) + 2nd – 3rd energy consumption (Cooling mode) … Eq(3.2)

= 833 + 646 **= 1479 kWh/Year**.

Chapter Four

Air to Water Chiller System (Air Cooled)

Chapter Four
Air to Water Chiller System (Air Cooled)

4.1 Air to Water Chiller Design

Chiller air to water air conditioning system or in other name (Air cooled liquid chillers ACLC), consists of many important parts: outdoor units, indoor units, water pumps, ductworks, and water pipes network. Every part integrates the other, and every part design should complete the other.

- Air to Water Chiller outdoor and indoor unit selection

- Selection of outdoor units

All components here selected based on **TRANE** air conditioning manufacturer catalogues. (Appendix 5)

The cooling load in the studied area is = 213 kW = 60 TOR and relating to TRANE catalogues; one unit was selected to cover four floors at ANCI building as shown in figure (4.1).

Table (4.1): Air cooled outdoor unit specification

Table PD-8 – 60Ton – CGAF-C60

		Entering Condenser Air Temperature (Degree F)														
		75.0			85.0			95.0			105.0			115.0		
LWT Deg F)	Percent Glycol	Capacity (Tons)	System KW	EER	Capacity (Tons)	System KW	EER	Capacity (Tons)	System KW	EER	Capacity (Tons)	System KW	EER	Capacity (Tons)	System KW	EER
20	28	37.2	50.1	8.9	35.3	55.0	7.7	33.4	60.7	6.6	31.3	67.2	5.6	29.2	74.6	4.7
25	24	41.6	51.3	9.7	39.6	56.4	8.4	37.4	62.2	7.2	35.2	68.8	6.1	32.9	76.3	5.2
30	19	46.4	52.6	10.6	44.1	57.8	9.2	41.8	63.8	7.9	39.4	70.6	6.7	36.8	78.2	5.7
35	14	51.4	54.0	11.4	48.9	59.3	9.9	46.4	65.4	8.5	43.7	72.3	7.3	41.0	80.1	6.1
40	0	57.2	55.6	12.3	54.5	61.1	10.7	51.7	67.3	9.2	48.8	74.4	7.9	45.8	82.2	6.7
42	0	59.2	56.2	12.7	56.5	61.7	11.0	53.6	68.0	9.5	50.6	75.1	8.1	47.5	83.0	6.9
44	0	61.4	56.8	13.0	58.5	62.3	11.3	55.6	68.7	9.7	52.5	75.9	8.3	49.3	83.8	7.1
45	0	62.5	57.1	13.1	59.6	62.7	11.4	56.6	69.1	9.8	53.4	76.2	8.4	50.2	84.2	7.2
46	0	63.6	57.4	13.3	60.6	63.0	11.5	57.6	69.4	9.9	54.4	76.6	8.5	51.1	84.6	7.2
48	0	65.8	58.0	13.6	62.7	63.7	11.8	59.6	70.2	10.2	56.3	77.4	8.7	52.9	85.4	7.4
50	0	68.0	58.6	13.9	64.9	64.4	12.1	61.7	70.9	10.4	58.3	78.2	8.9	54.8	86.3	7.6
55	0	73.8	60.3	14.7	70.4	66.1	12.8	66.9	72.8	11.0	63.3	80.2	9.5	59.6	88.4	8.1
60	0	79.7	62.0	15.4	76.1	68.0	13.4	72.4	74.8	11.6	68.5	82.4	10.0	64.5	90.7	8.5

Total area to be air conditioned and served in ground, first, second, and third floors at ANCI building = 786 $m^{\wedge 2}$, and total cooling load = 60 TOR. By assuming the design leaving chilled water temperature is 44^{o} F, and the entering condenser air temperature is 75^{o} F; one air cooled liquid chiller was chosen with code number of **CGAF-C60** with full capacity of 61.40 Tons (the shaded row in table (4.1)).

- Selection of Indoor units

Based on cooling load in every space, Indoor units were selected to cover all spaces in each of ANCI building floors with two types of indoor units; one is ducted indoor unit, and the other is decorative high wall indoor unit.

Related to TRANE catalogues (Appendix 6 and 7) for indoor units; HWCF -50 Hz series was chosen for decorative high wall, and HFCA series was chosen for ducted indoor units. Based on assumptions that the entering water temperature (EWT) in decorative wall mounted indoor type is 45^o F and the entering water temperature of ducted indoor type is 41^o F

Tables (4.2), (4.3), (4.4), and figure (4.5) contain all indoor units in each floor with their specifications. We can easily define every indoor unit in each space of all floors.

Table (4.2): Ground floor indoor units detail.

	Ground Floor						
Space	**Area m^2**	**Load kW**	**indoor unit type**	**indoor units #**	**total load kW**	**Indoor unit code#**	**Indoor unit air flow CFM**
Clinic Room1	14.60	4.20	decorative	1	4.20	HWCF06	600
Clinic Room2	15.00	4.20	decorative	1	4.20	HWCF06	600
Clinic Room3	12.25	4.20	decorative	1	4.20	HWCF06	600
Clinic Room4	12.25	4.20	decorative	1	4.20	HWCF06	600
Multisensory Room	40.40	16.50	ductable	1	16.50	HFCA14	1400
Intervention Room	45.30	4.20	decorative	2	8.40	HWCF10	2000
Waiting Room	28.00	16.50	ductable	1	16.50	HFCA14	1400
Lobby	4.60	0	ductable	0	0	-	-

Table (4.3): First floor indoor units detail.

	First Floor						
Space	**Area m^2**	**Load kW**	**indoor unit type**	**indoor units #**	**total load kW**	**Indoor unit code#**	**Indoor unit air flow CFM**
Class1	23.00	6.62	decorative	1	6.62	HWCF08	800
Class2	26.00	7.70	decorative	1	7.70	HWCF10	1000
Class3	24.60	7.20	decorative	1	7.20	HWCF08	800
Staff Room	35.40	10.60	decorative	1	10.60	HWCF12	1200
Meeting Room	21.60	5.70	decorative	1	5.70	HWCF08	800
Adminstrati on	17.40	5.10	decorative	1	5.10	HWCF06	600
Secretsry and waiting area	17.5	5.80	decorative	1	5.80	HWCF08	800
Pantry	4.60	0	ductable	0	0	-	-
Lobby	63.00	12.50	ductable	1	12.50	HFCA12	1200

Table (4.4): Second floor indoor units detail.

	Second Floor						
Space	**Area m^2**	**Load kW**	**indoor unit type**	**indoor units #**	**total load kW**	**Indoor unit code#**	**Indoor unit air flow CFM**
Music Room	23..00	6.20	decorative	1	6.20	HWCF08	800
LD Room	31.90	9.50	decorative	1	9.50	HWCF12	1200
Art Room	31.70	9.50	decorative	1	9.50	HWCF12	1200
Library	20.60	6.00	decorative	1	6.00	HWCF08	800
Resource and Service	19.40	2.90	decorative	1	2.90	HWCF03	300
Lobby	63.00	12.50	ductable	1	12.50	HFCA12	1200
Pantry	4.60	0	ductable	1	0	-	-

Table (4.5): Third floor indoor units detail.

	Third Floor						
Space	**Area m^2**	**Load kW**	**Indoor unit type**	**Indoor units #**	**Total load kW**	**Indoor unit code#**	**Indoor unit air flow CFM**
Meeting Room	28.40	8.30	decorative	1	8.30	HWCF10	1000
Admin Office1	19.60	5.70	decorative	1	5.70	HWCF08	800
Admin Office2	17.50	5.10	decorative	1	5.10	HWCF06	600
Admin Office3	17.50	5.10	decorative	1	5.10	HWCF06	600
Admin Office4	19.40	5.70	decorative	1	5.70	HWCF08	800
Research Room	16.30	4.80	decorative	1	4.80	HWCF06	600
Lobby	63.00	12.50	ductable	1	12.50	HFCA12	1200
Pantry	4.60	0	ductable	0	0	-	-

- Indoor units distribution

Indoor units distribution should covering all zones so that every zone reach its comfort condition.

Drawings given in figures (4.1, 4.2, 4.3, and 4.4) give a full description for all indoor units distribution and connection, in addition to pipes network and

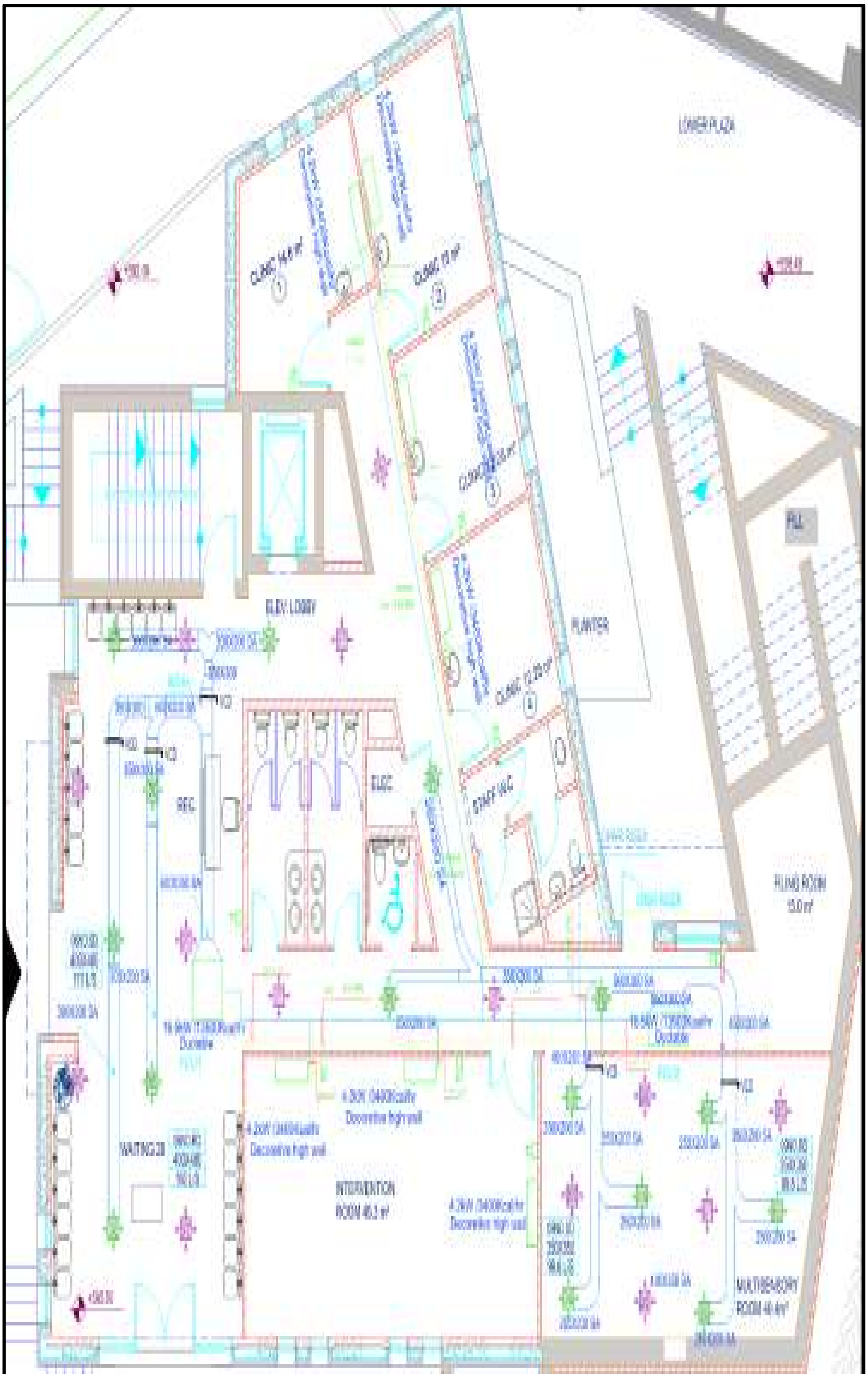


Figure (4.1): Ground floor Air cooled indoor unit's distribution.

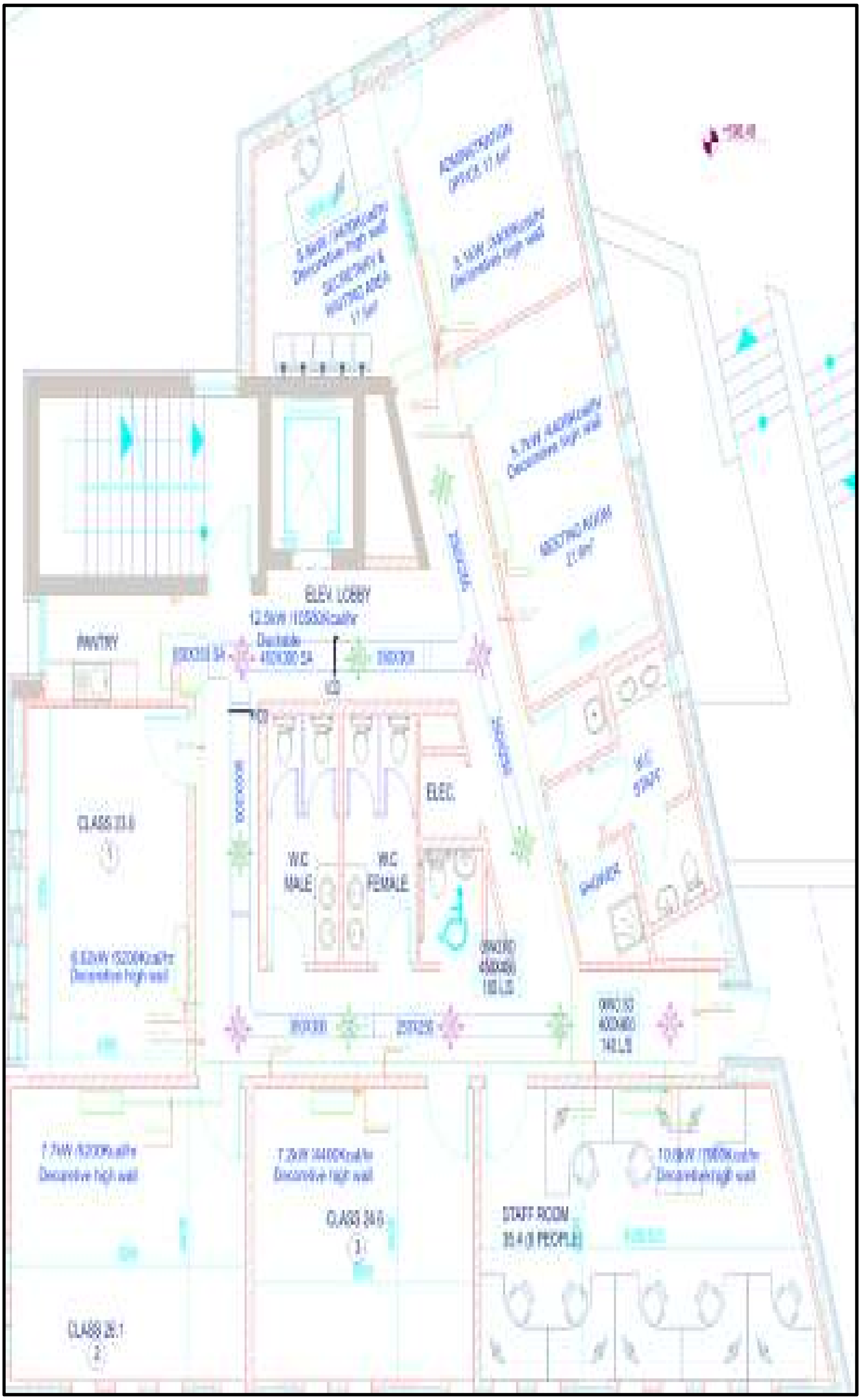


Figure (4.2): First floor Air cooled indoor unit's distribution

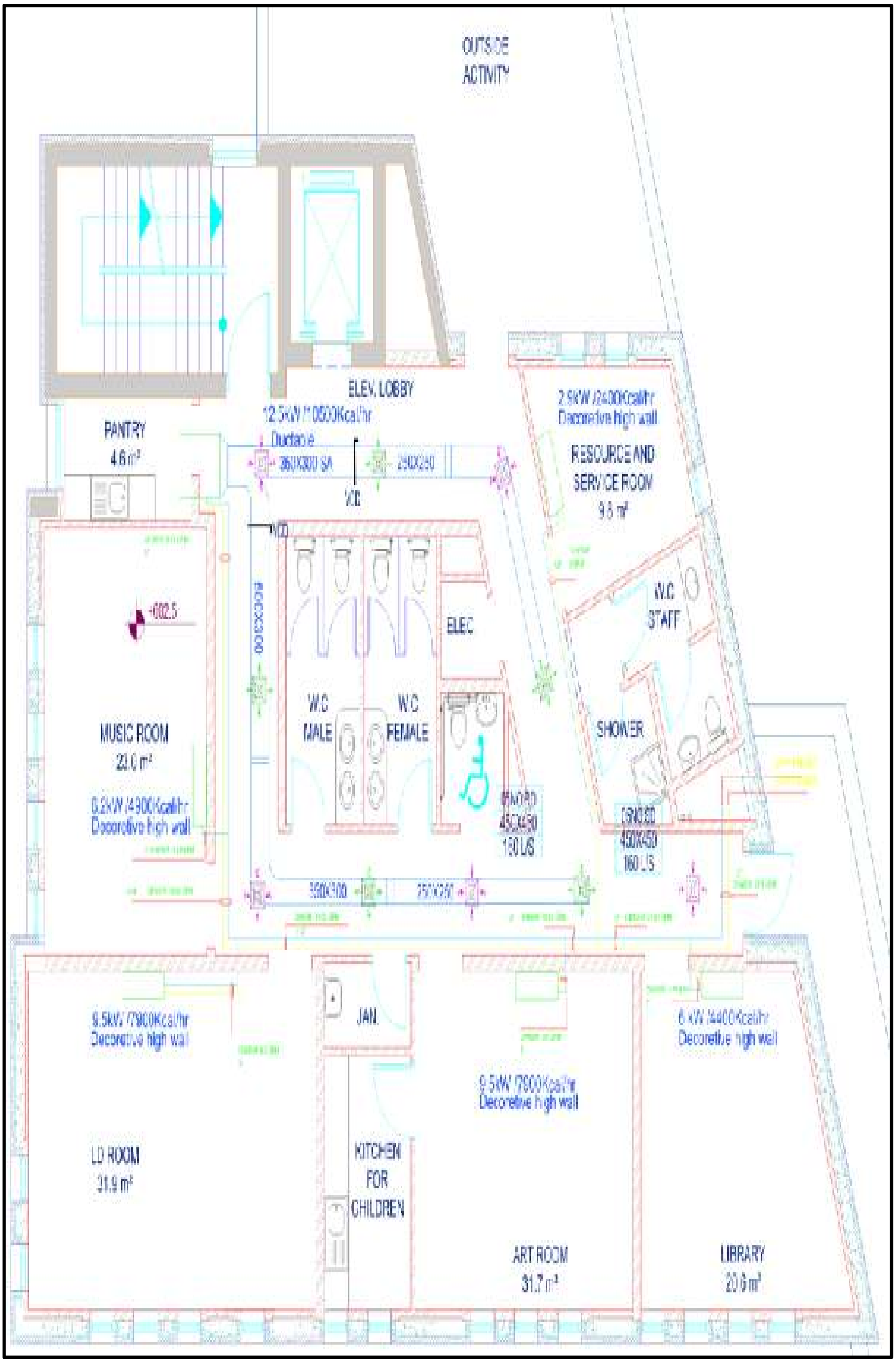


Figure (4.3): Second floor Air cooled indoor units distribution

Figure (4.4): Third floor Air cooled indoor units distribution

-Riser and Pumps selection

Secondary pump (Variable volume) for circulating chilled water through indoor units is operating with variable speed according to cooling load.

To select secondary pump, total head was calculated as following:

Table (4.6): Secondary pump total head calculations.

Description	Flow (gpm)	Equivalent length	Head loss	Total head m
3" elbow	138	4	0.031	0.248
4"X3" REDUCER		2	0.031	0.124
3" straight pipe		5	0.031	0.310
tee 3"x2"x3"		2	0.031	0.124
21/2" straight pipe		4	0.08	0.640
tee 21/2"x2"x21/2"		2	0.08	0.320
21/2" straight pipe		4	0.04	0.320
tee 21/2"x2"x21/2"		2	0.04	0.160
2" straight pipe		4	0.035	0.280
2" elbow		2.5	0.035	0.175
2" straight pipe		1.5	0.035	0.105
2" tee		1	0.035	0.070
2" straight pipe		3.5	0.02	0.140
tee 2"x11/4"x2"		2	0.02	0.080
2" straight pipe		1	0.02	0.040
2" 45 elbow		1	0.02	0.040
2" straight pipe		5	0.02	0.200
tee 11/4"x3/4"x11/4"		1	0.02	0.040
straight pipe 11/4"		3.5	0.02	0.140
tee 11/4"x3/4"x11/4"		1	0.02	0.040
11/4"X1" REDUCER		1	0.02	0.040
reducer 11/4"x1"		1	0.02	0.040
1" straight pipe		3	0.02	0.120
tee 1"x3/4"x1"		1	0.02	0.040
3/4" straight		2.5	0.02	0.100
3/4" elbow		1	0.02	0.040
tee 3/4"		1	0.02	0.040
3/4" gate valve		8	0.02	0.320
3/4" strainer		3	0.02	0.120
3/4" drv valve		3	0.02	0.120
3/4" union		1	0.02	0.040
3/4" motorised valve		3	0.02	0.120

We can see at figure (4.6) every section of chilled water pipe line has its own equivalent length, for example we got (Tee 3"x2"x3") installed on primary pump pipe line. Equivalent length for this Tee is (2), with head loos equal to 0.031. [12]

Total Pump Head = Equivalent length X Head loss …Eq (4.1)

Total head (Tee 4"x3"x4") = 2 x 0.031 x 2 = 0.124 m.

And so on we got Total head for all secondary pump pipe lines equal to 4.736.

By adding Factor of Safety of 15%, residual pressure (5m), and drop during FCU's (1.5m)

Total Head (Secondary pump) = 12.2 m

Note: fittings equivalent length table available within the Index.

To calculate the flow rate of secondary pump; each of building floors indoors units water flow rate was calculated, then accumulated sum was found.

Table (4.7): Ground and First floors indoor units' water flow rate.

Ground Floor				**First Floor**			
Space	**Indoor unit code#**	**Indoor unit air flow CFM**	**Indoor unit air flow CFM**	**Space**	**Indoor unit code#**	**Indoor unit air flow CFM**	**Indoor unit air flow CFM**
Clinic Room1	HWCF06	600	3.63	Class1	HWCF08	800	4.84
Clinic Room2	HWCF06	600	3.63	Class2	HWCF10	1000	6.10
Clinic Room3	HWCF06	600	3.63	Class3	HWCF08	800	4.84
Clinic Room4	HWCF06	600	3.63	Staff Room	HWCF12	1200	7.23
Multisensory Room	HFCA14	1400	12.20	Meeting Room	HWCF08	800	4.84
Intervention Room	HWCF10	2000	6.10	Adminstration	HWCF06	600	3.63
Waiting Room	HFCA14	1400	12.20	Secretsry and waiting area	HWCF08	800	4.84
Lobby	-	-	-	Pantry	-	-	-
-	-	-	-	Lobby	HFCA12	1200	10.93
Total	0	6600	51.12	total	0	7200	47.25

Table (4.8): Second and Third floors indoor units water flow rate.

Second Floor				**Third Floor**			
Space	**Indoor unit code#**	**Indoor unit air flow CFM**	**Indoor unit air flow CFM**	**Space**	**Indoor unit code #**	**Indoor unit air flow CFM**	**Water flow rate GPM**
Music Room	HWCF08	800	4.84	Meeting Room	HWCF10	1000	6.10
LD Room	HWCF12	1200	7.23	Admin Office1	HWCF08	800	4.84
Art Room	HWCF12	1200	7.23	Admin Office2	HWCF06	600	3.63
Library	HWCF08	800	4.84	Admin Office3	HWCF06	600	3.63
Resource and Service	HWCF03	300	1.83	Admin Office4	HWCF08	800	4.84
Lobby	HFCA12	1200	10.93	Research Room	HWCF06	600	3.63
Pantry	-	-	-	Lobby	HFCA12	1200	10.93
-	-	-	-	Pantry	-	-	-
total	0	5500	36.9	Total	0	5600	37.6

Table (4.7) shows ground and first floors indoor units' water flow rate, while table (4.8) shows second and third floors indoor units water flow rate.

Ground floor water flow rate = 51.00 GPM

First floor water flow rate = 47.00 GPM

Second floor water flow rate = 37.00 GPM

Third floor water flow rate = 37.00 GPM

Total water flow rate = Ground floor water flow rate + First floor water flow rate + Second floor water flow rate + Third floor water flow rate = 51.00 + 47.00 + 37.00 + 37.00 = **173.00 GPM**.

Primary pump (constant volume) for circulating chilled water through outdoor unit is operating with constant speed within chiller loop.

To select primary pump, total head was calculated as following:

Table (4.9): Primary pump total head calculations

Description	Flow (GPM)	Equivalent length	Head loss	Total head m
4" flexible connector	172.8	67	0.0015	0.201
straight pipe	172.8	12	0.0015	0.036
tee 4"x3"x4"	172.8	7	0.0015	0.021
tee 4"x3"x4"	172.8	7	0.0015	0.021
elbow 4"	172.8	3.5	0.0015	0.011
elbow 4"	172.8	3.5	0.0015	0.011
4" CHILLER STRAINER	172.8	20	0.0015	0.060
4" BUTTER FLY valve	172.8	40	0.0015	0.120
4" BUTTER FLY valve	172.8	40	0.0015	0.120
4" DRV	172.8	40	0.0015	0.120
PUMP VALVE	172.8	40	0.0015	0.120
PUMP STRAINER	172.8	20	0.0015	0.060
PUMP FLEXIBLE CONN	172.8	70	0.0015	0.210
PUMP STRAINER	172.8	20	0.0015	0.060
DROP DURING CHILLER	172.8			2.700

According to Table (4.9), Total fittings head = 3.9 m

By adding Factor of Safety of 15%, and residual pressure (5 m).

Total Head (primary pump) = 9.5 m

Note: fittings equivalent length table available within the Index.

Primary pump water flow rate equal to the sum of (GF, 1st, 2nd, 3rd) floors water flow rate.

Primary pump water flow rate = 172.8 GPM.

Figure (4.6) shows both primary and secondary pumps installation over the roof and also shows the design data.

Both primary and secondary pumps were selected based on two parameters (Flow 'GPM', Head 'm'):

Primary pump: Flow = 172 GPM, Head = 9.5 m
Secondary pump: Flow = 172 GPM, Head = 12.2 m

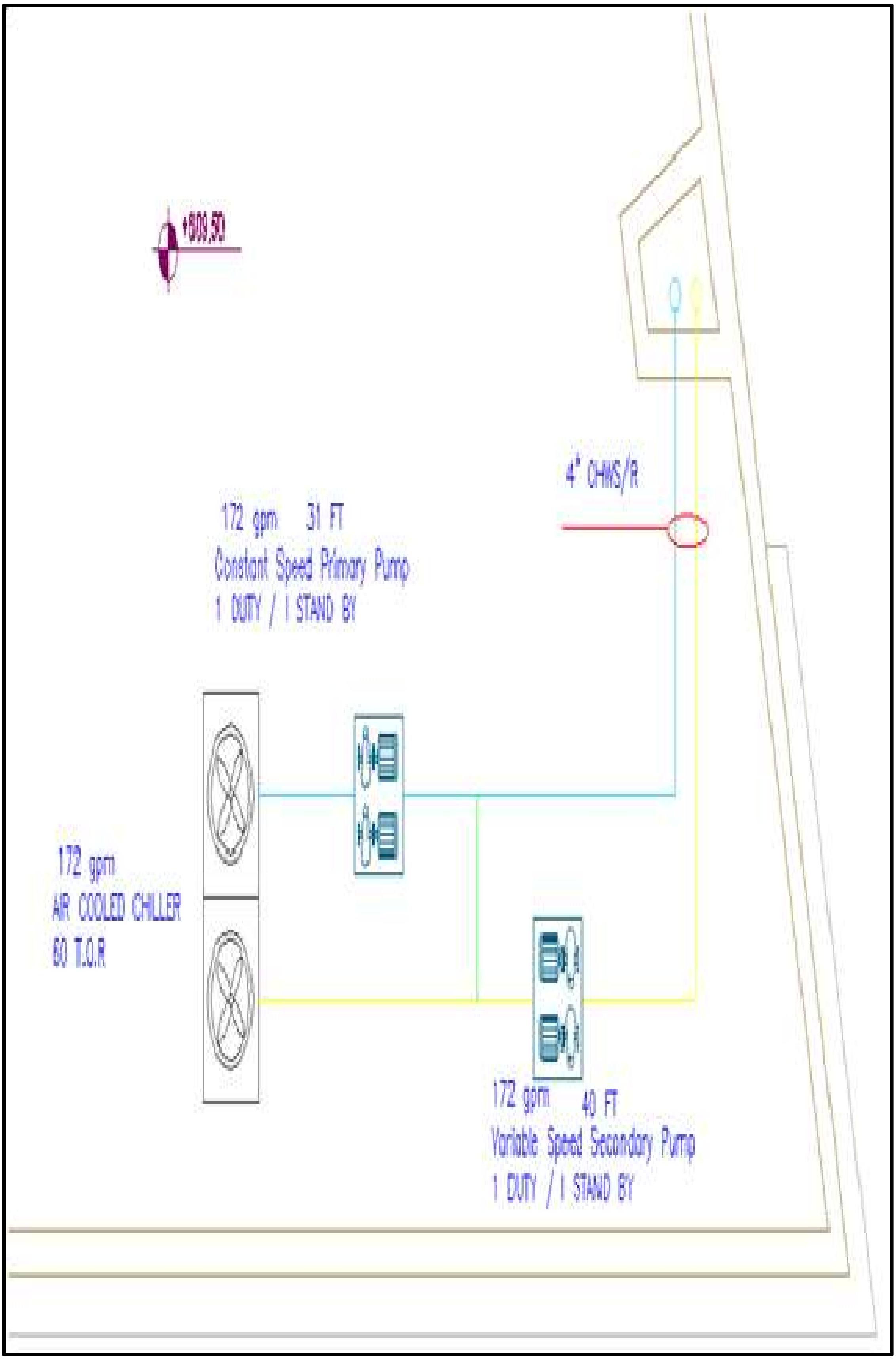


Figure (4.5): Primary and secondary pumps installation

These data were sent to the available pumps market in West bank, and we got the best offer from KSB Company sales engineer as shown in figure (4.7) for primary pumps, and figure (4.8) for secondary pumps.

1- 2x Inline primary pumps with actual flow rate = 43.31 m^3/h, actual Head = 14.65m, and serial number = 065-065-250-GG.

2- 2x Inline secondary pumps with actual flow rate = 39.41 m^3/h, actual Head = 9.22m, and serial number = 065-065-160-GG.

Note: official request available at the appendix. (Appendix 7)

Data sheet

Primary pump

KSB

Customer item no.:
Communication dated:
Doc. no.:
Quantity: 1

Number: ES 5044013
Item no.: 100
Date: 30/04/2017
Page: 1 / 5

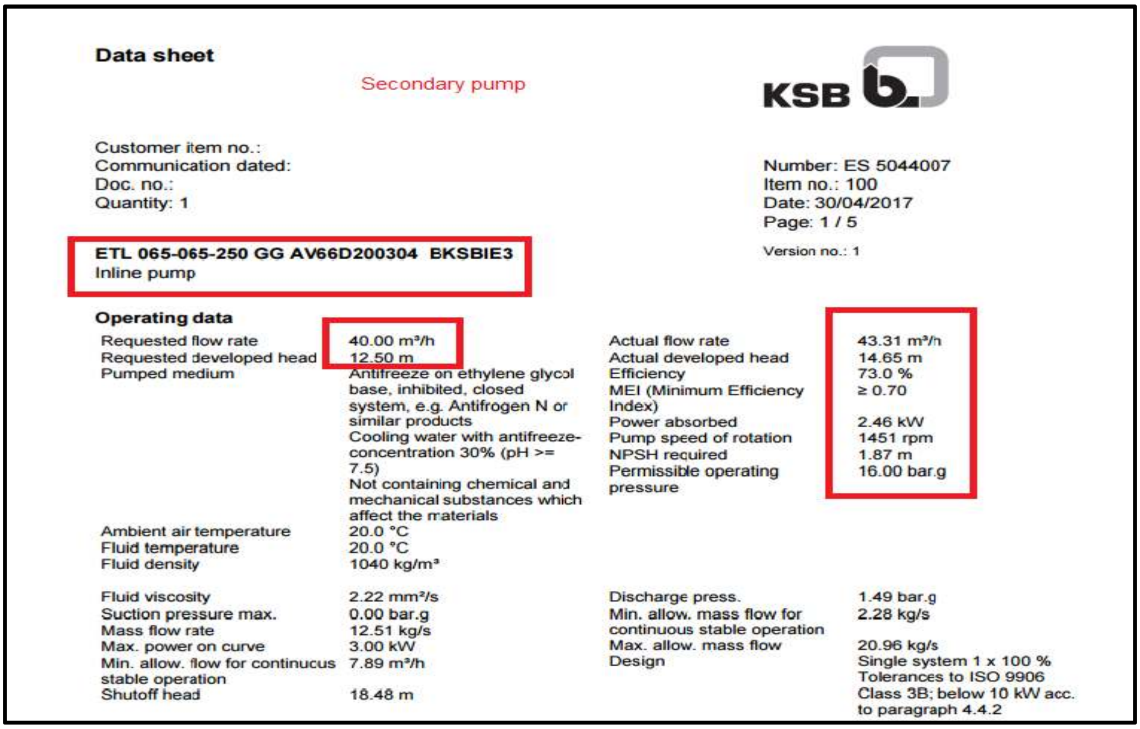
Version no.: 1

ETL 065-065-160 GG AV66D200154 BKSBIE3
Inline pump

Operating data

Requested flow rate	40.00 m^3/h	Actual flow rate	39.41 m^3/h
Requested developed head	9.50 m	Actual developed head	9.22 m
Pumped medium	Antifreeze on ethylene glycol base, inhibited, closed system, e.g. Antifrogen N or similar products Cooling water with antifreeze-concentration 30% (pH >= 7.5) Not containing chemical and mechanical substances which affect the materials	Efficiency	77.7 %
		MEI (Minimum Efficiency Index)	≥ 0.70
		Power absorbed	1.33 kW
		Pump speed of rotation	1451 rpm
		NPSH required	1.46 m
		Permissible operating pressure	16.00 bar.g
Ambient air temperature	20.0 °C		
Fluid temperature	20.0 °C		
Fluid density	1040 kg/m^3		
Fluid viscosity	2.22 mm^2/s	Discharge press.	0.94 bar.g
Suction pressure max.	0.00 bar.g	Min. allow. mass flow for continuous stable operation	2.01 kg/s
Mass flow rate	11.39 kg/s	Max. allow. mass flow	21.45 kg/s
Max. power on curve	1.70 kW	Design	Single system 1 x 100 %
Min. allow. flow for continuous stable operation	6.97 m^3/h		Tolerances to ISO 9906 Class 3B; below 10 kW acc. to paragraph 4.4.2
Shutoff head	11.29 m		

Figure (4.7): Primary pump specification. [Appendix 8]



Data sheet

Secondary pump

KSB

Customer item no.:
Communication dated:
Doc. no.:
Quantity: 1

Number: ES 5044007
Item no.: 100
Date: 30/04/2017
Page: 1 / 5

Version no.: 1

ETL 065-065-250 GG AV66D200304 BKSBIE3
Inline pump

Operating data

Requested flow rate	40.00 m³/h	Actual flow rate	43.31 m³/h
Requested developed head	12.50 m	Actual developed head	14.65 m
Pumped medium	Antifreeze on ethylene glycol base, inhibited, closed system, e.g. Antifrogen N or similar products Cooling water with antifreeze-concentration 30% (pH >= 7.5) Not containing chemical and mechanical substances which affect the materials	Efficiency	73.0 %
		MEI (Minimum Efficiency Index)	≥ 0.70
		Power absorbed	2.46 kW
		Pump speed of rotation	1451 rpm
		NPSH required	1.87 m
		Permissible operating pressure	16.00 bar.g
Ambient air temperature	20.0 °C		
Fluid temperature	20.0 °C		
Fluid density	1040 kg/m³		
Fluid viscosity	2.22 mm²/s	Discharge press.	1.49 bar.g
Suction pressure max.	0.00 bar.g	Min. allow. mass flow for continuous stable operation	2.28 kg/s
Mass flow rate	12.51 kg/s		
Max. power on curve	3.00 kW	Max. allow. mass flow	20.96 kg/s
Min. allow. flow for continucus stable operation	7.89 m³/h	Design	Single system 1 x 100 %
			Tolerances to ISO 9906 Class 3B; below 10 kW acc. to paragraph 4.4.2
Shutoff head	18.48 m		

Figure (4.8): Secondary pump specification. [Appendix 9]

4.2 Air to water chiller system Electrical consumption

Outdoor unit, indoor units, and both primary and secondary pumps are the main components that consume the large amount of electricity in air cooled system.

The main component within the outdoor unit system that consumes the most amount of energy is the compressor, but indoor units fans consumes the largest amount, while in the primary and secondary pumps the impellers need the most energy input when it converted to torque.

- Outdoor units

Relating to manufacturer catalogue for outdoor unit CGAF-C60; one outdoor unit was chosen as shown in figure (4.1), the electrical consumption equal to **56.8 kW**, and EER equal to 13. (Appendix 5)

*Assuming that operating hours per year = 700 hours [8 hours/day X 22 days/month X 4 months /year]

By applying equation (1) Annual energy consumption = over all electrical consumption X Total operation hours per year …Eq(3.1)

Annual energy consumption = 56.8 kW X 700 hrs = **39760 kWh**

- Indoor units

Indoor units distributed inside ANCI floors are divided into two types; one is ductable type, and the others are decorative type.

Figure (4.9) shows full electrical description for ducted indoor units from the main manufacturer catalogue. While figure (4.10) shows full electrical description for decorative type based on Trane manufacturer catalogue.

TRANE

Performance Data

Cooling Capacity (Example)

Cooling Capacity : kW	Cooling Rows : 3	SH : Sensible Cooling Capacity, kW
EAT : 26.0°C/ 60.0%	Motor Frequency : 50Hz	WPD : Water Pressure Drop, M
ESP : 0 Pa	TH : Total Cooling Capacity, kW	WFR : Water Flow Rate, L / S

Model	Nominal Airflow (CMH)	WTR (°C)	Entering Water Temperature											
			5°C				7°C				9°C			
			SH	TH	WFR	WPD	SH	TH	WFR	WPD	SH	TH	WFR	WPD
03	509	3.0	3.19	5.17	0.41	7.60	2.86	4.43	0.35	5.74	2.54	3.65	0.29	4.03
		5.0	2.92	4.55	0.22	2.47	2.59	3.78	0.18	1.77	2.30	3.02	0.14	1.18
		7.0	2.62	3.85	0.13	1.02	2.32	3.10	0.11	0.69	2.06	2.39	0.08	0.44
04	678	3.0	4.81	7.81	0.62	21.93	4.32	6.72	0.53	16.63	3.84	5.57	0.44	11.80
		5.0	4.45	7.02	0.33	7.35	3.97	5.87	0.28	5.31	3.52	4.74	0.23	3.60
		7.0	4.08	6.13	0.21	3.20	3.63	5.02	0.17	2.23	3.22	3.97	0.14	1.45
06	1018	3.0	5.32	8.58	0.68	9.38	4.78	7.35	0.58	7.06	4.24	6.05	0.48	4.96
		5.0	4.86	7.55	0.36	3.04	4.33	6.27	0.30	2.17	3.85	5.03	0.24	1.46
		7.0	4.39	6.41	0.22	1.26	3.90	5.16	0.18	0.86	3.46	3.99	0.14	0.54
08	1357	3.0	6.92	11.15	0.89	17.68	6.23	9.56	0.76	13.33	5.55	7.88	0.63	9.39
		5.0	6.38	9.90	0.47	5.80	5.69	8.24	0.39	4.16	5.06	6.63	0.32	2.81
		7.0	5.81	8.55	0.29	2.48	5.19	6.97	0.24	1.72	4.62	5.48	0.19	1.12
10	1696	3.0	8.42	13.48	1.07	4.87	7.56	11.50	0.91	3.64	6.71	9.40	0.75	2.53
		5.0	7.60	11.60	0.55	1.52	6.77	9.54	0.46	1.07	5.98	7.53	0.36	0.70
		7.0	6.66	9.27	0.32	0.57	5.85	7.15	0.24	0.36	5.12	5.15	0.18	0.20
12	2036	3.0	10.34	16.56	1.32	8.05	9.30	14.14	1.12	6.03	8.26	11.60	0.92	4.22
		5.0	9.41	14.41	0.69	2.56	8.40	11.93	0.57	1.82	7.46	9.53	0.45	1.21
		7.0	8.43	12.03	0.41	1.03	7.48	9.56	0.33	0.68	6.62	7.25	0.25	0.42
14	2366	3.0	11.19	17.92	1.43	14.15	10.06	15.06	1.24	11.51	8.93	13.15	1.05	8.21
		5.0	10.30	16.10	0.77	4.23	9.17	13.67	0.65	3.32	8.04	11.09	0.53	2.24
		7.0	9.35	14.08	0.48	2.15	8.21	11.49	0.39	1.40	7.13	8.89	0.30	0.91

Spec./ Input Power

Model	03	04	06	08	10	12	14
Nominal Airflow (CMH)	509	678	1018	1357	1696	2036	2366
Input Power (Watts)*							
Hi-Static Motor	88	110	138	180	218	250	317
Normal Moter	73	82	114	132	162	198	226

*Available with 115V/60Hz, 220V/50Hz, or 220V/60Hz

Options:

* Heat Capacity Type							
• Hot Water 1Row (kW)	2.86	3.71	4.95	6.16	6.91	7.94	9.26
	EWT=55°C; EAT=21°C; WFR=0.3L/S (Hot Water EWT must be below 60°C)						
• Electric Sheathed Element	1.0	1.5	2	3	3.5	4	4
	Available with high temperature cutout (Electric heater starts when the T[illegible] is below 27°C)						
* Plenum/Filters	Return air plenum with filters-washable foam or aluminum						

Note: It reserves the right to change design and specification without notice.

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Figure (4.9): Trane Electrical details for ducted indoor units HFCA. (Appendix 5)

General Data HFCE 50 Hz

Product Specification

MODEL		HFCE04	HFCE06	HFCE08	HFCE10	HFCE12	HFCE14	HFCE16	HFCE18	HFCE20
Rated - Volts/Ph/Hz		220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50
System Data										
Nominal Airflow	cfm	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000
Cooling Capacity	Btu/h	12,000	18,000	24,000	30,000	36,000	42,000	48,000	54,000	60,000
Water Inlet Connection Size	in	5/8	5/8	5/8	5/8	5/8	3/4	3/4	3/4	3/4
Water Outlet Connection Size	in	5/8	5/8	5/8	5/8	5/8	3/4	3/4	3/4	5/8
Water Connection Size		Brazed	Brazed	Brazed	Brazed	Brazed	Brazed	Brazed	Brazed	Brazed
INDOOR COIL										
Fin Type		Corrugate								
Fins per inch*										
3-Row coil		12	12	15	18	18	14	14	14	14
4-Row coil		14	15	16	15	15	16	16	16	16
Drain Connection Size	in	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2
FAN										
Fan Type		Double Inlet Centrifugal Forward Curved Fan								
No. used		2	2	2	2	2	2	2	2	2
FAN MOTOR (STANDARD)										
Motor Power	W	13	47	59	162	186	394	394	453	453
Qty x (RLA/LRA)		1 x (0.20/0.35)	1 x (0.49/0.71)	1 x (0.56/0.69)	1 x (1.36/2.31)	1 x (1.35/2.41)	1 x (3.33/5.08)	1 x (3.33/5.08)	1 x (0.43/6.98)	1 x (0.43/6.98)
DIMENSION (HxWxD)										
Uncrated with plenum (Net)	mm	265 x 824 x 510	278 x 940 x 510	278 x 1,117 x 510	300 x 1,087 x 608	300 x 1,240 x 608	433 x 1,095 x740	433 x 1,095 x740	433 x 1,248 x 670	433 x 1,248 x 670
WEIGHT										
3-Row Uncrated (Net)	kg	26	30	36	42	46	54	54	62	62
4-Row Uncrated (Net)	kg	27	32	38	44	48	57	57	66	66

Figure (4.10): Trane Electrical details for Decorative indoor units HFCE. [Appendix7]

Table (4.10): Ground floor indoor units with electrical specification.

	Ground Floor								
Space	**Area m^2**	**Load kW**	**indoor unit type**	**indoor units #**	**total load kW**	**Indoor unit code#**	**Indoor unit air flow CFM**	**Water flow rate GPM**	**Motor power Watt**
Clinic Room1	14.60	4.20	decorative	1	4.20	HFCE06	600	3.63	47
Clinic Room2	15.00	4.20	decorative	1	4.20	HFCE06	600	3.63	47
Clinic Room3	12.25	4.20	decorative	1	4.20	HFCE06	600	3.63	47
Clinic Room4	12.25	4.20	decorative	1	4.20	HFCE06	600	3.63	47
Multisensory Room	40.40	16.50	ductable	1	16.50	HFCA14	1400	12.20	317
Intervention Room	45.30	4.20	decorative	2	8.40	HFCE10	2000	12.20	162
Waiting Room	28.00	16.50	ductable	1	16.50	HFCA14	1400	12.20	317
Lobby	4.60	0	ductable	0	0	-	-	-	-
Total	172.40	54			58.20	0	7200	51.12	984

Table (4.11): First floor indoor units with electrical specification.

	First Floor								
Space	**Area m^2**	**Load kW**	**indoor unit type**	**indoor units #**	**total load kW**	**Indoor unit code#**	**Indoor unit air flow CFM**	**Water flow rate GPM**	**Motor power Watt**
Class1	23.00	6.62	decorative	1	6.62	HFCE08	800	4.84	59
Class2	26.10	7.70	decorative	1	7.70	HFCE10	1000	6.10	162
Class3	24.60	7.20	decorative	1	7.20	HFCE08	800	4.84	59
Staff Room	35.40	10.60	decorative	1	10.60	HFCE12	1200	7.23	186
Meeting Room	21.60	5.70	decorative	1	5.70	HFCE08	800	4.84	59
Administr ation	17.40	5.10	decorative	1	5.10	HFCE06	600	3.63	47
Secretary and waiting area	17.50	5.80	decorative	1	5.80	HFCE08	800	4.84	59
Pantry	4.60	0	ductable	0	0	-	-	-	-
Lobby	63	12.5	ductable	1	12.5	HFCA12	1200	10.93	250
total	233.2	61.22			61.22	0	7200	47.25	881

Table (4.12): Second floor indoor units with electrical specification.

	Second Floor								
Space	**Area m^2**	**Load kW**	**indoor unit type**	**indoor units #**	**total load kW**	**Indoor unit code#**	**Indoor unit air flow CFM**	**Water flow rate GPM**	**Motor power Watt**
Music Room	23.00	6.20	decorative	1	6.20	HFCE08	800	4.84	59
LD Room	31.90	9.50	decorative	1	9.50	HFCE12	1200	7.23	186
Art Room	31.70	9.50	decorative	1	9.50	HFCE12	1200	7.23	186
Library	20.60	6.00	decorative	1	6.00	HFCE08	800	4.84	59
Resource and Service	19.40	2.90	decorative	1	2.90	HFCE03	300	1.83	13
Lobby	63.00	12.50	ductable	1	12.50	HFCA12	1200	10.93	250
Pantry	4.60	0	ductable	1	0	-	-	-	-
total	194.2	46.6			46.6	0	5500	36.9	753

Table (4.13): Third floor indoor units with electrical specification.

	Third Floor								
Space	**Area m^2**	**Load kW**	**Indoor unit type**	**Indoor units #**	**Total load kW**	**Indoor unit code#**	**Indoor unit air flow CFM**	**Water flow rate GPM**	**Motor power Watt**
Meeting Room	28.40	8.30	decorative	1	8.30	HFCE10	1000	6.10	162
Admin Office1	19.60	5.70	decorative	1	5.70	HFCE08	800	4.84	59
Admin Office2	17.50	5.10	decorative	1	5.10	HFCE06	600	3.63	47
Admin Office3	17.50	5.10	decorative	1	5.10	HFCE06	600	3.63	47
Admin Office4	19.40	5.70	decorative	1	5.70	HFCE08	800	4.84	59
Research Room	16.30	4.80	decorative	1	4.80	HFCE06	600	3.63	47
Lobby	63.00	12.50	ductable	1	12.50	HFCA12	1200	10.93	250
Pantry	4.60	0	ductable	0	0	-	-	-	-
Total	186.30	47.20			47.20	0	5600	37.60	671

Indoor unit's electrical consumption for all floors was calculated Related to tables (4.9, 10, 11, and 4.12) as following:

Total electrical consumption at ANCI for Indoor units = GF electrical consumption + 1st electrical consumption + 2nd electrical consumption + 3rd electrical consumption = 984 + 881 + 753 + 671 = **3289 Watts**

*Assuming that operating hours per year = 700 hours [8 hours/day X 22 days/month X 4 months /year]

By applying equation (1) Annual energy consumption = over all electrical consumption X Total operation hours per year …Eq(3.1)

Annual energy consumption (Indoor units) = 3.289 kW X 700 Hrs = **2302 kWh**

-Pumps (Primary and secondary)

Related to KSB official offer for both primary and secondary pumps shown in figure (4.7), and figure (4.8). Appendix (Appendix 8) The electrical consumption as the following:

1- Inline primary pump (065-065-250-GG) with electrical consumption = 1.33 kW.

2-Inline secondary pump (065-065-160-GG) with electrical consumption = 2.46 kW.

*Assuming that operating hours per year = 700 hours [8 hours/day X 22 days/month X 4 months /year]

By applying equation (1) Annual energy consumption = over all electrical consumption X Total operation hours per year …Eq(3.1)

Annual energy consumption (Primary pump) = 1.33 kW X 700 Hrs = **931 kWh**

Annual energy consumption (Secondary pump) = 2.46 kW X 700 Hrs = **1722 kWh**

- Primary and Secondary pumps:

Total power consumed (Primary plus secondary)= 1.33 + 2.46 = **3.79 kW**

*Assuming that operating hours per year = 700 hours [8 hours/day X 22 days/month X 4 months /year]

By applying equation (3.1) Annual energy consumption = over all electrical consumption X Total operation hours per year …Eq(3.1)

Annual energy consumption (Primary plus secondary pumps) = 3.79 X 700 = **2653 kWh**

Chapter Five

Economic comparison between VRF and Air to water chiller system

Chapter Five

Economic comparison between VRF and Air to water chiller system

5.1 VRF economical part

In this section all system parts economically studied, Indoor units, outdoor units, piping system, ducts, and monitoring system.

Every system part has its own capital cost and there is some parts which time depending have running cost.

Economical study was carried out along 20 years, and all prices according to manufacturer official prices (Toshiba). (Appendix 1)

- Capital costs of <u>outdoor units</u> for VRF system

GF and 1st Floors served by one outdoor unit of 42HP heat pump capacity with capital cost = 22370 $.

2nd and 3rd floors served by one outdoor unit of 32HP heat pump capacity with capital cost = 19740 $.

- Running cost of <u>outdoor units</u> for VRF system

- Considering that the electrical cost of 1 kWh (grid supplied) = 0.17 $ (3 Phase).

42HP heat pump in summer power input (40.50) kW

32HP heat pump in summer power input (28.60) kW according to the assumption of operating hours = 700 hours. Overall energy consumption by 42HP and 32HP outdoor unit during the year = 28350 + 20020= **48370 kWh/year**.

And a total running cost of = 48370 X 0.6 = 29022 NIS/year = **8292 $/year**

- Capital cost of indoor units for VRF system

Related to figure (3.5) and figure (3.6), we got 33 indoor units at ANCI building and referring to the official offer for VRF indoor unit price, the total capital cost for 33 indoor units equal = **36214 $.** Note: Official offer for indoor unit price available within the (Appendix 2).

- Running cost of indoor units for VRF system

GF and 1st floors indoor units power consumption = (1x 0.172 + 2x 0.198 + 5 x 0.043 + 6 x 0.043 + 3 x 0.05 = 1.191 kW)

GF and 1st floors indoor units energy consumption= power consumption kW X operation hours per year = 1.191 X 700 = 833.00 kWh/year

By applying equation (3.3):

Running cost of GF and 1st floors indoor units = Energy consumption per year X unit price of kWh =833.7 X 0.6/3.5 = **142 $/year**.

2nd and 3rd floors indoor units power consumption = (2 x 0.172 + 1 x 0.021 + 6 x 0.043 + 7 x 0.043) = 0.924 kW.

By applying equation (3.3):

2nd and 3rd floors indoor units energy consumption= power consumption kW X operation hours per year = 0.924 X 700 = **646.8 kWh/year.**

Running cost of 3rd and 2nd floors indoor units = Energy consumption per year X unit price of kWh =646.00 X 0.60 = **112 $/year .**

Total capital cost of (VRF- 42HP and 32HP heat pumps) = 22370 + 19740 = 42110 $.

- Total capital cost for (VRF 33 indoor units) equal = 36214 $.

- Total running cost of (VRF Out door units) per year = 8292 $/year

- Total running cost of (VRF Indoor units) per year =142 + 112 = 254 $/year

-Piping network capital cost for VRF system:

The pipes used at ANCI building network was made of isolated copper, the pipes network was designed to cover all zones and serving all desired spaces.

Table (5.1) shows the full description of pipes network at ANCI building project with all pipes dimension and capital costs.\

Table (5.1): Pipes network dimensions and capital costs.

Pipe Diameter inch	Total Lenghth m	Unit Price $/m	Total unit lenghth price $
1/4"	50.50	1.50	75.75
3/8"	50.50	2.30	119.00
1/2"	72.00	3.00	219.00
5/8"	60.50	4.40	268.00
3/4"	18.50	5.80	108.00
7/8"	36.50	8.30	303.00
1 1/8"	24.00	8.30	199.00
1 3/8"	16.50	11.10	183.00
1 5/8"	24.00	14.70	353.00

Every pipe branch has its own dimensions in inches, the capital cost of pipes is depending on the dimension of the pipe section so that every pipe diameter has its own capital cost as clear in table (5.1). [Based on local market prices 2017]

Total capital cost of pipes network = $\sum (Ln \text{ X } Pn)$ … Eq (5.1)

Where:

n: Pipe diameter

Ln: Total length of pipe diameter n

Pn: Unit price of pipe diameter n

By applying equation (5.1):

Total capital cost of pipes network = **1830 $**.

Table (5.2) shows all VRF system capital and running costs for all system parts.

Table (5.2): VRF system parts capital and running costs.

	VRF system	
Part name	**Fixed cost $**	**Running cost $**
Outdoor units	42110	8292
Indoor units	36114	254
Piping system	1830	0
Total	80054	8564

The total Capital Cost of VRF parts = 80054 $.

The total running cost of VRF parts = 8564 $.

- Degree Days Method (DD)

- Using Degree Days method (DD) to find the real operating hours for the air conditioning system = Average summer months temperatures – (System temperature on-off) = 28.09 – 18.3 = 9.79 C^o [Appendix 13]

Energy consumption E (By degree days method)= $P_{cooling}$ X 8 hours/day X DD^o X C_v / T_i - T_o … Eq(5.2) [16].

Where: $P_{cooling}$ = Air conditioning system power consumption kw Cv: Correction factor = 0.77 [16]

T_i: Desire inside temperature, T_o: Desire outside temperature

E = 71.2 kW X 8h/day X 24Day/month X 9.79 X 0.77/ (35-24) = **<u>37473 kwh /summer season</u>**

Running cost according to DD method = 37473 kWh X 0.17$/kWh= **<u>6424 $/season</u>**

5.2 Chiller air to water system economical part

Economical part was studied for all air cooled parts, and the study covered both capital costs and running costs for every part in air cooled system such as outdoor unit, indoor units.

Every system part has its own capital cost and there is some parts which is time depending have running cost.

Economical study was carried out along 20 years, and all prices according to manufacturer official prices (**Daikin**). (Appendix 10)

Dear Sir,

Please find attached our offer for the supply of Air - Conditioning units as follows:

Total Price:

Description	Price (~~JD~~ USD)	Special price
EWYQ-F Chiller	63357	47,518
2-Pipe Flexi FWL (wall \ ceiling) Unit (Decorative)	19890	14,918
2-Pipe Flexi FWR (wall \ ceiling) Unit (Decorative)	9072	6,804
2-Pipe Ducted Unit FWD (Horizontal \ Vertical Concealed) High Static	13530	10,148
Total	**105849**	79,387 $

31/5/2017

Brand: DAIKIN

Figure (5.1): Air cooled system quotation for indoor and outdoor units. [Appendix 10]

- Capital costs of Outdoor units for Air cooled system

GF, 1st ,2nd, and 3rd Floors served by one outdoor unit of 61.4 Tons capacity, and relating to figure(4.13) the capital cost = 47518 $

- Running costs of Outdoor units for Air cooled system

- Considering that the electrical cost of 1 kWh (grid supplied) = 0.6 NIS (3 Phase).

- With an assumption of 700 hours operation time (8h/day – 22 day/month 4months/year)

61.4 Tons Chiller power input (**56.8**) kWh, and EER equal to 13.

By assuming that operating hours per year = 700 hours

By applying equation (3.1) Annual energy consumption = over all electrical consumption X Total operation hours per year …Eq(3.1)

Annual energy consumption = 56.8 kW X 700 Hrs = **39760 kWh**

Running cost of 61.4 Tons outdoor unit per year = overall energy consumption kWh/year X 1 kWh cost … Eq(3.3)

39760 X 0.6/3.5 = **6816 $**/year

- Capital costs of indoor units for Air cooled system

Related to tables (5.3, 5.4 , 5.5 , 5.6), we got 30 indoor units at ANCI building spreading air into spaces, referring to the official offer for indoor unit quotation, the total capital cost for 30 indoor units equal = 41906 $ = (**31870 $.**

After discount made by the manufacturer sales engineer). Note: Official offer for indoor unit price available within (Appendix10).

Table (5.3): Ground floor indoor units with electrical specification and unit prices for air to water chiller system.

Ground Floor							
Space	**indoor unit type**	**indoor units #**	**Indoor unit code#**	**Indoor unit air flow CFM**	**Motor power Watt**	**Unit Price $**	**Total Price $**
Clinic Room1	decorative	1	HFCE06	600	47	916	916
Clinic Room2	decorative	1	HFCE06	600	47	916	916
Clinic Room3	decorative	1	HFCE06	600	47	916	916
Clinic Room4	decorative	1	HFCE06	600	47	916	916
Multisensory Room	ductable	1	HFCA14	1400	317	2706	2706
Intervention Room	decorative	2	HFCE10	1000	162	916	1832
Waiting Room	ductable	1	HFCA14	1400	317	2706	2706
Lobby	ductable	0	-	-	-	-	-
Total			0	6200	984	9992	10908

Table (5.4): First floor indoor units with electrical specification and unit prices for air to water chiller system.

First Floor							
Space	**indoor unit type**	**indoor units #**	**Indoor unit code#**	**Indoor unit air flow CFM**	**Motor power Watt**	**Unit Price $**	**Total Price $**
Class1	decorative	1	HFCE08	800	59	1234	1234
Class2	decorative	1	HFCE10	1000	162	1392	1392
Class3	decorative	1	HFCE08	800	59	1234	1234
Staff Room	decorative	1	HFCE12	1200	186	1512	1512
Meeting Room	decorative	1	HFCE08	800	59	1234	1234
Adminstration	decorative	1	HFCE06	600	47	1234	1234
Secretsry and waiting area	decorative	1	HFCE08	800	59	1234	1234
Pantry	ductable	0	-	-	-	-	-
Lobby	ductable	1	HFCA12	1200	250	2706	2706
total			0	7200	881	11780	11780

Table (5.5): Second floor indoor units with electrical specification and unit prices for air to water chiller system.

Second Floor							
Space	**indoor unit type**	**indoor units #**	**Indoor unit code#**	**Indoor unit air flow CFM**	**Motor power Watt**	**Unit Price $**	**Total Price $**
Music Room	decorative	1	HFCE08	800	59	1234	1234
LD Room	decorative	1	HFCE12	1200	186	1512	1512
Art Room	decorative	1	HFCE12	1200	186	1512	1512
Library	decorative	1	HFCE08	800	59	1234	1234
Resource and Service	decorative	1	HFCE03	300	13	752	752
Lobby	ductable	1	HFCA12	1200	250	2706	2706
Pantry	ductable	1	-	-	-	-	-
total			0	5500	753	8950	8950

Table (5.6): Third floor indoor units with electrical specification and unit prices for air to water chiller system.

Third Floor							
Space	**Indoor unit type**	**Indoor units #**	**Indoor unit code#**	**Indoor unit air flow CFM**	**Motor power Watt**	**Unit Price $**	**Total Price $**
Meeting Room	decorative	1	HFCE10	1000	162	1392	1392
Admin Office1	decorative	1	HFCE08	800	59	1234	1234
Admin Office2	decorative	1	HFCE06	600	47	1234	1234
Admin Office3	decorative	1	HFCE06	600	47	1234	1234
Admin Office4	decorative	1	HFCE08	800	59	1234	1234
Research Room	decorative	1	HFCE06	600	47	1234	1234
Lobby	ductable	1	HFCA12	1200	250	2706	2706
Pantry	ductable	0	-	-	-	-	-
Total			0	5600	671	10268	10268

- Running costs of Indoor units for Air cooled system

Total power consumption by Indoor units at ANCI = GF power consumption + 1st power consumption + 2nd power consumption + 3rd power consumption = 984 + 881 + 753 + 671 = **3289 Watts**

*With an assumption of operating hours per year = 700 hours

8 hours/day X 22 days/month X 4 months/year

By applying equation (3.1) Annual energy consumption = over all electrical consumption X Total operation hours per year …Eq(3.1)

Annual energy consumption = 3.289 KW X 700 Hrs = **2302 kWh**

By applying equation (3.3):

Running cost of GF, 1st, 2nd and 3rd floors indoor units = Energy consumption per year X unit price of kWh =2302 X 0.6 = **394 $/year**.

- Capital cost for Air cooled system pumps

Air cooled system got two pump lines, one is primary with two pieces in parallel and the other line is secondary with two pieces in parallel also. So the capital cost was taken for all pumps in air cooled system, four pumps, two are online, and the others are standby.

Related to figure (5.2), primary and secondary pumps capital cost was calculated as the following:

Capital cost for two primary pumps = **<u>7400 $</u>**

Capital cost for two primary pumps = **<u>9240 $</u>**

Running cost for primary pump was calculated based on one pump only since the other primary pump will be offline and doesn't absorb energy.

Related to KSB official offer for both primary and secondary pumps shown in figure (4.11), and figure (4.12). The electrical consumption as the following:

1- Inline primary pump (065-065-250-GG) with electrical consumption = 1.33 kW.

2-Inline secondary pump (065-065-160-GG) with electrical consumption = 2.46 kW.

- Assuming that the operating hours per year = 700 hours

Consignee: eng. Ameer Khaleel	
Customer: PWA	Ref no. : 26 - 2017
Address: Ramallah – West Bank	Currency: EURO VA.T: not include
Phone : 0592854808	Payment: 80% in advance 20% after delivery
Email : eng.ameer.ps@gmail.com	Validity: 30 days

Item#	Description	QTY	Unit Price	Line Total
1	**ETL 065-065-250 GG AV66D200304 BKSBIE3** **Inline pump** Actual flow rate 43.31 m^3/h Actual developed head 14.65 m	2	4620	9240
2	**ETL 065-065-160 GG AV66D200154 BKSBIE3** **Inline pump** Actual flow rate 39.41 m^3/h Actual developed head 9.22 m	2	3700	7400
			TOTAL	16640

We hope our offer meets your kind approval and we look forward to hear from you soon, should you require any additional information/clarification, kindly do not hesitate to contact us.

Figure (5.2): Primary and secondary pumps official quotation. [Appendix 11]

By applying equation (3.1) Annual energy consumption = over all electrical consumption X Total operation hours per year …Eq(3.1)

Annual energy consumption (Primary pump) = 1.33KW X 700 Hrs = **931 kWh**

Annual energy consumption (Secondary pump) = 2.46 kW X 700 Hrs = **1722 kWh**

- Primary and Secondary pumps:

Total power consumed (Primary plus secondary)= 1.33 + 2.46 = **3.79 kW**

Assuming that the operating hours per year = 700 hours

By applying equation (3.1) Annual energy consumption = over all electrical consumption X Total operation hours per year …Eq(3.1)

Annual energy consumption (Primary and secondary) = 3.79 X 700 = **2653 kWh**

By applying equation (3.3):

Running cost of Primary and secondary pumps (online pumps only) = Energy consumption per year X unit price of kWh =2653 X 0.6/3.5 = **455 $/year**.

- Duct work capital cost for Air cooled system:

Ducts was designed to cover all zones with different dimensions spreading cooled air all over desired spaces.

Isolated rectangular duct was chosen in ANCI building project, and all duct branches quantities was measured in order to find to capital cost. Table (5.7) shows the full description of all rectangular dimensions and costs.

Table (5.7): Duct work dimension and costs all over ANCI building.

ITEM NO.	qty	Duct size Width (mm)	Height (mm)	Length (mm)	Duct area = {(H+W)x2}L Surface Area (m^2)	type	Unit Price $
1	3	350	300	5000	19.50	isolated	594
2	3	250	250	5000	15.00	isolated	457
3	3	500	300	5500	26.40	isolated	805
4	3	350	300	8500	33.15	isolated	1011
5	3	500	300	2000	9.60	isolated	292
6	2	350	200	10000	22.00	isolated	671
7	2	250	200	4000	7.20	isolated	219
8	1	500	300	3500	5.60	isolated	170
9	1	350	200	5000	5.50	isolated	167
10	2	250	200	7000	12.60	isolated	384
11	1	600	350	5000	9.50	isolated	289
12	1	300	200	7000	7.00	isolated	213
13	1	350	300	7500	9.75	isolated	297
14	1	350	200	9000	9.90	isolated	301

Related to table (5.7) the area of duct was calculated using equation Duct area = [(High + Width) x 2] x Length … Eq (5.3).

The cost of 1 m^2 area of isolated duct = 30.5 \$. [Based on local market prices 2017]

Total capital cost of isolated ducts = Total area of isolated duct m^2 X price of 1 \$/m^2 of isolated duct … Eq (5.4).

All unit prices was calculated and then the summation was found.

Total duct work capital cost = **5877 $**.

Table (5.8) shows all Air cooled system capital and running costs for all system parts.

Table (5.8): Air cooled system parts capital and running costs.

	Air cooled system	
Part name	**Fixed cost $**	**Running cost $**
Outdoor units	47518	6816
Indoor units	31870	394
Duct work	5877	0
Pumps	16640	455
Total	101905	7665

The total Capital Cost of VRF parts = 101905 $.

The total running cost of VRF parts = 7665 $.

-Degree Days Method (DD)

- Using Degree Days method (DD) to find the real operating hours for the air conditioning system = Average summer months temperatures – (system temperature on-off) = 28.09 – 18.3 = 9.79 C^o [Appendix 13]

Energy consumption E (Degree Days Method)= $P_{cooling}$ X 8 hours/day X DD^o X C_v / T_i - T_o …Eq(5.2) [16]

Where: $P_{cooling}$ = Air conditioning system power consumption kw

Cv: Correction factor = 0.77 [16]

T_i: Desire inside temperature, T_o: Desire outside temperature

E = 63.87 kw X 8h/day X 24Day/month X 9.79 X 0.77/ (35-24) = **33615 kwh /summer season**

Running cost according to DD method = 37473 kWh X 0.17$/kWh= **5714 $/season**

5.3 Economical comparison between VRF and Air cooled air systems using Degree Days Method (DD $_{cooling}$).

Based on all calculations performed in previous chapters, the final comparison between the two air conditioning systems (VRF, Air cooled) be based on the economical calculations (Present worth PW).

Economic analysis were done in order to use them in present worth calculation. Capital cost, running cost, selvage cost, and maintenance cost for every system were calculated as following:

- Capital costs were calculated in previous chapters for both systems, and the same was done for running cost.
- Running costs related to Degree Days ($DD_{cooling}$) method were taken.
- Selvage value was taken in both air conditioning systems as a fixed percentage for every system capital cost, this percentage equal 6%.

Selvage value = Capital Cost X 0.06 … Eq(5.4)

Selvage value $^{(\text{Air cooled})}$ = 101905 X 0.06 = 6114 $.

Selvage value $^{(\text{VRF})}$ = 80054 X 0.06 = 4803 $.

- Maintenance cost was taken as 5% percentage for every system fixed cost as following:

Maintenance cost = Fixed cost X 0.05 …Eq(5.6)

Maintenance cost $^{(\text{Air cooled})}$ = 101905 X 0.05 = 5095 $.

Maintenance cost $^{(VRF)}$ = 80054 X 0.05 = 4002 $.

In order to calculate the present worth PW for both air conditioning systems discussed, cash flow should be designed first. By using an interest rate of 10% and a life time of 15 years which is the average life time of any mechanical system. Figure (5.3) and figure (5.4) shows the cash flow for air cooled and VRF air conditioning system.

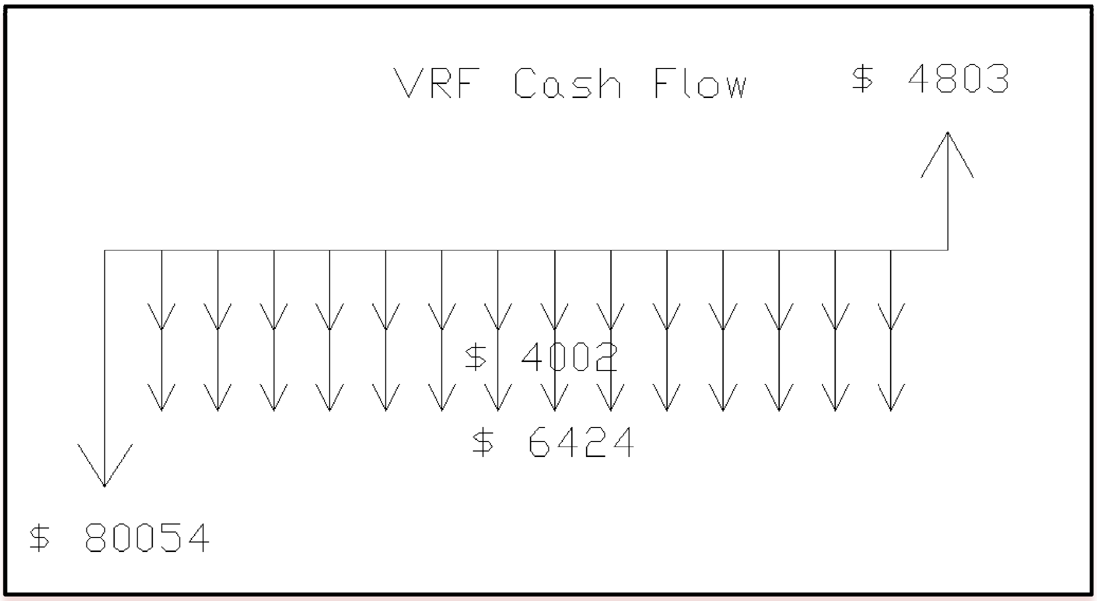


Figure (5.3): VRF air conditioning system cash flow.

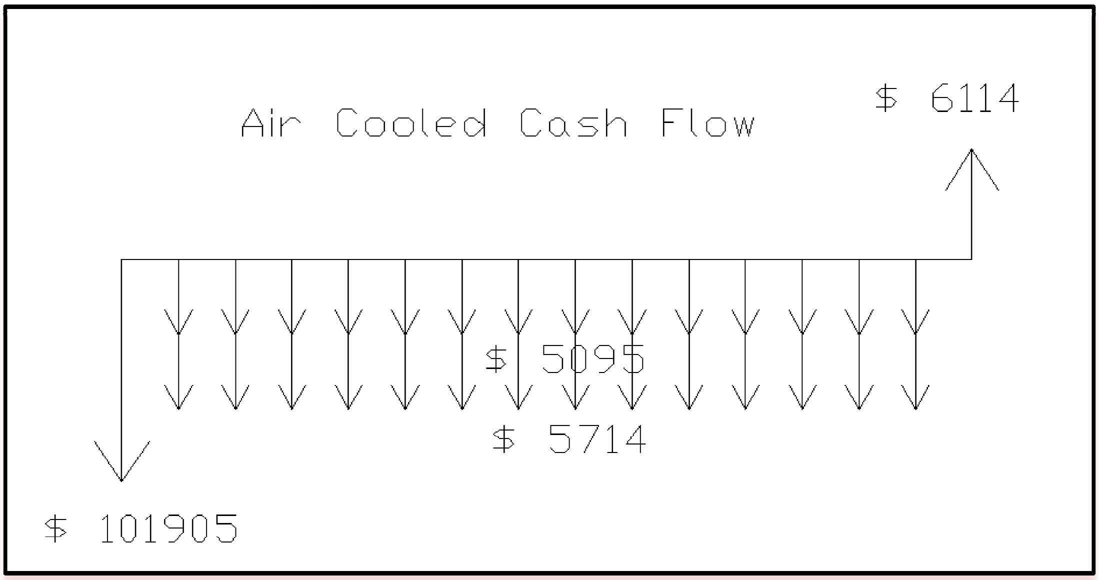


Figure (5.4): Air Cooled air conditioning system cash flow.

Present Worth (PW) = -Capital Cost –[(Maintenance cost + Running cost) X (P/A, i, n)] + [Salvage value X (P/F, i , n)] … Eq(5.7)

The factors (P/F and P/A) was found relating to reference [14]. Also available in (Appendix 12).

$PW_{1(\text{ VRF system})}$ = - 80054 – (4002+ 6424) X (P/A, 10% , 15) $^{7.606}$ + 4803 X (P/F, 10% , 15) $^{0.2394}$ **= - 158,204 $**

$PW_{2\ (\text{Air Cooled system})}$ = - 101905 – (5095 + 5714) X (P/A, 10% , 15) $^{7.606}$ + 6114 (P/F , 10% , 15) $^{0.2394}$ = **-182,654 $**

Present worth for both air conditioning systems was done using equation (5.3) and using Degree Days ($DD_{cooling}$) method, it is clear that the present worth PW for Air Cooled is less than PW for VRF system. And by the rule of present worth formula " less negative is more feasible". So that the VRF air conditioning system is more feasible than the Air cooled system proofed by present worth economical test. [13]

Chapter Six

Conclusion and Recommendation

Chapter Six
Conclusion and Recommendation

6.1 Conclusion

This research main objective was making a full comparison between two air conditioning systems at an educational building ANCI (An-Najah child institute), one of these systems was VRF (Variable refrigerant flow) and the other was Chiller Air to water (Air cooled). Full design was made for both systems including outdoor units, indoor units, piping network, and duct work based on cooling load for ANCI building. The comparison was made based on electrical consumption for every system component, and economically based on present worth value for each air conditioning system to find which is more feasible and can conserve more energy than the other to choose it as the suitable air conditioning system at ANCI building.

The design of VRF and Air cooled systems were made based on 60 TR cooling load at ANCI building calculated by air conditioning program HAP 4.6. VRF system consists of two outdoor units; one was 42HP and the other was 32HP to serve all zones. While Air cooled system consists of one outdoor unit with 61 TR.

For the VRF system 33 indoor units were selected, where the number of indoor units was 30 units for the air cooled system. Some of the air cooled indoor units were ducted, and the others were high wall mounted. Every type got its own description and so its energy consumption. As a result; the seasonal energy consumption for those which belongs to VRF was (1480 kWh) while for Air cooled system was (2302 kWh) based on an assumption of 700 working hours, and it is clear that the amount of energy consumption by indoor units in Air cooled system is larger than VRF system. Figure (6.1) shows a simple comparison between two air conditioning systems VRF and Air cooled by their main components. As we can see the amount of energy consumed by Air cooled system components is larger and there is an extra source of energy consumption within this system which is the chilled water pumps (Primary and Secondary pump), that add an additional amount of energy consumption to Air Cooled system.

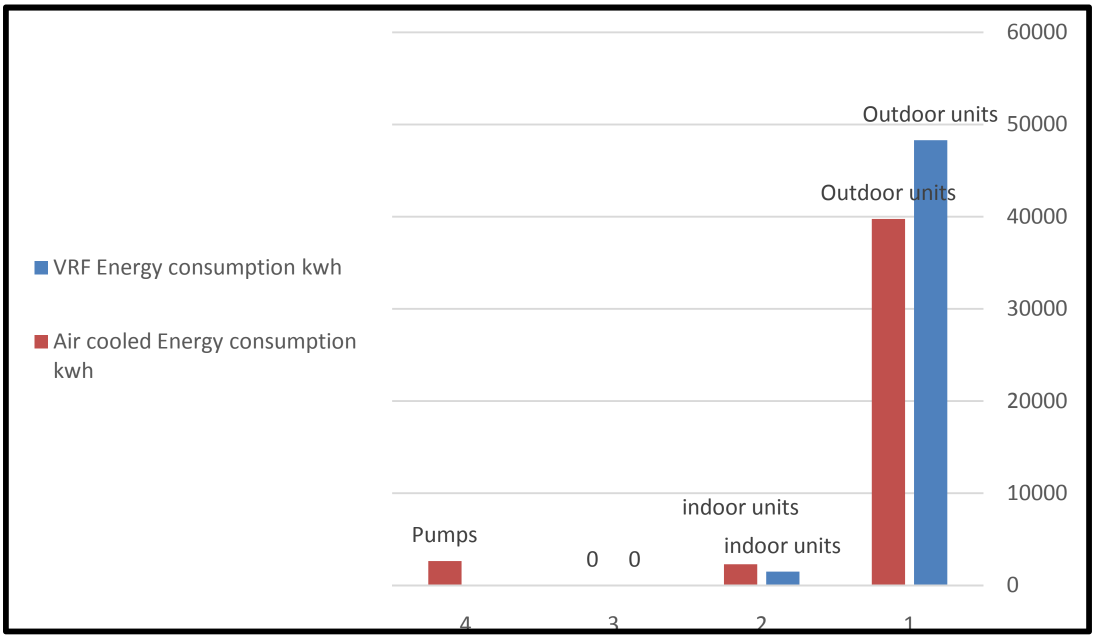


Figure (6.1): Energy consumption comparison between VRF and Air cooled air conditioning systems.

More energy consumption means more cost, relating to figure (6.1) the outdoor unit of VRF system consumes more energy than Air cooled system and that means VRF outdoor system will pay much more money than Air cooled system for electricity per year. As a result the total annual energy consumption by all mechanical and electrical components including outdoor units, indoor units, and pumps in VRF system = (49850 kWh/year), while in Air cooled system = (44715 kWh/year) based on an assumption of 700 working hours. Figure (6.2) shows the fixed costs for indoor units, outdoor units, piping network, duct work, and pumps for both air conditioning systems (VRF and Air cooled). The total fixed cost of VRF system equal (80054 $), and the total fixed cost of Air cooled system is equal (101905 $). It is clear that the fixed cost of Air cooled system more than VRF system with around (21851 $) difference.

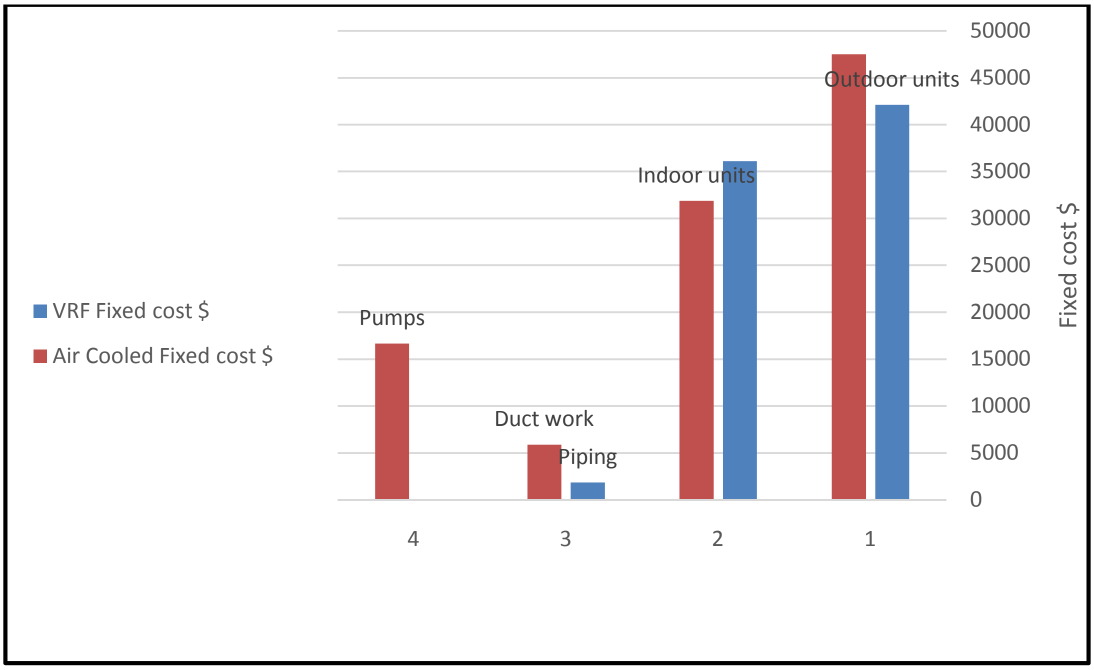
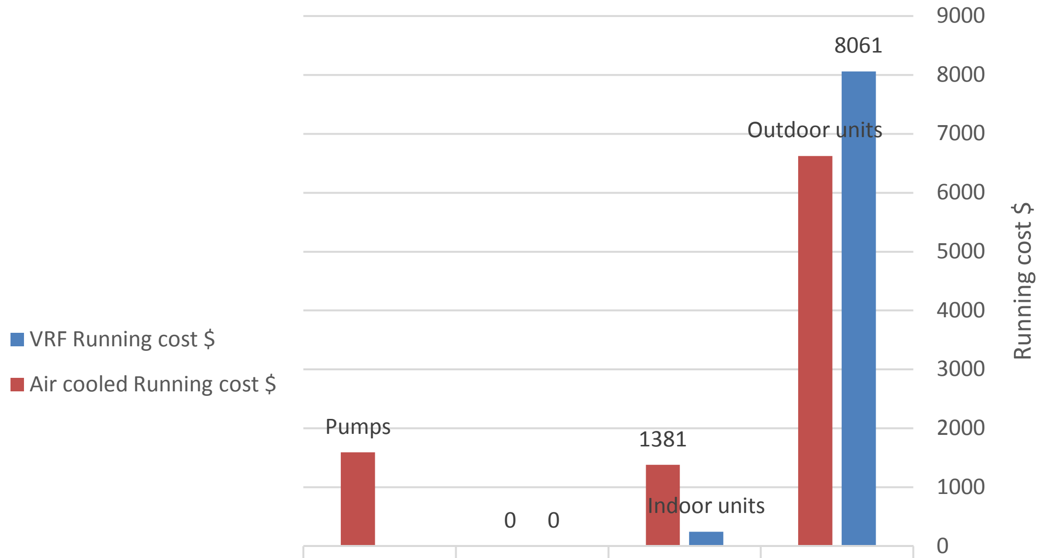


Figure (6.2): VRF and Air Cooled system components fixed costs.

Figure (6.3) shows both air conditioning systems components running costs. For outdoor units installed to Air cooled system the running cost was (6626 $) while the running cost for outdoor units installed to VRF was (8061 $). Indoor units running cost for Air cooled system equal to (1381 $), and for VRF system was (247 $). Finally the pumps which is exclusive for Air cooled system, the running cost was about (1591 $) all results depending on an assumption of 700 working hours.



	4	3	2	1
VRF Running cost $		0	247	8061
Air cooled Running cost $	1591	0	1381	6626

Figure (6.3): VRF and Air cooled system components running costs.

Based on Degree Days ($DD_{cooling}$) method; the results show that the total running cost of Air cooled system equal to (5714 $), and for VRF system equal to (6424 $).

Total fixed cost and total running cost for Air cooled system are much higher than VRF system. In order to find which one is more feasible; present worth value was calculated for both air conditioning systems.

Present worth value for VRF air conditioning system equal (-158204 $) based on $DD_{cooling}$ method, and for Air cooled air conditioning system equal to (-182654 $) relating to equation (5.3) and based on $DD_{cooling}$

equation (5.2). Since $PW_{1(\text{ VRF system})}$ is less negative than $PW_{2\ (\text{Air Cooled system})}$ this means that the VRF system is more feasible than Air cooled system to install and use this system at ANCI building to cover all desired spaces.

Present Worth (PW) = -Capital Cost –[(Maintenance cost + Running cost) X (P/A, i, n)] + [Salvage value X (P/F, i , n)] … Eq (5.6)

The factors (P/F and P/A) was found relating to reference [14]. Also available in the Appendix (C).

$PW_{1(\text{ VRF system})}$ = - 80054 – (4002+6424) X (P/A, 10% , 15) $^{7.606}$ + 4803 X (P/F, 10% , 15) $^{0.2394}$ = **<u>- 158,204 $</u>**

$PW_{2\ (\text{Air Cooled system})}$ = - 101905 – (5095 + 5714) X (P/A, 10% , 15) $^{7.606}$ + 6114 (P/F , 10% , 15) $^{0.2394}$ = **<u>-182,654 $</u>**

6.2 Recommendation

Although this research got many applicable and accurate results and conclusions, it might be more accurate and better and can be improved. There a lot of suggestions and recommendations can be performed to improve the results and were not possible to perform and accomplish during one year of work within this research.

Using better and stronger software for air conditioning design like (Revit), this program can do heating and cooling loads easily, and can do all mechanical calculations on building plans with two dimensions and three dimensions. Selection of outdoor units and indoor units can easily accomplished by Revit, because this program offer many international manufacturers and brands for every air conditioning system components. Finally this program can do all piping and ducts networks easily and accurately and by this way we can save a lot of time and money too.

For future work, one can make some energy conservation to both air conditioning systems (VRF, Air cooled), as mentioned in the first two chapters shading one of many ways to conserve energy and save energy and money. Another way for energy saving is scheduling as mentioned in chapter two. It is recommended to be added to research calculations and find results after energy saving, and after that find the net between the result before saving and results after saving.

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16- **Heating and Air Conditioning. For residential buildings**. 5th Edition

Appendices

Appendix (1)

VRF outdoor unit catalogues

Toshiba Design AIRS - Project Equipment List

Tulkarm-Health Care Center Equipment List

Outdoor Units

Model name	Description	Quantity
MMY-AP3216HT8P-E	32HP SMMSe	1
MMY-AP4216HT8P-E	42HP SMMSe	1

Indoor Units

Model name	Description	Quantity
MMD-AP0366BHP-E	4.0HP Standard Concealed Duct	3
MMD-AP0566BHP-E	6.0HP Standard Concealed Duct	2
MMK-AP0123H	1.25HP High Wall Standard (Series 3)	1
MMK-AP0153H	1.7HP High Wall Standard (Series 3)	11
MMK-AP0183H	2.0HP High Wall Standard (Series 3)	13
MMK-AP0243H	2.5HP High Wall Standard (Series 3)	3

Y joints

Model name	Description	Quantity
RBM-BY55E	Y Joint	10
RBM-BY105E	Y Joint	12
RBM-BY205E	Y Joint	7
RBM-BY305E	Y Joint	2
RBM-BT24E	Outdoor Unit Branch Kit	2

Accessories

Model name	Description	Quantity
RBC-AMT32E	Main Wired RC	33

Central Control Devices

Model name	Description	Quantity
BMS-CM1280TLE	Compliant Manager	1.0

Piping Length

Pipe Diameter	Gas side (m)	Discharge side (m)	Liquid side (m)	Total Length (m)
¼"	0	0	50.5	50.5
⅜"	7	0	43.5	50.5
½"	43.5	0	28.5	72
⅝"	43.5	0	17	60.5
¾"	0	0	18.5	18.5
⅞"	28.5	0	13	41.5
1⅛"	20	0	0	20
1⅜"	15.5	0	0	15.5

Model Name	Cooling (kW) Rated	Cooling (kW) Corrected	Heating (kW) Rated	Heating (kW) Corrected	Diversity System	Diversity Building
MMY-AP3216HT8P-E	90.00	79.30	100.00	76.50	104.5%	0%

Indoor Units

Model Name	Unit Name & Room	Capacity Code	Fan Speed	Mode	Capacity (Total/Sensible) [kW] Rated	Corrected	Required
MMD-AP0366BHP-E		4.0HP	High	Cooling	11.20/8.80	9.53/7.62	
				Heating	12.50	9.25	
MMD-AP0366BHP-E		4.0HP	High	Cooling	11.20/8.80	9.49/7.58	
				Heating	12.50	9.23	
MMK-AP0123H		1.25HP	High	Cooling	3.60/2.60	3.08/2.26	
				Heating	4.00	2.96	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.83/2.77	
				Heating	5.00	3.70	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.82/2.76	
				Heating	5.00	3.70	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.82/2.77	
				Heating	5.00	3.70	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.91/2.83	
				Heating	5.00	3.72	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.91/2.83	
				Heating	5.00	3.72	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.83/2.77	
				Heating	5.00	3.70	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.81/3.41	
				Heating	6.30	4.68	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.85/3.44	
				Heating	6.30	4.69	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.91/3.48	
				Heating	6.30	4.70	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.97/3.52	
				Heating	6.30	4.72	

Toshiba Design AIRS - System Details

Indoor Units

Model Name	Unit Name & Room	Capacity Code	Fan Speed	Mode	Capacity (Total/Sensible) [kW] Rated	Corrected	Required
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.85/3.44	
				Heating	6.30	4.69	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.78/3.39	
				Heating	6.30	4.66	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.92/3.49	
				Heating	6.30	4.70	

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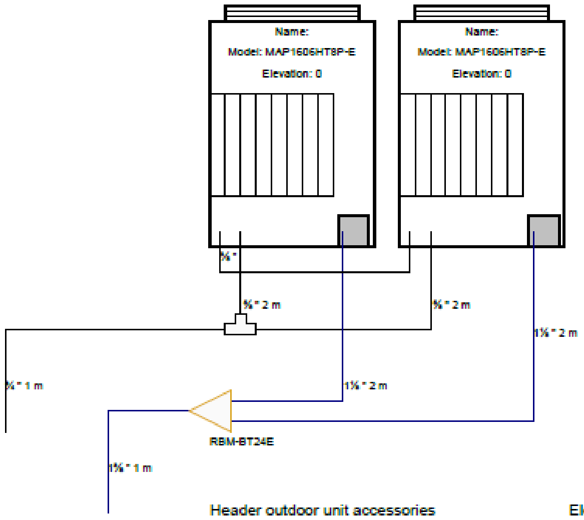
Toshiba Design AIRS - Outdoor Unit Details

3rd-2nd_Floors

MMY-AP3216HT8P-E



Header outdoor unit accessories

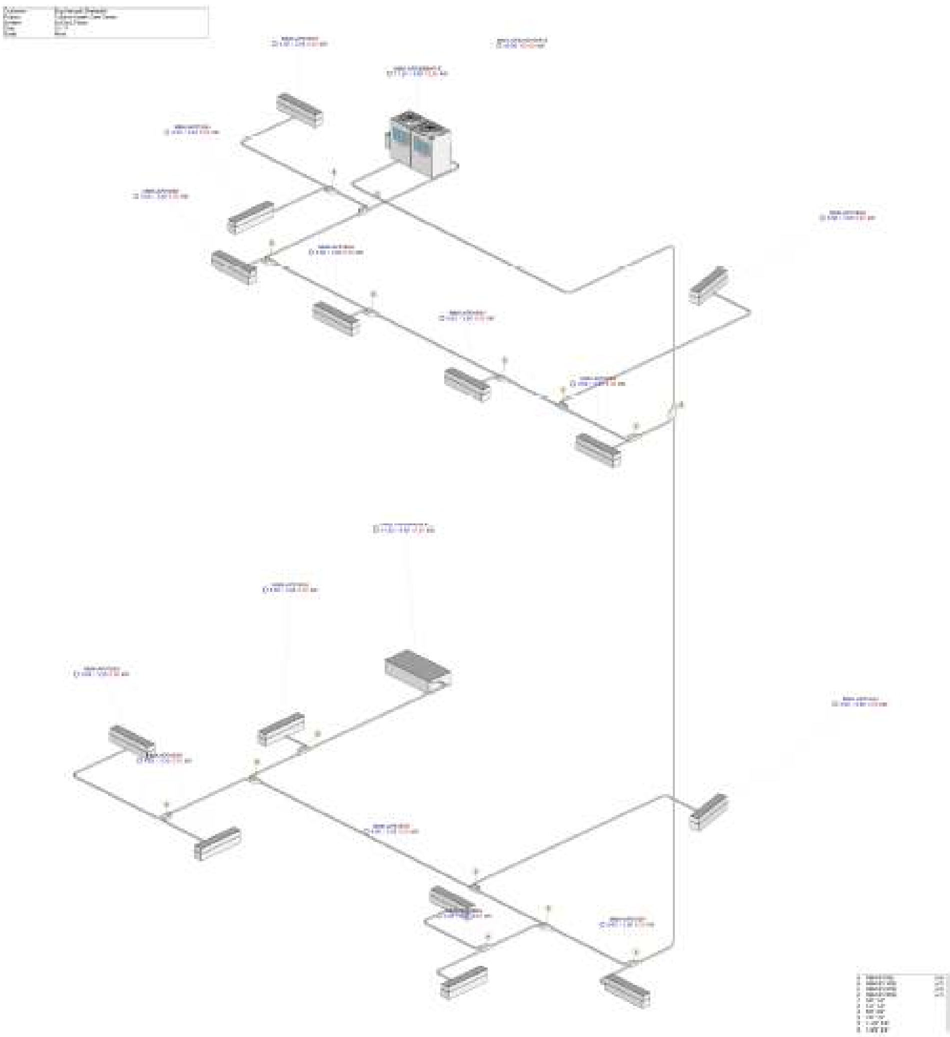
Slot 1
Slot 2
Slot 3
Slot 4
Slot 5

Electrical Information

Summary: 3N AC 380-400-415V 50Hz
Voltage:
Frequency:
Phase:

TOSHIBA Leading Innovation >>>

Toshiba Design AIRS - Floor Perspective



Toshiba Design AIRS - System Details

Indoor Units

Model Name	Unit Name & Room	Capacity Code	Fan Speed	Mode	Capacity (Total/Sensible) [kW] Rated	Corrected	Required
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.84/3.43	
				Heating	6.30	4.51	
MMK-AP0243H		2.5HP	High	Cooling	7.10/4.80	6.16/4.23	
				Heating	8.00	5.74	
MMK-AP0243H		2.5HP	High	Cooling	7.10/4.80	6.12/4.21	
				Heating	8.00	5.73	
MMK-AP0243H		2.5HP	High	Cooling	7.10/4.80	6.08/4.19	
				Heating	8.00	5.72	

ESEER

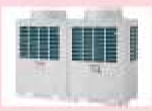
ESEER	EER @ 100%	EER @ 75%	EER @ 50%	EER @ 25%
7.13	2.90	4.80	7.48	10.39
	A = 0.03	B = 0.33	C = 0.41	D = 0.23

SCOP

SCOP	COP @ 100%	COP @ 75%	COP @ 50%	COP @ 25%
4.75	2.93	4.13	5.06	6.28
	A = 0.12	B = 0.32	C = 0.36	D = 0.20

Toshiba Design AIRS	PHOTOS

TOSHIBA Leading Innovation >>>	Customer: Eng.Hamzah Shehadeh Project: Tulkarm-Health Care Center Revision: Reference: T-VRF_M	AL BADER

	Type: Outdoor Unit Model: MMY-AP3216HT8P-E	Date: 2/1/17 Scale: none Unit: - Page:

Model	Name	Heat pump		MMY-AP3216HT8P-E	MMY-AP3416HT8P-E	MMY-AP3616HT8P-E	MMY-AP3816HT8P-E
	Combination	Heat pump		MMY-MAP1606HT8P-E	MMY-MAP1806HT8P-E	MMY-MAP2006HT8P-E	MMY-MAP2206HT8P-E
				MMY-MAP1606HT8P-E	MMY-MAP1606HT8P-E	MMY-MAP1606HT8P-E	MMY-MAP1606HT8P-E
Outdoor unit type				Inverter unit	Inverter unit	Inverter unit	Inverter unit
Cooling capacity (*1)			kW	90.0	95.4	101.0	106.5
Heating capacity (*1)			kW	100.0	106.0	113.0	114.0
Capacity range			HP	32	34	36	38
Power supply				3N~ 50Hz 400V(380-415V)	3N~ 50Hz 400V(380-415V)	3N~ 50Hz 400V(380-415V)	3N~ 50Hz 400V(380-415V)
Voltage range (*2)		Minimum	V	342	342	342	342
		Maximum	V	456	456	456	456
Electrical characteristic (*1)	Cooling	Running current	A	44.8	45.3	49.2	58.0
		Power input	kW	28.6	28.9	31.6	37.5
		EER	kW/kW	3.15	3.3	3.2	2.84
	Heating	Running current	A	40.4	42.3	46.3	46.7
		Power input	kW	25.8	27.0	29.9	30.0
		COP	kW/kW	3.88	3.93	3.78	3.8
	Starting current		A	Soft Start	Soft Start	Soft Start	Soft Start
Weight	Heat pump		kg	300 + 300	371 + 300	371 + 300	371 + 300
Colour				Silky shade (Munsell 1Y8.5/0.5)	Silky shade (Munsell 1Y8.5/0.5)	Silky shade (Munsell 1Y8.5/0.5)	Silky shade (Munsell 1Y8.5/0.5)
Compressor	Type			Hermetic twin rotary compressor	Hermetic twin rotary compressor	Hermetic twin rotary compressor	Hermetic twin rotary compressor
	Motor output		kW	5.8x2 + 5.8x2	6.5x2 + 5.8x2	7.6x2 + 5.8x2	9.0x2 + 5.8x2
Fan unit	Fan			Propeller fan	Propeller fan	Propeller fan	Propeller fan
	Motor output		kW	1.0 + 1.0	2.0 + 1.0	2.0 + 1.0	2.0 + 1.0
	Air volume		m3/h	12600 + 12600	17300 + 12600	17900 + 12600	18500 + 12600
Max. external static pressure			Pa	40	40	40	40
Heat exchanger				Finned tube	Finned tube	Finned tube	Finned tube
Refrigerant	Name			R410A	R410A	R410A	R410A
	Charge	Heat pump	kg	11.5 + 11.5	11.5 + 11.5	11.5 + 11.5	11.5 + 11.5
High-pressure switch			Pa	OFF:3.2 ON:4.15	OFF:3.2 ON:4.15	OFF:3.2 ON:4.15	OFF:3.2 ON:4.15
Protective devices				(*3)	(*3)	(*3)	(*3)
Power supply wiring		MCA (*4)	A	71.8	76.4	80.7	85.1
		MOCP (*5)	A	80.0	100.0	100.0	100.0
Piping connections	Gas	Type		Brazing	Brazing	Brazing	Brazing
		Diameter	mm	34.9	34.9	41.3	41.3
	Liquid	Type		Flare	Flare	Flare	Flare
		Diameter	mm	19.1	19.1	22.2	22.2
	Balance	Type		Flare	Flare	Flare	Flare
		Diameter	mm	9.5	9.5	9.5	9.5
Max. number of connected indoor units				64	64	64	64
Sound pressure level		Cooling	dB(A)	65.0	64.5	64.5	64.5
		Heating	dB(A)	67.0	66.0	66.5	66.5
Sound power level		Cooling	dB(A)	84.0	84.0	84.5	85.5
		Heating	dB(A)	86.0	86.0	86.5	86.5
Operation temperature range		Cooling	CDB	-5.0 to 46.0	-5.0 to 46.0	-5.0 to 46.0	-5.0 to 46.0
		Heating(*6)	CWB	-25.0 to 15.5	-25.0 to 15.5	-25.0 to 15.5	-25.0 to 15.5

Note

(*1) Rated conditions   Cooling : Indoor 27 degC Dry Bulb /19 degC Wet Bulb , Outdoor 35 degC Dry Bulb.
Heating : Indoor 20 degC Dry Bulb, Outdoor 7 degC Dry Bulb / 6 degC WetBulb.
Based on equivalent piping length of 7.5m and piping height difference of 0m.

(*2) Voltage range : Units are suitable for use on electrical systems where voltage supplied to unit terminal is not below or above listed range limits.

(*3) Discharge temp. sensor / Suction temp. sensor / High-pressure sensor / Low-pressure sensor / Compressor case thermostat / PC board fuse

(*4) Select wire size base on the larger value of MCA.
MCA : Minimum Circuit Amps

(*5) MOCP : Maximum Overcurrent Protection(Amps)

(*6) Low ambient heating (-20degC or less) for extended periods of time is not allowed

Appendix (2)

VRF indoor units catalogues

Toshiba Design AIRS | SPECIFICATIONS

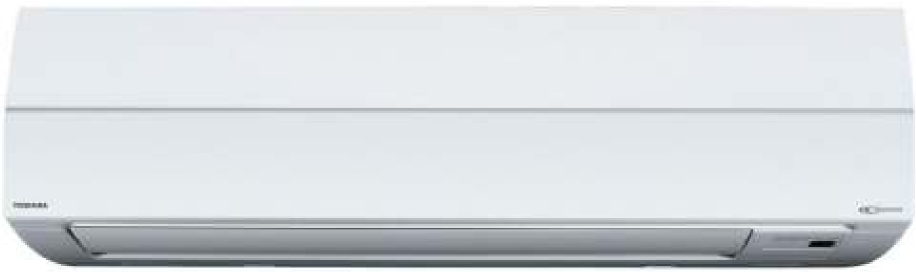
Concealed Duct Type (6 series)

Model name		MMD-	AP0076	AP0096	AP0126	AP0156	AP0186	AP0246	AP0276	AP0306	AP0366	AP0486	AP0566
Cooling / Heating capacity (*1)		kW	2.2 / 2.5	2.8 / 3.2	3.6 / 4.0	4.5 / 5.0	5.6 / 6.3	7.1 / 8.0	8.0 / 9.0	9.0 / 10.0	11.2 / 12.5	14.0 / 16.0	16.0 / 18.0
Electrical characteristics	Power supply		1 phase 50 Hz 220-240 V / 1 phase 60 Hz 220 V (Separate power supply for indoor units is required.)										
Electrical characteristics	Running current 50 Hz	A	0.26	0.29		0.42		0.63		0.61	1.07	1.20	
Electrical characteristics	Running current 60 Hz	A	0.27	0.31		0.44		0.65		0.64	1.12	1.20	
Electrical characteristics	Power consumption	kW	0.036	0.043		0.060		0.077		0.096	0.112	0.156	
Electrical characteristics	Starting current	A	0.40 / 0.47	0.50 / 0.54		0.73 / 0.76		0.90 / 0.98		1.06 / 1.11	1.80 / 1.94	2.10 / 2.22	
Appearance			Zinc hot dipping steel plate										
Dimension	Height	mm	275										
Dimension	Width	mm	700					1000			1400		
Dimension	Depth	mm	750										
Total weight		kg	25					30			40		
Heat exchanger			Finned tube										
Soundproof / Heat-insulating material			Polyethlene foam										
Fan unit	Fan		Centrifugal fan										
Fan unit	Standard air flow (High / Mid. / Low)	m³/h	440 / 400 / 388	570 / 450 / 390		798 / 660 / 540		1050 / 900 / 678		1260 / 1110 / 930	1620 / 1500 / 1350	2100 / 1740 / 1500	
Fan unit	Motor output	W	150								250		
Fan unit	External static pressure (factory default)	Pa	30					40			50		
Fan unit	External static pressure	Pa	30 · 40 · 50 · 65 · 80 · 100 · 120 (7 steps)										
Air filter			Standard filter (Long life filter)										
Controller			Remote controller										
Connecting pipe	Gas side	mm	Ø9.5			Ø12.7		Ø15.9					
Connecting pipe	Liquid side	mm	Ø6.4					Ø9.5					
Connecting pipe	Drain port (Nominal dia.)	mm	25 (Polyvinyl chloride tube)										
Sound pressure level (High / Mid. / Low)		dB(A)	28 / 26 / 22	30 / 28 / 25		33 / 28 / 25		36 / 31 / 27			40 / 36 / 33		

Note

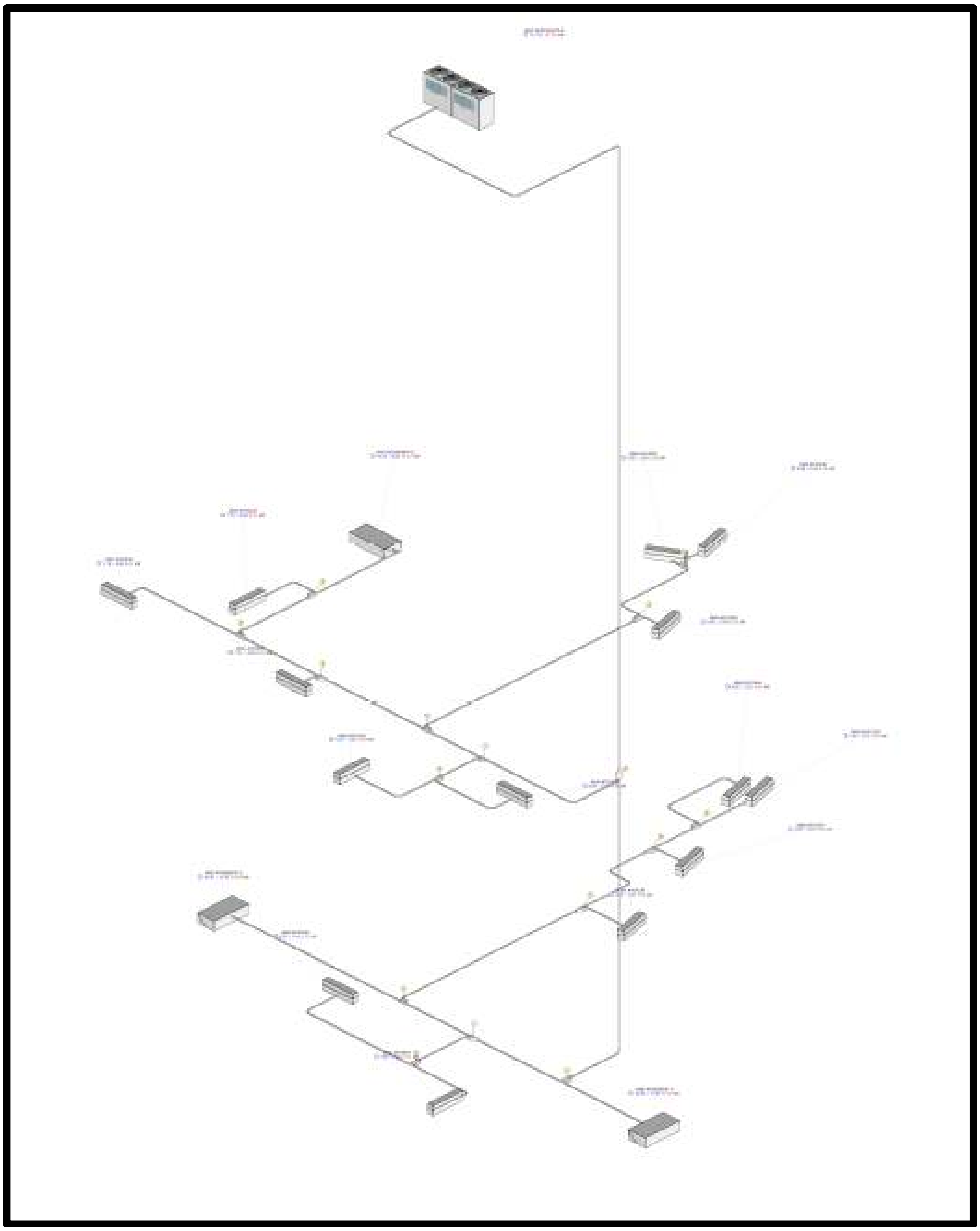
(*1) Rated conditions: Cooling : Indoor 27 degC Dry Bulb / 19 degC Wet Bulb, Outdoor 35 degC Dry Bulb.
Heating : Indoor 20 degC Dry Bulb, Outdoor 7 degC Dry Bulb / 6 degC Wet Bulb.
Based on equivalent piping length of 7.5 m and piping height difference of 0 m.

Toshiba Design AIRS	PHOTOS



TOSHIBA
Leading Innovation

Customer:	Eng.Hamzah Shehadeh		
Project:	Tulkarm-Health Care Center		
Revision:			
Reference:	T-VRF_M		
Type:	High Wall Standard (Series 3)	Date:	2/1/17
Model:	MMK-AP0123H	Scale:	none
		Unit:	-
		Page:	



Indoor Units

Model Name	Unit Name & Room	Capacity Code	Fan Speed	Mode	Capacity (Total/Sensible) [kW] Rated	Corrected	Required
MMD-AP0366BHP-E		4.0HP	High	Cooling	11.20/8.80	9.56/7.65	
				Heating	12.50	8.93	
MMD-AP0566BHP-E		6.0HP	High	Cooling	16.00/11.50	13.74/10.05	
				Heating	18.00	12.87	
MMD-AP0566BHP-E		6.0HP	High	Cooling	16.00/11.50	13.94/10.20	
				Heating	18.00	12.93	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.93/2.84	
				Heating	5.00	3.59	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.78/2.73	
				Heating	5.00	3.55	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.78/2.73	
				Heating	5.00	3.55	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.80/2.75	
				Heating	5.00	3.56	
MMK-AP0153H		1.7HP	High	Cooling	4.50/3.20	3.83/2.77	
				Heating	5.00	3.57	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.80/3.40	
				Heating	6.30	4.50	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.79/3.39	
				Heating	6.30	4.50	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.83/3.42	
				Heating	6.30	4.51	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.89/3.46	
				Heating	6.30	4.53	
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.83/3.42	
				Heating	6.30	4.51	

Toshiba Design AIRS - System Details

Indoor Units

Model Name	Unit Name & Room	Capacity Code	Fan Speed	Mode	Capacity (Total/Sensible) [kW] Rated	Corrected	Required
MMK-AP0183H		2.0HP	High	Cooling	5.60/3.90	4.84/3.43	
				Heating	6.30	4.51	
MMK-AP0243H		2.5HP	High	Cooling	7.10/4.80	6.16/4.23	
				Heating	8.00	5.74	
MMK-AP0243H		2.5HP	High	Cooling	7.10/4.80	6.12/4.21	
				Heating	8.00	5.73	
MMK-AP0243H		2.5HP	High	Cooling	7.10/4.80	6.08/4.19	
				Heating	8.00	5.72	

Toshiba Design AIRS	PHOTOS

TOSHIBA Leading Innovation	Customer: Eng.Hamzah Shehadeh Project: Tulkarm-Health Care Center Revision: Reference: T-VRF_M	AL BADER
	Type: Standard Concealed Duct Model: MMD-AP0366BHP-E	Date: 2/1/17 Scale: none Unit: - Page:

Appendix (3)

VRF piping system

Piping Length

Pipe Diameter	Gas side (m)	Discharge side (m)	Liquid side (m)	Total Length (m)
¼"	0	0	50.5	50.5
⅜"	7	0	43.5	50.5
½"	43.5	0	28.5	72
⅝"	43.5	0	17	60.5
¾"	0	0	18.5	18.5
⅞"	28.5	0	13	41.5
1⅛"	20	0	0	20
1⅜"	15.5	0	0	15.5

Appendix (4)

VRF system official offers

سعر المتر الواحد $	سعر المتر الواحد NIS	الصنف
1.527777778	5.5	نحاس معزول ابيض ١/٤
2.361111111	8.5	نحاس معزول ابيض ٣/٨
3.055555556	11	نحاس معزول ابيض ١/٢
4.444444444	16	نحاس معزول ابيض ٥/٨
5.833333333	21	نحاس معزول ابيض ٣/٤
8.333333333	30	نحاس معزول ابيض ٧/٨
8.333333333	30	ماسورة نحاس ١,١/٨
11.1111111	40	ماسورة نحاس ١,٣/٨
14.72222222	53	ماسورة نحاس ١,٥/٨

TOSHIBA-VRF-Heat Pump System

السعر الاجمالي	السعر $	الكمية	الوصف	النوعية
19740	19740	1	Toshiba VRF Heat Pump 32 hp Outdoor Unit	T-MMY-MAP3216HT8P-E
22370	22370	1	Toshiba VRF Heat Pump 42 hp Outdoor Unit	T-MMY-MAP4216HT8P-E
4095	1365	3	Concealed Ducted-Type Indoor Unit 11.2 KW CC/ 12.5 KW HC	T-MMD-AP0366BHP-E
2956	1478	2	Concealed Ducted-Type Indoor Unit 16.0 KW CC/ 18.0 KW HC	T-MMD-AP0566BHP-E
958	958	1	Wall Mounted-Type Indoor Unit 3.6 KW CC/ 4.5 KW HC	T-MMK-AP0123H
11330	1030	11	Wall Mounted-Type Indoor Unit 4.5 KW CC/ 5.0 KW HC	T-MMK-AP0153H
13650	1050	13	Wall Mounted-Type Indoor Unit 5.6 KW CC/ 6.0 KW HC	T-MMK-AP0183H
3225	1075	3	Wall Mounted-Type Indoor Unit 7.1 KW CC/ 8.0 KW HC	T-MMK-AP0243H
2700	2700	1	Central Smart Manager (optional), but highly recommended for the facility	T-BMS-SM1280ETLE
81024				المجموع

ملاحظات هامة :-

1- الاسعار أعلاه بالدولار الأمريكي شاملة لضريبة القيمة المضافة.
2- العرض ساري المفعول لمدة إسبوعين من تاريخه.
3- الأسعار أعلاه شاملة للشبكة النحاسية والرفنت مع كوابل الكهرباء والتحكم والثيرموستات.
4- الأسعار أعلاه شاملة لتركيب النظام كاملا بجميع البنود أعلاه حتى التسليم مع التشغيل. وغير شاملة أعمال قنوات الدكت أو أية أعمال غير مذكورة.
5- النظام شامل لكفالة ٣ سنوات.

Appendix (5)

Air cooled outdoor unit's catalogues

TRANE

Air-Cooled Liquid Chillers

10 to 60 Tons

April 2004

CG-PRC007-EN

Table PD-8 – 60 Ton – CGAF-C60

		Entering Condenser Air Temperature (Degree F)														
		75.0			85.0			95.0			105.0			115.0		
LWT Deg F)	Percent Glycol	Capacity (Tons)	System KW	EER	Capacity (Tons)	System KW	EER	Capacity (Tons)	System KW	EER	Capacity (Tons)	System KW	EER	Capacity (Tons)	System KW	EER
20	28	37.2	50.1	8.9	35.3	55.0	7.7	33.4	60.7	6.6	31.3	67.2	5.6	29.2	74.6	4.7
25	24	41.6	51.3	9.7	39.6	56.4	8.4	37.4	62.2	7.2	35.2	68.8	6.1	32.9	76.3	5.2
30	19	46.4	52.6	10.6	44.1	57.8	9.2	41.8	63.8	7.9	39.4	70.6	6.7	36.8	78.2	5.7
35	14	51.4	54.0	11.4	48.9	59.3	9.9	46.4	65.4	8.5	43.7	72.3	7.3	41.0	80.1	6.1
40	0	57.2	55.6	12.3	54.5	61.1	10.7	51.7	67.3	9.2	48.8	74.4	7.9	45.8	82.2	6.7
42	0	59.2	56.2	12.7	56.5	61.7	11.0	53.6	68.0	9.5	50.6	75.1	8.1	47.5	83.0	6.9
44	0	61.4	56.8	13.0	58.5	62.3	11.3	55.6	68.7	9.7	52.5	75.9	8.3	49.3	83.8	7.1
45	0	62.5	57.1	13.1	59.6	62.7	11.4	56.6	69.1	9.8	53.4	76.2	8.4	50.2	84.2	7.2
46	0	63.6	57.4	13.3	60.6	63.0	11.5	57.6	69.4	9.9	54.4	76.6	8.5	51.1	84.6	7.2
48	0	65.8	58.0	13.6	62.7	63.7	11.8	59.6	70.2	10.2	56.3	77.4	8.7	52.9	85.4	7.4
50	0	68.0	58.6	13.9	64.9	64.4	12.1	61.7	70.9	10.4	58.3	78.2	8.9	54.8	86.3	7.6
55	0	73.8	60.3	14.7	70.4	66.1	12.8	66.9	72.8	11.0	63.3	80.2	9.5	59.6	88.4	8.1
60	0	79.7	62.0	15.4	76.1	68.0	13.4	72.4	74.8	11.6	68.5	82.4	10.0	64.5	90.7	8.5

Electrical Data - 50 HZ

(10–60 Ton)

Table ED-2 – Electrical Data

		Unit Wiring					Motor Data					
							Compressor (Ea)			Fans (Ea)		
Tons	Model Number	Nameplate Voltage	Voltage Range	MCA	Max Fuse Size	Rec. Dual Element	Qty.	RLA	LRA	Qty	KW	FLA
10	CGA100BD	380-415/50/3	342-456	24.1	30	–	2	9.5	63	1	0.57	2.7
15	CGA150BD	380-415/50/3	342-456	32.7	45	–	2	13.1	99.5	2	0.33	1.6
20	CGAF-C20	380/50/3	342-418	44	60	50	2	17.2	110	2	0.75	1.7
		415/50/3	373-456	44	60	50	2	17.2	110	2	0.75	1.7
25	CGAF-C25	380/50/3	342-418	55	80	70	2	17.2/25.2	110/174	3	0.75	1.7
		415/50/3	373-456	55	80	70	2	17.2/25.2	110/174	3	0.75	1.7
30	CGAF-C30	380/50/3	342-418	65	80	80	2	25.2	174	4	0.75	1.7
		415/50/3	373-456	65	80	80	2	25.2	174	4	0.75	1.7
40	CGAF-C40	380/50/3	342-418	81	90	90	4	17.2	110	4	0.75	1.7
		415/50/3	373-456	81	90	90	4	17.2	110	4	0.75	1.7
50	CGAF-C50	380/50/3	342-418	97	110	110	4	15.5/24.2	110/174	6	0.75	1.7
		415/50/3	373-456	97	110	110	4	15.5/24.2	110/174	6	0.75	1.7
60	CGAF-C60	380/50/3	342-418	119	125	125	4	25.2	174	6	0.75	1.7
		415/50/3	373-456	119	125	125	4	25.2	174	6	0.75	1.7

Notes:

1. MCA: Minimum Circuit Ampacity is 125% of the largest compressor RLA, plus 100% of the other compressor(s) RLA, plus the sum of the condenser fan FLA, plus any other load rated at 1 AMP or more.
2. Maximum Fuse Size: 225% of the largest compressor RLA, plus 100% of the other compressor(s) RLA, plus the sum of the condenser fan FLA, plus any other load rated at 1 AMP or more.
3. Recommended Dual Element Fuse Size: 150% of the largest compressor RLA, plus 100% of the other compressor(s) RLA, plus the sum of the condenser fan FLA, plus any other load rated at 1 AMP or more.
4. RLA: Rated in accordance with UL standard 1995.
5. Local codes may take precedence.
6. Control kw includes operational controls only. Does not include evaporator heat tape.
7. All units are across the line starting. Compressors will never start simultaneously.
8. One 240/50/1, 5 AMP jobsite provided power connection is required to operate the evaporator heat tape.

TRANE

General Data

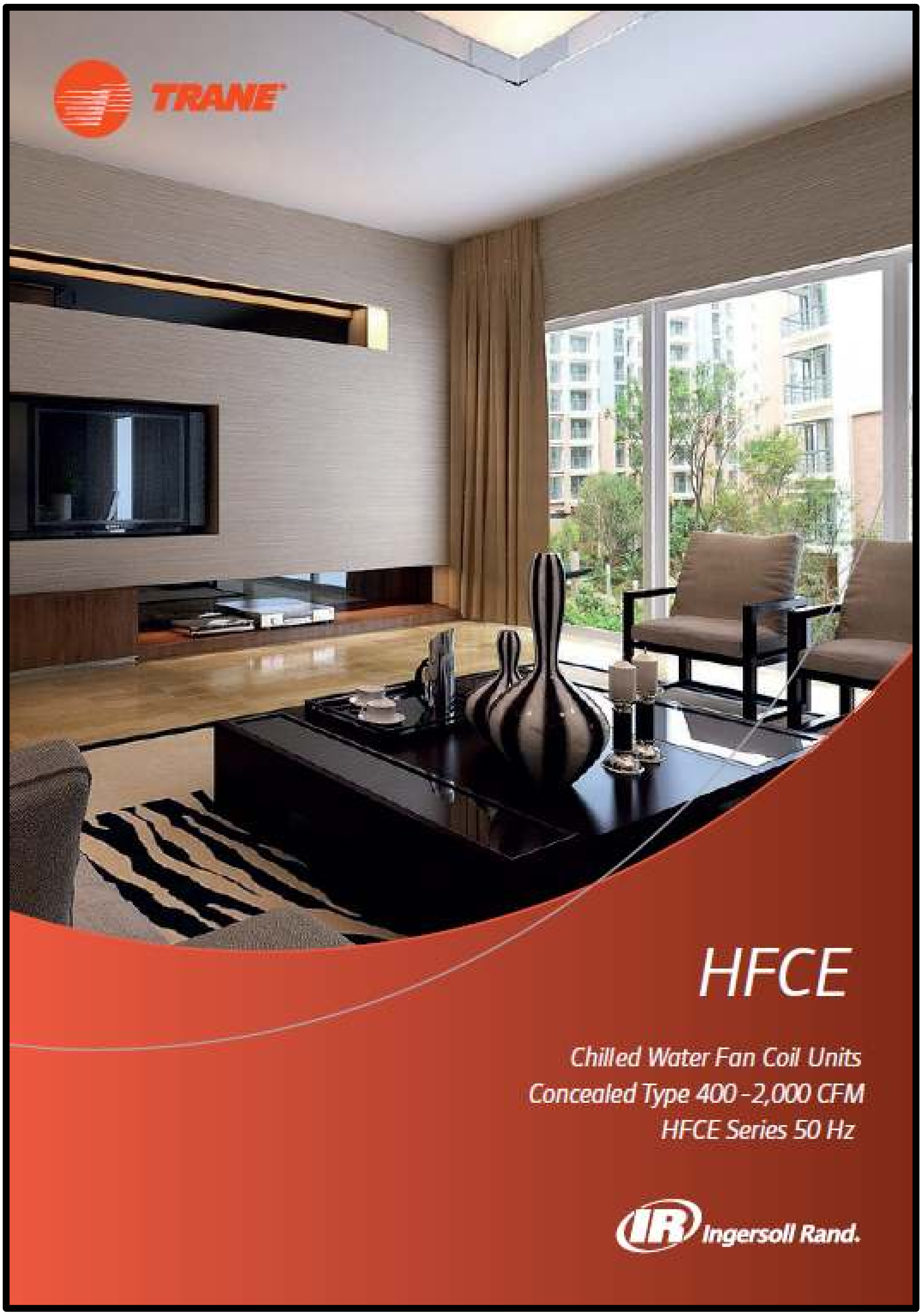
Table GD-1 – General Data – 10-60 Ton Units

Model Number	10 Ton CGA120	15 Ton CGA180	20 Ton CGAF-C20	25 Ton CGAF-C25	30 Ton CGAF-C30	40 Ton CGAF-C40	50 Ton CGAF-C50	60 Ton CGAF-C60
Compressor Data								
Model	Scroll	Scroll	Scroll	Scroll	Scroll	Scroll	Scroll	Scroll
Quantity	2	2	2	1/1	2	4	2/2	4
Nominal Tons per Compressor	5	7.5	10	10/15	15	10	10/15	15
Evaporator								
Nominal Size (Tons)	10	15	20	25	30	40	50	60
Water Storage Capacity (Gallons)[1]	1.4	1.5	2.2	2.7	3.2	4.1	5.0	7.4
Min. Flow Rate (GPM)	12.0	18.0	24	30	36	48	60	72
Max. Flow Rate (GPM)	36.0	54.0	72	90	108	144	180	216
Max EWT At Start-Up – Deg F[1]	100	100	108	108	108	108	108	108
Condenser								
Nominal Size (Tons)	10	15	20	25	30	40	50	60
Number of Coils	1	2	1	2	2	2	2	2
Coil Size (sq., Inches)[1]	28 x 108	28 x 83	61 x 71	45 x 71/35 x 71	56 x 70	56 x 70	57 x 96	57 x 96
Number of Rows	2	2	3	3	3	3	3	4
Subcooler Size (sq., Inches)	4 x 108	4 x 83	10 x 71	14 x 71	9 x 70	9 x 70	9 x 96	9 x 96
Condenser Fans								
Quantity	1	2	2	3	4	4	6	6
Diameter (Inches)	28	26	26	26	26	26	26	26
CFM (Total)	9,120	11,600	15,000	21,650	29,200	29,200	42,300	40,700
Nominal RPM	1100	1100	1140	1140	1140	1140	1140	1140
Tip Speed (Ft/Min)	8060	7490	7750	7750	7750	7750	7750	7750
Motor HP (ea.)	1.0	1/2	1.0	1.0	1.0	1.0	1.0	1.0
Drive Type	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
Minimum Outdoor Air Temperature Permissible For Mechanical Cooling[1]								
Standard Ambient Control Unit (°F)	50	50	30	30	30	30	30	30
Standard Ambient w/Hot Gas Bypass (°F)	60	60	40	40	40	40	40	40
Low Ambient Option (°F)	0	0	0	0	0	0	0	0
Low Ambient Control w/Hot Gas Bypass(°F)	15	15	10	10	10	10	10	10
General Unit								
Unload Steps	100-50	100-50	100-50	100-60-40	100-50	100-75-50-25	100-80-60-30	100-75-50-25
No. of Independent Refrig. Circuits	2	2	1	1	1	2	2	2
Refrigerant Charge (lbs. R22/Circuit)	8.25	11.5	40.5	54.0	72.0	36.0	49.0	75.00
Oil Charge (Pints/Circuit)	4.1	7.5	17.0	22.3	27.6	17.0	22.3	27.6

*Unloading steps depend upon which compressor is lead compressor.

Appendix (6)

Air cooled indoor unit's catalogues (Concealed type)



General Data HFCE 50 Hz

Product Specification

MODEL		HFCE04	HFCE06	HFCE08	HFCE10	HFCE12	HFCE14	HFCE16	HFCE18	HFCE20
Rated - Volts/Ph/Hz		220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50	220-240/1/50
System Data										
Nominal Airflow	cfm	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000
Cooling Capacity	Btu/h	12,000	18,000	24,000	30,000	36,000	42,000	48,000	54,000	60,000
Water Inlet Connection Size	in	5/8	5/8	5/8	5/8	5/8	3/4	3/4	3/4	3/4
Water Outlet Connection Size	in	5/8	5/8	5/8	5/8	5/8	3/4	3/4	3/4	5/8
Water Connection Size		Brazed	Brazed	Brazed	Brazed	Brazed	Brazed	Brazed	Brazed	Brazed
INDOOR COIL										
Fin Type		Corrugate								
Fins per inch*										
3-Row coil		12	12	15	18	18	14	14	14	14
4-Row coil		14	15	16	15	15	16	16	16	16
Drain Connection Size	in	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2
FAN										
Fan Type		Double Inlet Centrifugal Forward Curved Fan								
No. used		2	2	2	2	2	2	2	2	2
Drive Type		Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
FAN MOTOR (STANDARD)										
Motor Power	W	13	47	59	162	186	394	394	453	453
No. of Speed		3	3	3	4	4	4	4	4	4
Qty x (RLA/LRA)		1 x (0.20/0.35)	1 x (0.49/0.71)	1 x (0.56/0.69)	1 x (1.36/2.31)	1 x (1.35/2.41)	1 x (3.33/5.08)	1 x (3.33/5.08)	1 x (0.43/6.98)	1 x (0.43/6.98)
DIMENSION (HxWxD)										
Uncrated with plenum (Net)	mm	265 x 824 x 510	278 x 940 x 510	278 x 1,117 x 510	300 x 1,087 x 608	300 x 1,240 x 608	433 x 1,095 x740	433 x 1,095 x740	433 x 1,248 x 670	433 x 1,248 x 670
WEIGHT										
3-Row Uncrated (Net)	kg	26	30	36	42	46	54	54	62	62
4-Row Uncrated (Net)	kg	27	32	38	44	48	57	57	66	66

Note 1. 3-Row coil is standard coil
2. 4-Row coil is optional coil
3. Unit dimensions is not included hanging legs
4. Blower size for HFCA08 will be 7x8 in when using with optional high static motor

Performance Data Cooling Capacities
Model HFCE04-20

TC = Total Capacity, MBH
SC = Sensible Capacity, MBH
GPM = Water Flow Rate, gpm
PD = Water Pressure Drop, Ft of Water
EWT = Entering Water Temperature
WTR = Water Temperature Rise

Cooling Capacity for 3-Row Coil

EWT (F)	Unit Size	Rated Airflow CFM	WTR	Entering Air Temp - EDB/EWB (F) 72 /61 TC	SC	GPM	PD	74 /63 TC	SC	GPM	PD	80 /67 TC	SC	GPM	PD	84 /71 TC	SC	GPM	PD
45	04	400	8	8.46	7.29	2.11	5.18	10.04	7.78	2.50	6.97	13.82	9.65	3.44	12.15	18.08	10.80	4.50	19.42
			10	7.51	6.90	1.50	2.85	8.96	7.34	1.79	3.87	12.66	9.18	2.52	7.04	16.85	10.32	3.36	11.58
			12	6.52	6.24	1.08	1.62	7.85	6.90	1.30	2.23	11.48	8.73	1.91	4.31	15.53	9.81	2.58	7.28
			15	4.75	4.68	0.63	0.63	6.01	5.73	0.80	0.95	9.66	8.04	1.28	2.16	13.41	9.03	1.78	3.81
	06	600	8	12.04	10.59	3.00	4.10	14.30	11.28	3.56	5.52	19.75	14.00	4.92	9.68	25.93	15.65	6.46	15.56
			10	10.57	9.98	2.11	2.21	12.63	10.61	2.52	3.01	18.00	13.30	3.59	5.56	24.04	14.92	4.79	9.20
			12	8.97	8.56	1.49	1.21	10.88	9.92	1.81	1.69	16.19	12.60	2.69	3.35	21.99	14.15	3.65	5.71
			15	6.17	6.09	0.82	0.43	7.67	7.55	1.02	0.62	13.31	11.54	1.77	1.61	18.73	12.97	2.49	2.91
	08	800	8	16.61	15.90	4.14	8.79	19.62	16.98	4.89	11.74	26.76	21.69	6.67	20.17	34.83	23.51	8.68	31.98
			10	14.99	14.26	2.99	4.97	17.80	16.13	3.55	6.69	24.76	20.08	4.94	11.87	32.66	22.52	6.51	19.25
			12	13.29	13.21	2.21	2.93	15.90	15.25	2.64	3.99	22.78	19.18	3.78	7.45	30.32	21.48	5.04	12.25
			15	10.36	10.26	1.38	1.29	12.80	12.66	1.70	1.85	19.68	17.82	2.62	3.90	26.81	19.97	3.56	6.66
	10	1000	8	21.50	20.60	5.36	5.94	25.29	22.26	6.30	7.87	34.55	27.03	8.61	13.56	44.81	30.03	11.16	21.37
			10	19.12	18.53	3.81	3.27	22.65	21.08	4.51	4.39	31.70	25.77	6.32	7.87	41.53	28.62	8.28	12.60
			12	16.15	15.75	2.68	1.77	19.81	19.45	3.29	2.53	28.86	24.55	4.79	4.84	38.25	27.26	6.35	7.91
			15	11.12	11.00	1.48	0.63	14.80	14.64	1.97	1.03	24.26	22.63	3.23	2.42	33.24	25.23	4.42	4.17
	12	1200	8	26.33	24.96	6.56	9.87	30.81	26.55	7.67	12.98	41.53	32.82	10.34	21.85	53.33	36.56	13.29	33.88
			10	23.83	23.80	4.75	5.60	27.95	25.25	5.57	7.39	38.35	31.38	7.64	12.81	49.72	34.95	9.91	20.17
			12	21.18	21.15	3.52	3.31	25.03	23.94	4.16	4.42	35.25	30.01	5.86	8.01	46.11	33.37	7.66	12.80
			15	16.50	16.46	2.19	1.45	20.18	19.95	2.68	2.06	30.52	27.98	4.06	4.20	40.71	31.09	5.41	6.93
	14	1400	8	28.14	25.12	7.01	3.58	33.38	26.73	8.31	4.81	46.18	33.14	11.50	8.45	60.74	37.03	15.13	13.63
			10	24.39	23.61	4.87	1.89	29.21	25.06	5.82	2.58	42.03	31.47	8.41	4.82	55.93	35.18	11.15	7.96
			12	19.98	19.72	3.32	0.97	24.63	23.29	4.09	1.39	37.38	29.76	6.21	2.86	50.86	33.30	8.45	4.89
			15	13.27	13.09	1.76	0.33	15.03	14.81	2.00	0.40	29.94	27.02	3.98	1.32	42.73	30.40	5.68	2.44
	16	1600	8	30.78	27.86	7.67	4.18	36.34	29.55	9.05	5.57	50.14	36.51	12.49	9.75	65.95	40.67	16.43	15.73
			10	26.90	26.28	5.36	2.23	31.99	27.81	6.38	3.02	48.07	34.74	9.61	5.56	60.58	38.64	12.07	9.14
			12	22.58	21.51	3.75	1.20	27.31	25.99	4.54	1.67	40.80	32.95	6.78	3.33	55.11	36.63	9.15	5.62
			15	14.00	13.82	1.86	0.36	18.25	17.98	2.43	0.56	33.21	30.15	4.41	1.57	46.59	33.61	6.19	2.83
	18	1800	8	36.33	32.13	9.05	6.50	42.78	34.10	10.66	8.64	58.68	42.09	14.62	14.98	76.90	46.91	19.15	24.03
			10	32.37	30.51	6.45	3.60	38.31	32.28	7.64	4.82	54.10	40.13	10.82	8.66	71.19	44.72	14.19	14.15
			12	28.10	26.85	4.67	2.04	33.62	30.45	5.58	2.78	48.84	38.28	8.11	5.32	65.26	42.52	10.84	8.81
			15	19.62	19.35	2.61	0.74	25.48	24.24	3.39	1.17	41.18	35.43	5.47	2.67	56.55	39.37	7.52	4.62
	20	2000	8	38.85	34.76	9.77	7.30	45.61	36.80	11.36	9.65	62.53	45.37	15.57	16.73	81.94	50.45	20.41	26.86
			10	34.76	33.11	6.93	4.07	40.96	34.94	8.16	5.41	60.04	43.29	12.01	9.65	75.73	48.09	15.09	15.76
			12	30.39	29.03	5.05	2.34	36.13	33.05	6.00	3.15	52.09	41.34	8.65	5.95	69.35	45.74	11.52	9.78
			15	22.19	21.90	2.95	0.92	27.97	26.58	3.72	1.37	44.21	38.43	5.88	3.02	60.19	42.47	8.00	5.15

TRANE

Trane optimizes the performance of home and buildings around the world. A business of Ingersoll Rand, the leader in creating and sustaining safe,comfortable, and energy efficient environments, Trane offers a broad portfolio of advance controls and HVAC systems, comprehensive building services, and parts. For more information, visit www.tranethailand.com

เทรน (ประเทศไทย)
เลขที่ 1126/2 ชั้น 30-31 อาคารวานิช 2 ถ.เพชรบุรีตัดใหม่ แขวงมักกะสัน เขตราชเทวี กรุงเทพฯ 10400
0-2704-9999

Appendix (7)

Air cooled indoor unit's catalogues (Ducted type)

TRANE

The Best Choice for Comfort

The Best Results

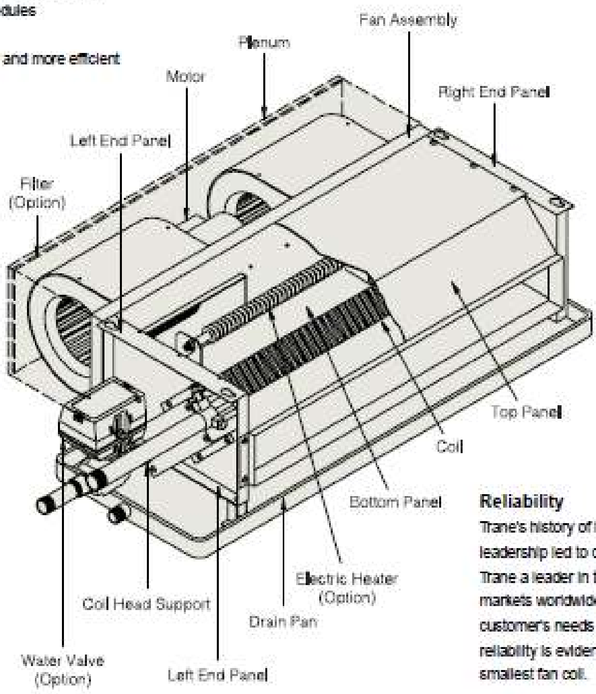
- Quiet Comfort
  - Slope coil avoid air flow perpendicular impact
  - Low noise permanent split capacitor motor
  - Metal fan wheel both statically and dynamically balanced
  - Treaded connection, match up duct collars and keyholes for hangers shorten installation time
  - Quick delivery helps meet tight installation schedules
- Latest Perfection
  - Cleaner, quieter and more efficient fin design.

The Best System

- Design for hidden comfort in home, office or shop. HFCA is easily installed in a false ceiling or closet, HFCA is the ideal solution for new or replacement applications.

The Best Fit

- Seven sizes to meet capacity requirements while minimizing the size fan coil needed
- One unit provides total comfort requirements: both cooling and heating
- Low height of just 250mm on all sizes means no difficulty in fitting tight ceiling applications



Reliability

Trane's history of innovation and technology leadership led to quality products making Trane a leader in the air conditioning markets worldwide. Trane's commitment to customer's needs for quality, efficiency and reliability is evident from the largest chiller to smallest fan coil.

TRANE

Performance Data

Cooling Capacity (Example)

Cooling Capacity : kW	Cooling Rows : 3	SH : Sensible Cooling Capacity, kW
EAT : 26.0°C/ 60.0%	Motor Frequency : 50Hz	WPD : Water Pressure Drop, M
ESP : 0 Pa	TH : Total Cooling Capacity, kW	WFR : Water Flow Rate, L / S

Model	Nominal Airflow (CMH)	WTR (°C)	Entering Water Temperature											
			5°C				7°C				9°C			
			SH	TH	WFR	WPD	SH	TH	WFR	WPD	SH	TH	WFR	WPD
03	509	3.0	3.19	5.17	0.41	7.60	2.86	4.43	0.35	5.74	2.54	3.65	0.29	4.03
		5.0	2.92	4.55	0.22	2.47	2.59	3.78	0.18	1.77	2.30	3.02	0.14	1.18
		7.0	2.62	3.85	0.13	1.02	2.32	3.10	0.11	0.69	2.06	2.39	0.08	0.44
04	678	3.0	4.81	7.81	0.62	21.93	4.32	6.72	0.53	16.63	3.84	5.57	0.44	11.80
		5.0	4.45	7.02	0.33	7.35	3.97	5.87	0.28	5.31	3.52	4.74	0.23	3.60
		7.0	4.08	6.13	0.21	3.20	3.63	5.02	0.17	2.23	3.22	3.97	0.14	1.45
06	1018	3.0	5.32	8.58	0.68	9.38	4.78	7.35	0.58	7.06	4.24	6.05	0.48	4.96
		5.0	4.86	7.55	0.36	3.04	4.33	6.27	0.30	2.17	3.85	5.03	0.24	1.46
		7.0	4.39	6.41	0.22	1.26	3.90	5.16	0.18	0.86	3.46	3.99	0.14	0.54
08	1357	3.0	6.92	11.15	0.89	17.68	6.23	9.56	0.76	13.33	5.55	7.88	0.63	9.39
		5.0	6.38	9.90	0.47	5.80	5.69	8.24	0.39	4.16	5.06	6.63	0.32	2.81
		7.0	5.81	8.55	0.29	2.48	5.19	6.97	0.24	1.72	4.62	5.48	0.19	1.12
10	1696	3.0	8.42	13.48	1.07	4.87	7.56	11.50	0.91	3.64	6.71	9.40	0.75	2.53
		5.0	7.60	11.60	0.55	1.52	6.77	9.54	0.46	1.07	5.98	7.53	0.36	0.70
		7.0	6.66	9.27	0.32	0.57	5.85	7.15	0.24	0.36	5.12	5.15	0.18	0.20
12	2036	3.0	10.34	16.56	1.32	8.05	9.30	14.14	1.12	6.03	8.26	11.60	0.92	4.22
		5.0	9.41	14.41	0.69	2.56	8.40	11.93	0.57	1.82	7.46	9.53	0.45	1.21
		7.0	8.43	12.03	0.41	1.03	7.48	9.56	0.33	0.68	6.62	7.25	0.25	0.42
14	2366	3.0	11.19	17.92	1.43	14.15	10.06	15.06	1.24	11.51	8.93	13.15	1.05	8.21
		5.0	10.30	16.10	0.77	4.23	9.17	13.67	0.65	3.32	8.04	11.09	0.53	2.24
		7.0	9.35	14.08	0.48	2.15	8.21	11.49	0.39	1.40	7.13	8.89	0.30	0.91

Spec./ Input Power

Model	03	04	06	08	10	12	14
Nominal Airflow (CMH)	509	678	1018	1357	1696	2036	2366
Input Power (Watts)*							
Hi-Static Motor	88	110	138	180	218	250	317
Normal Moter	73	82	114	132	162	198	226
*Available with 115V/60Hz, 220V/50Hz, or 220V/60Hz							
Options:							
* Heat Capacity Type							
• Hot Water 1Row (kW)	2.86	3.71	4.95	6.16	6.91	7.94	9.26
	EWT=55°C; EAT=21°C; WFR=0.3L/S (Hot Water EWT must be below 60°C)						
• Electric Sheathed Element	1.0	1.5	2	3	3.5	4	4
	Available with high temperature cutout (Electric heater starts when the T[illegible] is below 27°C)						
* Plenum/Filters	Return air plenum with filters-washable foam or aluminum						

Note: It reserves the right to change design and specification without notice.

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Appendix (8)

Air Cooled Primary Pump Catalogues

Data sheet

KSB

Customer item no.:	Number: ES 5044013
Communication dated:	Item no.: 100
Doc. no.:	Date: 30/04/2017
Quantity: 1	Page: 1 / 5
	Version no.: 1

ETL 065-065-160 GG AV66D200154 BKSBIE3
Inline pump

Operating data

Requested flow rate	40.00 m^3/h	Actual flow rate	39.41 m^3/h
Requested developed head	9.50 m	Actual developed head	9.22 m
Pumped medium	Antifreeze on ethylene glycol base, inhibited, closed system, e.g. Antifrogen N or similar products	Efficiency	77.7 %
	Cooling water with antifreeze-concentration 30% (pH >= 7.5)	MEI (Minimum Efficiency Index)	≥ 0.70
	Not containing chemical and mechanical substances which affect the materials	Power absorbed	1.33 kW
		Pump speed of rotation	1451 rpm
		NPSH required	1.46 m
		Permissible operating pressure	16.00 bar.g
Ambient air temperature	20.0 °C		
Fluid temperature	20.0 °C		
Fluid density	1040 kg/m^3		
Fluid viscosity	2.22 mm^2/s	Discharge press.	0.94 bar.g
Suction pressure max.	0.00 bar.g	Min. allow. mass flow for continuous stable operation	2.01 kg/s
Mass flow rate	11.39 kg/s	Max. allow. mass flow	21.45 kg/s
Max. power on curve	1.70 kW	Design	Single system 1 x 100 % Tolerances to ISO 9906 Class 3B; below 10 kW acc. to paragraph 4.4.2
Min. allow. flow for continuous stable operation	6.97 m^3/h		
Shutoff head	11.29 m		

Design

Pump standard	Without	Material code	Q7Q7EGG
Caution: The face-to-face dimension of suction to discharge can be different to the previous generation of Etaline.		Shaft seal code	66
		Sealing plan	Single-acting mechanical seal with vented chamber (A-type casing cover, taper bore)
Design	Close-coupled in-line		
Orientation	Vertical		
Suction nominal dia.	DN 65	Seal chamber design	Conical seal chamber (A-type cover)
Suction nominal pressure	PN 16		
Suction position	180° (down)	Contact guard	With
Suction flange drilled according to standard	EN1092-2	Wear ring	Casing wear ring
		Impeller diameter	174.0 mm
Discharge nominal dia.	DN 65	Free passage size	11.6 mm
Discharge norminal pressure	PN 16	Direction of rotation from drive	Clockwise
Discharge position	top (0°/360°)		
Discharge flange drilled according to standard	EN1092-2	Silicon free pump assembly	Yes
		Bearing bracket construction	Close-coupled
Shaft seal	Single acting mechanical seal	Bearing bracket size	25
Manufacturer	Burgmann	Bearing type	Anti-friction bearings
Type	MG13G6	Lubrication type	Grease
		Color	Vermilion (RAL 2002)

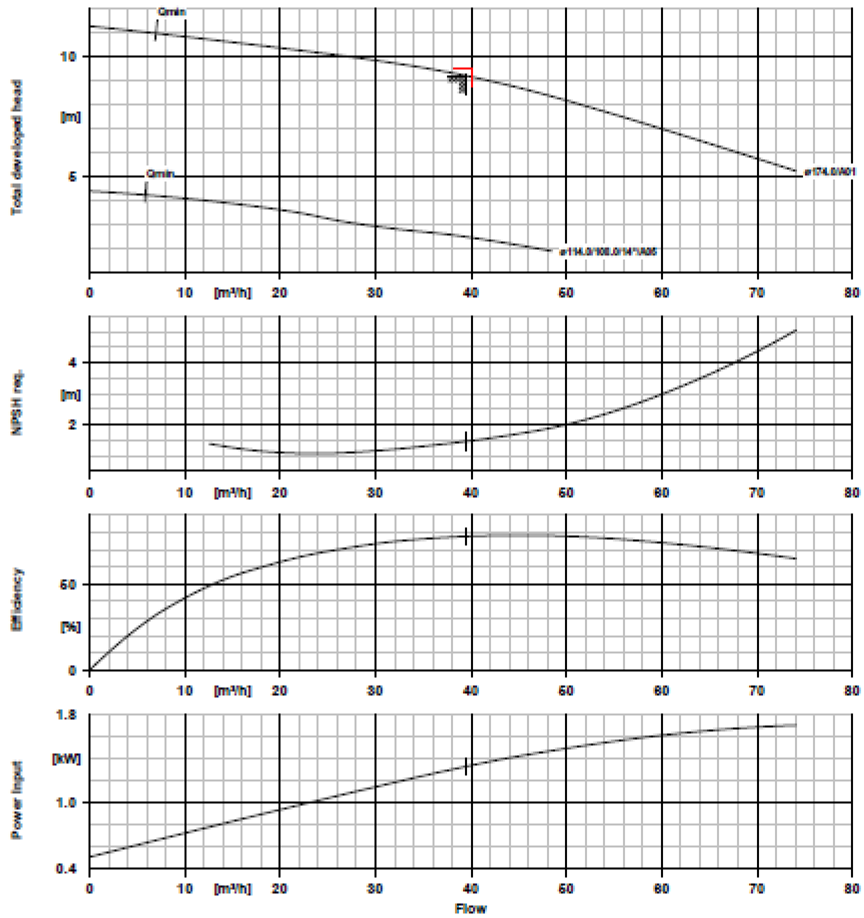
Performance curve

Customer item no.:
Communication dated:
Doc. no.:
Quantity: 1

Number: ES 5044013
Item no.:100
Date: 30/04/2017
Page: 3 / 5

Version no.: 1

ETL 065-065-160 GG AV66D200154 BKSBIE3
Inline pump



Curve data

Speed of rotation	1451 rpm	Efficiency	77.7 %
Fluid density	1040 kg/m³	MEI (Minimum Efficiency Index)	≥ 0.70
Viscosity	2.22 mm²/s	Power absorbed	1.33 kW
Flow rate	39.41 m³/h	NPSH required	1.46 m
Requested flow rate	40.00 m³/h	Curve number	K1159.454/31
Total developed head	9.22 m	Effective impeller diameter	174.0 mm
Requested developed head	9.50 m	Acceptance standard	Tolerances to ISO 9906 Class 3B; below 10 kW

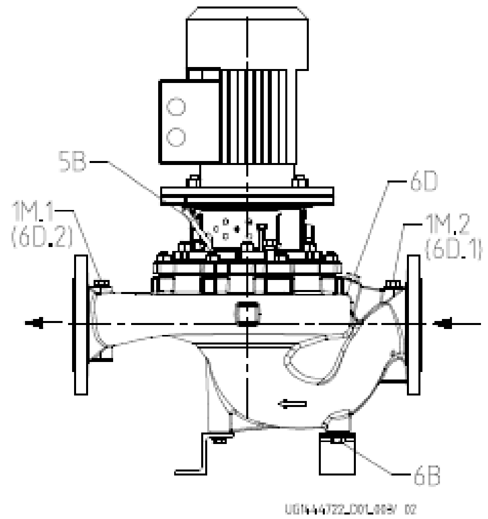
Connection plan

Customer item no.:
Communication dated:
Doc. no.:
Quantity: 1

Number: ES 5044013
Item no.:100
Date: 30/04/2017
Page: 5 / 5

ETL 065-065-160 GG AV66D200154 BKSBIE3
Inline pump

Version no.: 1



Appendix (9)

Air Cooled Secondary Pump Catalogues

Data sheet

KSB

Customer item no.:
Communication dated:
Doc. no.:
Quantity: 1

Number: ES 5044007
Item no.: 100
Date: 30/04/2017
Page: 1 / 5

Version no.: 1

ETL 065-065-250 GG AV66D200304 BKSBIE3
Inline pump

Operating data

Requested flow rate	40.00 m^3/h	Actual flow rate	43.31 m^3/h
Requested developed head	12.50 m	Actual developed head	14.65 m
Pumped medium	Antifreeze on ethylene glycol base, inhibited, closed system, e.g. Antifrogen N or similar products Cooling water with antifreeze-concentration 30% (pH >= 7.5) Not containing chemical and mechanical substances which affect the materials	Efficiency	73.0 %
		MEI (Minimum Efficiency Index)	≥ 0.70
		Power absorbed	2.46 kW
		Pump speed of rotation	1451 rpm
		NPSH required	1.87 m
		Permissible operating pressure	16.00 bar.g
Ambient air temperature	20.0 °C		
Fluid temperature	20.0 °C		
Fluid density	1040 kg/m^3		
Fluid viscosity	2.22 mm^2/s	Discharge press.	1.49 bar.g
Suction pressure max.	0.00 bar.g	Min. allow. mass flow for continuous stable operation	2.28 kg/s
Mass flow rate	12.51 kg/s		
Max. power on curve	3.00 kW	Max. allow. mass flow	20.96 kg/s
Min. allow. flow for continuous stable operation	7.89 m^3/h	Design	Single system 1 x 100 % Tolerances to ISO 9906 Class 3B; below 10 kW acc. to paragraph 4.4.2
Shutoff head	18.48 m		

Design

Pump standard	Without	Shaft seal code	66
Design	Close-coupled in-line	Sealing plan	Single-acting mechanical seal with vented chamber (A-type casing cover, taper bore)
Orientation	Vertical		
Suction nominal dia.	DN 65		
Suction nominal pressure	PN 16	Seal chamber design	Conical seal chamber (A-type cover)
Suction position	180° (down)		
Suction flange drilled according to standard	EN1092-2	Contact guard	With
		Wear ring	Casing wear ring
Discharge nominal dia.	DN 65	Impeller diameter	223.0 mm
Discharge norminal pressure	PN 16	Free passage size	10.0 mm
Discharge position	top (0°/360°)	Direction of rotation from drive	Clockwise
Discharge flange drilled according to standard	EN1092-2		
		Silicon free pump assembly	Yes
Shaft seal	Single acting mechanical seal	Bearing bracket construction	Close-coupled
Manufacturer	Burgmann	Bearing bracket size	25
Type	MG13G6	Bearing type	Anti-friction bearings
Material code	Q7Q7EGG	Lubrication type	Grease
		Color	Vermilion (RAL 2002)

Performance curve

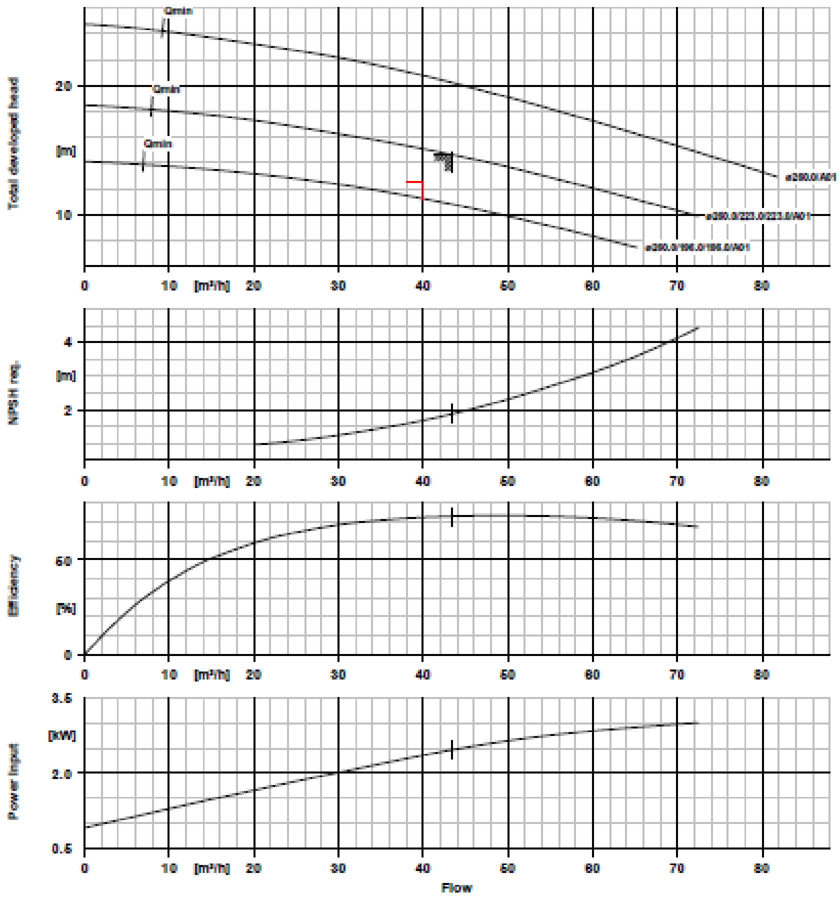
KSB

Customer item no.:
Communication dated:
Doc. no.:
Quantity: 1

Number: ES 5044007
Item no.:100
Date: 30/04/2017
Page: 3 / 5

Version no.: 1

ETL 065-065-250 GG AV66D200304 BKSBIE3
Inline pump



Curve data

Speed of rotation	1451 rpm	Efficiency	73.0 %
Fluid density	1040 kg/m³	MEI (Minimum Efficiency Index)	≥ 0.70
Viscosity	2.22 mm²/s	Power absorbed	2.46 kW
Flow rate	43.31 m³/h	NPSH required	1.87 m
Requested flow rate	40.00 m³/h	Curve number	K1159.454/33
Total developed head	14.65 m	Effective impeller diameter	223.0 mm
Requested developed head	12.50 m	Acceptance standard	Tolerances to ISO 9906 Class 3B; below 10 kW acc. to paragraph 4.4.2

Installation plan

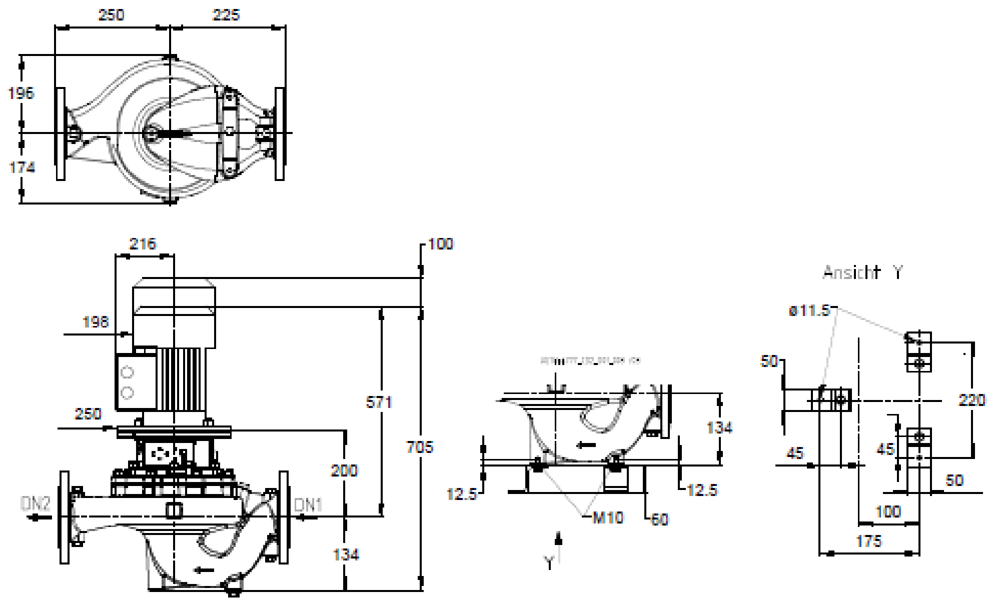
KSB

Customer item no.:
Communication dated:
Doc. no.:
Quantity: 1

Number: ES 5044007
Item no.:100
Date: 30/04/2017
Page: 4 / 5

Version no.: 1

ETL 065-065-250 GG AV66D200304 BKSBIE3
Inline pump



Drawing is not to scale *Dimensions in mm*

Motor

Motor manufacturer	KSB-Motor
Motor size	100L
Motor power	3.00 kW
Number of poles	4
Speed of rotation	1451 rpm
Position of terminal box	0° same orientation Viewed from the drive

Connections

Suction nominal size DN1	DN 65 / EN1092-2
Discharge nominal size DN2	DN 65 / EN1092-2
Nominal pressure suct.	PN 16
Rated pressure disch.	PN 16

Weight net

Pump	43 kg
Motor	34 kg
Total	77 kg

Connect pipes without stress or strain!

For auxiliary connections see separate drawing.

Appendix (10)

Air Cooled Official Offers Catalogues

Dear Sir,

Please find attached our offer for the supply of Air - Conditioning units as follows:

Total Price:

Description	Price (~~JD~~ USD)	Special price
EWYQ-F Chiller	63357	47,518
2-Pipe Flexi FWL (wall \ ceiling) Unit (Decorative)	19890	14,918
2-Pipe Flexi FWR (wall \ ceiling) Unit (Decorative)	9072	6,804
2-Pipe Ducted Unit FWD (Horizontal \ Vertical Concealed) High Static	13530	10,148
Total	**105849**	79,387 $

م. هيثم عيسى
31/5/2017

Brand: DAIKIN

Flexi (wall \ ceiling)

2-Pipe Flexi (wall \ ceiling) Unit (Decorative)							
Model	Heating (W)	Heating (Kcal/h)	Cooling (Kw)	Cooling (Ton)	Quantity	Unit Price (USD)	Total Price (USD)
FWL03DTN	8760	7560	2.93	0.84	1	752	752
FWL04DTN	12890	11124	4.33	1.24	4	854	3416
FWL06DTN	14620	12617	4.77	1.36	2	916	1832
FWL08DTN	19550	16872	6.71	1.92	9	1234	11106
FWL10DTN	25350	21877	8.71	2.49	2	1392	2784
						Total	19890

Note: All units are without controller.

2-Pipe Flexi (wall \ ceiling) Unit (Decorative)							
Model	Heating (W)	Heating (Kcal/h)	Cooling (Kw)	Cooling (Ton)	Quantity	Unit Price (USD)	Total Price (USD)
FWR08ATN	11180	9648	10.08	2.88	6	1512	9072
						Total	9072

Note: All units are without controller.

Ducted High Static

2-Pipe Ducted Unit (Horizontal \ Vertical Concealed) High Static							
Model	Heating (W)	Heating (Kcal/h)	Cooling (Kw)	Cooling (Ton)	Quantity	Unit Price (USD)	Total Price (USD)
FWD16AT	44570	38464	16.40	4.69	5	2706	13530
						Total	13530

Note: All units are without controller.

Appendix (11)

Cooling load final report using HAP 4.6

Air System Sizing Summary for AHU1 FF

Project Name: Child institute 06/02/2016
Prepared by: ameer 01:520

Air System Information

Air System Name	AHU1 FF		Number of zones	7	
Equipment Class	CW AHU		Floor Area	1733.0	ft²
Air System Type	VAV		Location	Amman, Jordan	

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM	Peak zone sensible load	Calculation Months	Jan to Dec
Space CFM	Individual peak space loads	Sizing Data	Calculated

Central Cooling Coil Sizing Data

Total coil load	61.4	Tons	Load occurs at	Sep 1500	
Total coil load	238.7	MBH	OA DB / WB	102.7 / 63.6	°F
Sensible coil load	238.7	MBH	Entering DB / WB	77.1 / 59.9	°F
Coil CFM at Sep 1500	10520	CFM	Leaving DB / WB	54.1 / 51.3	°F
Max block CFM at Oct 1500	11493	CFM	Coil ADP	51.5	°F
Sum of peak zone CFM	11810	CFM	Bypass Factor	0.100	
Sensible heat ratio	1.000		Resulting RH	39	%
ft²/Ton	87.1		Design supply temp.	55.0	°F
BTU/(hr-ft²)	137.7		Zone T-stat Check	7 of 7	OK
Water flow @ 10.0 °F rise	47.77	gpm	Max zone temperature deviation	0.0	°F

Preheat Coil Sizing Data

Max coil load	4.6	MBH	Load occurs at	Des Htg	
Coil CFM at Des Htg	288	CFM	Ent. DB / Lvg DB	33.7 / 50.0	°F
Max coil CFM	11493	CFM			
Water flow @ 20.0 °F drop	0.46	gpm			

Supply Fan Sizing Data

Actual max CFM at Oct 1500	11493	CFM	Fan motor BHP	2.05	BHP
Standard CFM	10478	CFM	Fan motor kW	1.63	kW
Actual max CFM/ft²	6.63	CFM/ft²	Fan static	0.60	in wg

Outdoor Ventilation Air Data

Design airflow CFM	282	CFM	CFM/person	8.31	CFM/person
CFM/ft²	0.16	CFM/ft²			

Zone Sizing Summary for AHU1 FF

Project Name: Child Institute 06/02/2016
Prepared by: ameer 01:52

Air System Information

Air System Name .... AHU1 FF
Equipment Class .... CW AHU
Air System Type .... VAV

Number of zones 7
Floor Area .... 1733.0 ft²
Location .... Amman, Jordan

Sizing Calculation Information

Zone and Space Sizing Method:

Zone CFM .... Peak zone sensible load
Space CFM .... Individual peak space loads

Calculation Months .... Jan to Dec
Sizing Data .... Calculated

Zone Sizing Data

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	9.9	503	22	Jun 1500	3.4	187.3	2.69
Zone 2	36.3	1846	36	Jul 1500	2.3	247.6	7.46
Zone 3	38.3	1945	35	Oct 1500	3.9	232.5	8.37
Zone 4	41.1	2088	37	Nov 1500	2.0	264.8	7.88
Zone 5	37.0	1877	46	Jun 1500	2.1	232.5	8.07
Zone 6	4.7	240	43	Jun 1500	2.2	187.3	1.28
Zone 7	60.6	3075	65	Oct 1500	4.8	381.0	8.07

Zone Terminal Sizing Data

Zone Name	Reheat Coil Load (MBH)	Reheat Coil Water gpm @ 20.0 °F	Zone Htg Coil Load (MBH)	Zone Htg Water gpm @ 20.0 °F	Mixing Box Fan Airflow (CFM)
Zone 1	3.8	0.38	0.0	0.00	0
Zone 2	2.8	0.28	0.0	0.00	0
Zone 3	4.5	0.45	0.0	0.00	0
Zone 4	2.5	0.25	0.0	0.00	0
Zone 5	2.8	0.28	0.0	0.00	0
Zone 6	2.8	0.28	0.0	0.00	0
Zone 7	5.8	0.58	0.0	0.00	0

Space Loads and Airflows

Zone Name / Space Name	Mult.	Cooling Sensible (MBH)	Time of Load	Air Flow (CFM)	Heating Load (MBH)	Floor Area (ft²)	Space CFM/ft²
Zone 1							
FF Administration office	1	9.9	Jun 1500	503	3.4	187.3	2.69
Zone 2							
FF Class1 N	1	36.3	Jul 1500	1846	2.3	247.6	7.46
Zone 3							
FF Class1W	1	38.3	Oct 1500	1945	3.9	232.5	8.37
Zone 4							
FF Class2 E	1	41.1	Nov 1500	2088	2.0	264.8	7.88
Zone 5							
FF Meeting room	1	37.0	Jun 1500	1877	2.1	232.5	8.07
Zone 6							
FF secreteray and waitin	1	4.7	Jun 1500	240	2.2	187.3	1.28
Zone 7							
FF staff room	1	60.6	Oct 1500	3075	4.8	381.0	8.07

Air System Design Load Summary for AHU1 FF

Project Name: Child institute 08/02/2016

Prepared by: ameer 01:52Ö

	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Sep 1500 COOLING OA DB / WB 102.7 °F / 63.6 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 33.0 °F / 27.5 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	405 ft²	17495	-	405 ft²	-	-
Wall Transmission	1456 ft²	6478	-	1456 ft²	12144	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	405 ft²	5531	-	405 ft²	8542	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	2889 ft²	0	-	2889 ft²	0	-
Ceiling	1633 ft²	2325	-	1633 ft²	0	-
Overhead Lighting	4025 W	7012	-	0	0	-
Task Lighting	2340 W	5823	-	0	0	-
Electric Equipment	57190 W	171428	-	0	0	-
People	34	5160	4084	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	409	409	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	221661	4493	-	20687	0
Zone Conditioning	-	216439	4493	-	17118	0
Plenum Wall Load	13%	1286	-	0	0	-
Plenum Roof Load	70%	0	-	0	0	-
Plenum Lighting Load	30%	4120	-	0	0	-
Return Fan Load	10520 CFM	0	-	288 CFM	0	-
Ventilation Load	282 CFM	7302	-4129	282 CFM	9865	0
Supply Fan Load	10520 CFM	5129	-	288 CFM	-1610	-
Space Fan Coil Fans	-	0	-	-	0	-
Duct Heat Gain / Loss	2%	4433	-	2%	414	-
>> Total System Loads	-	238709	364	-	25786	0
Central Cooling Coil	-	238709	0	-	0	0
Preheat Coil	-	0	-	-	4623	-
Terminal Reheat Coils	-	0	-	-	21163	-
>> Total Conditioning	-	238709	0	-	25786	0
Key:	Positive values are clg loads Negative values are htg loads			Positive values are htg loads Negative values are clg loads		

Zone Design Load Summary for AHU1 FF

Project Name: Child institute
Prepared by: ameer

06/02/2016
01:52O

Zone 1	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jun 1500 COOLING OA DB / WB 104.1 °F / 65.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 33.0 °F / 27.5 °F		
	OCCUPIED T-STAT 75.0 °F			OCCUPIED T-STAT 70.0 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	30 ft^2	1286	-	30 ft^2	-	-
Wall Transmission	336 ft^2	2127	-	336 ft^2	2802	-
Roof Transmission	0 ft^2	0	-	0 ft^2	0	-
Window Transmission	30 ft^2	434	-	30 ft^2	633	-
Skylight Transmission	0 ft^2	0	-	0 ft^2	0	-
Door Loads	0 ft^2	0	-	0 ft^2	0	-
Floor Transmission	0 ft^2	0	-	0 ft^2	0	-
Partitions	396 ft^2	0	-	396 ft^2	0	-
Ceiling	187 ft^2	0	-	187 ft^2	0	-
Overhead Lighting	435 W	758	-	0	0	-
Task Lighting	1740 W	4330	-	0	0	-
Electric Equipment	200 W	600	-	0	0	-
People	2	304	240	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	68	68	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	9906	308	-	3435	0

Zone 2	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jul 1500 COOLING OA DB / WB 105.1 °F / 65.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 33.0 °F / 27.5 °F		
	OCCUPIED T-STAT 75.0 °F			OCCUPIED T-STAT 70.0 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	60 ft^2	1960	-	60 ft^2	-	-
Wall Transmission	120 ft^2	538	-	120 ft^2	999	-
Roof Transmission	0 ft^2	0	-	0 ft^2	0	-
Window Transmission	60 ft^2	902	-	60 ft^2	1266	-
Skylight Transmission	0 ft^2	0	-	0 ft^2	0	-
Door Loads	0 ft^2	0	-	0 ft^2	0	-
Floor Transmission	0 ft^2	0	-	0 ft^2	0	-
Partitions	450 ft^2	0	-	450 ft^2	0	-
Ceiling	248 ft^2	0	-	248 ft^2	0	-
Overhead Lighting	575 W	1002	-	0	0	-
Task Lighting	100 W	249	-	0	0	-
Electric Equipment	10350 W	31024	-	0	0	-
People	4	607	480	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	68	68	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	36350	549	-	2264	0

Zone 3	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Oct 1500 COOLING OA DB / WB 98.1 °F / 61.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 33.0 °F / 27.5 °F		
	OCCUPIED T-STAT 75.0 °F			OCCUPIED T-STAT 70.0 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	90 ft²	5437	-	90 ft²	-	-
Wall Transmission	245 ft²	877	-	245 ft²	2041	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	90 ft²	994	-	90 ft²	1898	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	366 ft²	0	-	366 ft²	0	-
Ceiling	233 ft²	0	-	233 ft²	0	-
Overhead Lighting	540 W	941	-	0	0	-
Task Lighting	100 W	249	-	0	0	-
Electric Equipment	9720 W	29136	-	0	0	-
People	4	607	480	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	68	68	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	38309	549	-	3940	0

Zone 4	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Nov 1500 COOLING OA DB / WB 90.7 °F / 58.2 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 33.0 °F / 27.5 °F		
	OCCUPIED T-STAT 75.0 °F			OCCUPIED T-STAT 70.0 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	60 ft²	5296	-	60 ft²	-	-
Wall Transmission	82 ft²	227	-	82 ft²	685	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	60 ft²	409	-	60 ft²	1266	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	477 ft²	0	-	477 ft²	0	-
Ceiling	265 ft²	0	-	265 ft²	0	-
Overhead Lighting	615 W	1071	-	0	0	-
Task Lighting	100 W	249	-	0	0	-
Electric Equipment	11070 W	33183	-	0	0	-
People	4	607	480	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	68	68	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	41110	549	-	1950	0

Zone 5	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jun 1500 COOLING OA DB / WB 104.1 °F / 65.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 33.0 °F / 27.5 °F		
	OCCUPIED T-STAT 75.0 °F			OCCUPIED T-STAT 70.0 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	45 ft²	1928	-	45 ft²	-	-
Wall Transmission	136 ft²	828	-	136 ft²	1133	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	45 ft²	651	-	45 ft²	949	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	407 ft²	0	-	407 ft²	0	-
Ceiling	233 ft²	2325	-	233 ft²	0	-
Overhead Lighting	540 W	941	-	0	0	-
Task Lighting	100 W	249	-	0	0	-
Electric Equipment	9720 W	29136	-	0	0	-
People	6	911	721	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	0	0	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	36968	721	-	2082	0

Zone 6	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jun 1500 COOLING OA DB / WB 104.1 °F / 65.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 33.0 °F / 27.5 °F		
	OCCUPIED T-STAT 75.0 °F			OCCUPIED T-STAT 70.0 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	30 ft²	863	-	30 ft²	-	-
Wall Transmission	185 ft²	837	-	185 ft²	1545	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	30 ft²	434	-	30 ft²	633	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	425 ft²	0	-	425 ft²	0	-
Ceiling	187 ft²	0	-	187 ft²	0	-
Overhead Lighting	435 W	758	-	0	0	-
Task Lighting	100 W	249	-	0	0	-
Electric Equipment	200 W	600	-	0	0	-
People	6	911	721	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	68	68	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads		4719	789		2178	0

Zone Design Load Summary for AHU1 FF

Project Name: Child institute
Prepared by: ameer

06/02/2016
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Zone 7	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Oct 1500 COOLING OA DB / WB 98.1 °F / 61.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 33.0 °F / 27.5 °F		
	OCCUPIED T-STAT 75.0 °F			OCCUPIED T-STAT 70.0 °F		
ZONE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	90 ft²	7186	-	90 ft²	-	-
Wall Transmission	352 ft²	1559	-	352 ft²	2939	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	90 ft²	994	-	90 ft²	1898	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	368 ft²	0	-	368 ft²	0	-
Ceiling	281 ft²	0	-	281 ft²	0	-
Overhead Lighting	885 W	1542	-	0	0	-
Task Lighting	100 W	249	-	0	0	-
Electric Equipment	15930 W	47750	-	0	0	-
People	8	1214	961	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	68	68	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	60562	1029	-	4837	0

Space Design Load Summary for AHU1 FF

Project Name: Child institute
Prepared by: ameer

06/02/2016
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TABLE 1.1.A. COMPONENT LOADS FOR SPACE " FF Administration office " IN ZONE " Zone 1 "						
	DESIGN COOLING			DESIGN HEATING		
	COOLING DATA AT Jun 1500 COOLING OA DB / WB 104.1 °F / 65.0 °F OCCUPIED T-STAT 75.0 °F			HEATING DATA AT DES HTG HEATING OA DB / WB 33.0 °F / 27.5 °F OCCUPIED T-STAT 70.0 °F		
SPACE LOADS	Details	Sensible (BTU/hr)	Latent (BTU/hr)	Details	Sensible (BTU/hr)	Latent (BTU/hr)
Window & Skylight Solar Loads	30 ft²	1286	-	30 ft²	-	-
Wall Transmission	336 ft²	2127	-	336 ft²	2802	-
Roof Transmission	0 ft²	0	-	0 ft²	0	-
Window Transmission	30 ft²	434	-	30 ft²	633	-
Skylight Transmission	0 ft²	0	-	0 ft²	0	-
Door Loads	0 ft²	0	-	0 ft²	0	-
Floor Transmission	0 ft²	0	-	0 ft²	0	-
Partitions	396 ft²	0	-	396 ft²	0	-
Ceiling	187 ft²	0	-	187 ft²	0	-
Overhead Lighting	435 W	758	-	0	0	-
Task Lighting	1740 W	4330	-	0	0	-
Electric Equipment	200 W	600	-	0	0	-
People	2	304	240	0	0	0
Infiltration	-	0	0	-	0	0
Miscellaneous	-	68	68	-	0	0
Safety Factor	0% / 0%	0	0	0%	0	0
>> Total Zone Loads	-	9906	308	-	3435	0

TABLE 1.1.B. ENVELOPE LOADS FOR SPACE " FF Administration office " IN ZONE " Zone 1 "						
	Area (ft²)	U-Value (BTU/(hr-ft²-°F))	Shade Coeff.	COOLING TRANS (BTU/hr)	COOLING SOLAR (BTU/hr)	HEATING TRANS (BTU/hr)
NE EXPOSURE						
WALL	336	0.225	-	2127	-	2802
WINDOW 1	30	0.570	0.887	434	1286	633

Appendix (12)

Compound interest table

10%	Compound Interest Factors								10%
	Single Payment		Uniform Payment Series				Arithmetic Gradient		
n	Compound Amount Factor Find F Given P F/P	Present Worth Factor Find P Given F P/F	Sinking Fund Factor Find A Given F A/F	Capital Recovery Factor Find A Given P A/P	Compound Amount Factor Find F Given A F/A	Present Worth Factor Find P Given A P/A	Gradient Uniform Series Find A Given G A/G	Gradient Present Worth Find P Given G P/G	n
1	1.100	.9091	1.0000	1.1000	1.000	0.909	0	0	1
2	1.210	.8264	.4762	.5762	2.100	1.736	0.476	0.826	2
3	1.331	.7513	.3021	.4021	3.310	2.487	0.937	2.329	3
4	1.464	.6830	.2155	.3155	4.641	3.170	1.381	4.378	4
5	1.611	.6209	.1638	.2638	6.105	3.791	1.810	6.862	5
6	1.772	.5645	.1296	.2296	7.716	4.355	2.224	9.684	6
7	1.949	.5132	.1054	.2054	9.487	4.868	2.622	12.763	7
8	2.144	.4665	.0874	.1874	11.436	5.335	3.004	16.029	8
9	2.358	.4241	.0736	.1736	13.579	5.759	3.372	19.421	9
10	2.594	.3855	.0627	.1627	15.937	6.145	3.725	22.891	10
11	2.853	.3505	.0540	.1540	18.531	6.495	4.064	26.396	11
12	3.138	.3186	.0468	.1468	21.384	6.814	4.388	29.901	12
13	3.452	.2897	.0408	.1408	24.523	7.103	4.699	33.377	13
14	3.797	.2633	.0357	.1357	27.975	7.367	4.996	36.801	14
15	4.177	.2394	.0315	.1315	31.772	7.606	5.279	40.152	15
16	4.595	.2176	.0278	.1278	35.950	7.824	5.549	43.416	16
17	5.054	.1978	.0247	.1247	40.545	8.022	5.807	46.582	17
18	5.560	.1799	.0219	.1219	45.599	8.201	6.053	49.640	18
19	6.116	.1635	.0195	.1195	51.159	8.365	6.286	52.583	19
20	6.728	.1486	.0175	.1175	57.275	8.514	6.508	55.407	20
21	7.400	.1351	.0156	.1156	64.003	8.649	6.719	58.110	21
22	8.140	.1228	.0140	.1140	71.403	8.772	6.919	60.689	22
23	8.954	.1117	.0126	.1126	79.543	8.883	7.108	63.146	23
24	9.850	.1015	.0113	.1113	88.497	8.985	7.288	65.481	24
25	10.835	.0923	.0102	.1102	98.347	9.077	7.458	67.696	25
26	11.918	.0839	.00916	.1092	109.182	9.161	7.619	69.794	26
27	13.110	.0763	.00826	.1083	121.100	9.237	7.770	71.777	27
28	14.421	.0693	.00745	.1075	134.210	9.307	7.914	73.650	28
29	15.863	.0630	.00673	.1067	148.631	9.370	8.049	75.415	29
30	17.449	.0573	.00608	.1061	164.494	9.427	8.176	77.077	30
31	19.194	.0521	.00550	.1055	181.944	9.479	8.296	78.640	31
32	21.114	.0474	.00497	.1050	201.138	9.526	8.409	80.108	32
33	23.225	.0431	.00450	.1045	222.252	9.569	8.515	81.486	33
34	25.548	.0391	.00407	.1041	245.477	9.609	8.615	82.777	34
35	28.102	.0356	.00369	.1037	271.025	9.644	8.709	83.987	35
40	45.259	.0221	.00226	.1023	442.593	9.779	9.096	88.953	40
45	72.891	.0137	.00139	.1014	718.905	9.863	9.374	92.454	45
50	117.391	.00852	.00086	.1009	1 163.9	9.915	9.570	94.889	50
55	189.059	.00529	.00053	.1005	1 880.6	9.947	9.708	96.562	55

Appendix (13)

Hourly data report for Nablus city

Hourly Data Report

From date: 01/01/2015 To Date: 31/12/2015

Station Name: NAB00003 Nablus (Latitude: 32. 13 N) (Longitude: 35 .15 E) (Elv. 570)

Element Name: Dry bulb temp. ?c

Month: 06/2015

Day \ Time	0	3	6	9	12	15	18	21	Avg	Min	Max
01	16.8	16.3	19.0	25.0	26.0	21.0	18.6	18.0	20.1	16.3	26.0
02	17.7	18.0	19.0	24.5	26.0	24.3	20.5	17.6	21.0	17.6	26.0
03	17.2	16.0	22.5	26.5	28.6	24.0	20.0	17.8	21.6	16.0	28.6
04	17.2	16.4	21.0	25.0	25.8	24.0	18.0	16.8	20.5	16.4	25.8
05	16.4	16.0	18.6	23.0	23.0	20.0	19.0	18.0	19.3	16.0	23.0
06	16.0	14.8	23.0	24.4	25.7	22.2	20.0	18.2	20.5	14.8	25.7
07	17.5	17.0	21.5	27.0	28.0	25.7	21.2	20.8	22.3	17.0	28.0
08	19.3	18.2	27.0	32.0	34.0	35.3	30.0	26.5	27.8	18.2	35.3
09	25.0	23.3	26.5	27.5	29.9	26.0	21.2	19.6	24.9	19.6	29.9
10	19.0	18.6	20.4	24.0	25.7	22.0	19.5	18.6	21.0	18.6	25.7
11	18.0	17.8	20.0	24.0	24.5	23.7	19.4	18.0	20.7	17.8	24.5
12	17.0	15.3	22.6	25.2	26.8	23.2	18.0	17.2	20.7	15.3	26.8
13	17.0	16.7	19.2	23.2	27.0	23.0	19.8	18.6	20.6	16.7	27.0
14	18.7	17.6	21.0	24.5	24.6	23.6	20.0	18.5	21.1	17.6	24.6
15	18.0	18.3	20.0	26.0	27.7	23.8	20.0	19.2	21.6	18.0	27.7
16	18.4	18.0	21.8	29.5	29.8	25.7	22.8	22.0	23.5	18.0	29.8
17	20.7	20.1	27.0	30.4	31.2	28.0	25.0	23.5	25.7	20.1	31.2
18	22.0	20.0	28.6	31.5	32.5	28.2	24.3	22.8	26.2	20.0	32.5
19	22.9	21.7	28.9	29.6	29.0	24.6	21.3	20.6	24.8	20.6	29.6
20	19.7	19.2	20.0	23.0	25.9	23.8	22.0	19.0	21.6	19.0	25.9
21	19.0	18.7	24.0	26.3	25.1	23.0	19.7	19.2	21.9	18.7	26.3
22	18.0	18.2	24.0	25.6	26.8	23.8	20.0	19.2	22.0	18.0	26.8
23	18.7	18.0	19.2	26.4	28.0	23.6	20.0	19.0	21.6	18.0	28.0
24	18.8	18.5	23.0	24.0	25.8	23.4	21.0	18.6	21.6	18.5	25.8
25	17.6	17.2	20.8	24.2	26.4	23.2	20.0	19.0	21.1	17.2	26.4
26	18.8	19.0	22.4	24.2	27.2	24.3	21.0	20.4	22.2	18.8	27.2
27	20.0	19.7	26.0	28.2	31.1	30.0	26.0	25.5	25.8	19.7	31.1
28	23.4	21.0	23.0	24.6	26.0	24.6	20.6	19.7	22.9	19.7	26.0
29	18.7	18.1	23.5	25.2	26.4	24.7	20.6	19.0	22.0	18.1	26.4
30	18.4	17.8	23.0	24.0	26.0	24.0	20.2	19.2	21.6	17.8	26.0
Avg	18.9	18.2	22.6	26.0	27.4	24.6	21.0	19.7			
Min	16.0	14.8	18.6	23.0	23.0	20.0	18.0	16.8			
Max	25.0	23.3	28.9	32.0	34.0	35.3	30.0	26.5			

From date: 01/01/2015 To Date: 31/12/2015

Station Name: NAB00003 Nablus (Latitude: 32. 13 N) (Longitude: 35 .15 E) (Elv. 570)

Element Name: Dry bulb temp. ?c

Month: 07/2015

Time / Day	0	3	6	9	12	15	18	21	Avg	Min	Max
01	18.1	17.8	21.0	26.8	29.2	27.0	22.0	20.0	22.7	17.8	29.2
02	20.0	19.8	23.0	26.8	28.7	25.6	22.0	20.8	23.3	19.8	28.7
03	20.0	19.0	24.4	26.0	28.0	26.0	21.4	19.6	23.1	19.0	28.0
04	18.5	18.1	23.2	26.5	28.3	26.8	21.6	19.7	22.8	18.1	28.3
05	19.8	18.8	26.3	28.2	32.6	30.8	24.7	22.7	25.5	18.8	32.6
06	23.0	21.7	28.2	31.5	31.5	26.4	23.6	21.0	25.9	21.0	31.5
07	19.9	19.1	21.0	26.3	27.4	25.4	21.0	19.8	22.5	19.1	27.4
08	19.2	18.7	23.0	26.3	28.4	27.0	22.0	21.0	23.2	18.7	28.4
09	20.0	19.0	27.0	29.0	31.5	27.2	22.8	20.2	24.6	19.0	31.5
10	19.4	19.1	21.0	28.0	29.0	26.2	21.2	20.4	23.0	19.1	29.0
11	20.0	20.3	23.0	26.0	27.6	26.6	23.0	22.0	23.6	20.0	27.6
12	21.0	20.2	25.0	26.3					23.1	20.2	26.3
13			22.0	27.5	28.0	26.0	22.4	21.2	24.5	21.2	28.0
14	21.1	20.5	24.0	28.6	29.0	26.6	23.2	22.0	24.4	20.5	29.0
15	21.0	20.0	25.3	28.0	29.0	27.5	24.2	22.5	24.7	20.0	29.0
16	21.7	20.0	24.4	27.4	30.7	28.3			25.4	20.0	30.7
17	22.8	20.8	24.4	31.8	32.0	28.0	24.0	22.8	25.8	20.8	32.0
18	22.6	22.0	25.0	30.0	30.3	28.3	25.0	24.0	25.9	22.0	30.3
19	22.6	20.5	25.8	31.0	32.0	28.2	24.3	22.7	25.9	20.5	32.0
20	21.5	20.4	26.0	29.3	31.2	29.5	24.2	22.2	25.5	20.4	31.2
21	21.2	20.8	26.0	29.5	30.0	28.6	24.4	22.7	25.4	20.8	30.0
22	21.8	22.2	26.0	30.0	31.5	29.3	24.9	23.2	26.1	21.8	31.5
23	21.9	20.6	28.2	32.0	33.7	29.3	25.6	22.2	26.7	20.6	33.7
24	21.7	24.8	27.2	32.2	35.8	31.8	26.3	26.9	28.3	21.7	35.8
25	28.2	24.0	32.0	33.7	33.2	30.0	25.6	22.8	28.7	22.8	33.7
26	22.3	22.3	24.5	30.4	30.6	27.6	23.6	22.4	25.5	22.3	30.6
27	21.7	21.5	23.2	27.2	30.2	27.2	22.2	21.7	24.4	21.5	30.2
28	21.2	20.8	24.0	28.6	29.0	27.4	24.2	24.2	24.9	20.8	29.0
29	24.3	24.2	27.0	32.0	33.1	29.3	24.6	23.2	27.2	23.2	33.1
30	20.9	20.3	27.0	32.0	35.0	31.0	28.0	25.8	27.5	20.3	35.0
31	24.4	23.8	28.0	35.0	35.7	31.9	26.6	24.7	28.8	23.8	35.7
Avg	21.4	20.7	25.0	29.2	30.7	28.0	23.7	22.2			
Min	18.1	17.8	21.0	26.0	27.4	25.4	21.0	19.6			
Max	28.2	24.8	32.0	35.0	35.8	31.9	28.0	26.9			

Hourly Data Report

From date: 01/01/2015 To Date: 31/12/2015

Station Name: NAB00003 Nablus (Latitude: 32. 13 N) (Longitude: 35 .15 E) (Elv. 570)

Element Name: Dry bulb temp. ?c

Month: 08/2015

Day \ Time	0	3	6	9	12	15	18	21	Avg	Min	Max
01	25.0	23.1	30.2	35.0	35.5	31.6	28.2	29.0	29.7	23.1	35.5
02	25.8	25.0	32.0	38.0	39.5	38.3	34.4	32.9	33.2	25.0	39.5
03	29.7	29.2	29.0	35.0	36.5	34.2	29.2	26.7	31.2	26.7	36.5
04	24.9	24.4	28.8	34.0	36.2	31.4	27.4	26.0	29.1	24.4	36.2
05	24.2	24.0	27.4	33.2	32.5	29.8	25.6	24.5	27.7	24.0	33.2
06	24.0	23.0	26.4	30.0	30.5	28.6	24.5	23.4	26.3	23.0	30.5
07	22.6	21.8	30.0	33.0	35.4	33.4	28.3	27.2	29.0	21.8	35.4
08	25.5	24.5	34.6	35.7	37.3	32.7	26.0	24.8	30.1	24.5	37.3
09	24.3	22.9	26.4	31.0	31.0	26.6	24.8	23.7	26.3	22.9	31.0
10	23.1	22.7	25.4	29.5	30.0	28.7	24.9	23.7	26	22.7	30.0
11	23.1	23.0	25.4	30.0	31.6	27.0	25.0	23.6	26.1	23.0	31.6
12	23.2	22.6	24.0	28.0	31.8	27.2	24.2	23.6	25.6	22.6	31.8
13	23.0	22.5	24.5	29.4	30.0	28.5	24.3	22.8	25.6	22.5	30.0
14	22.4	22.3	25.5	30.2	32.4	27.4	24.8	23.1	26.0	22.3	32.4
15	22.6	21.7	25.4	31.2	35.0	30.0	26.7	26.3	27.4	21.7	35.0
16	25.0	23.2	32.0	35.0	37.0	34.7	32.1	30.2	31.2	23.2	37.0
17	30.1	27.2	31.3	35.0	35.9	32.4	28.0	25.4	30.7	25.4	35.9
18	25.0	24.2	27.6	32.5	33.0	30.0	25.5	24.4	27.8	24.2	33.0
19	24.0	23.4	26.0	30.0	31.5	29.6	25.3	23.7	26.7	23.4	31.5
20	23.2	22.8	26.0	30.0	32.0	29.6	25.2	23.5	26.5	22.8	32.0
21	23.3	22.5	25.0	27.8	30.3	27.6	24.0	22.8	25.4	22.5	30.3
22	22.4	21.8	23.4	28.0	32.0	27.6	24.0	23.0	25.3	21.8	32.0
23	22.4	22.0	24.0	28.5	30.4	28.8	24.4	23.3	25.5	22.0	30.4
24	22.8	22.8	24.2	28.0	30.3	27.5	24.4	21.8	25.2	21.8	30.3
25	22.2	21.7	23.8	26.0	28.6	26.5	23.6	22.2	24.3	21.7	28.6
26	21.4	21.0	25.0	29.0	32.0	27.8	24.6	23.5	25.5	21.0	32.0
27	22.6	22.7	25.5	30.0	31.2	28.4	24.2	23.1	26.0	22.6	31.2
28	22.8	23.4	25.6	31.5	32.0	27.4	24.0	23.6	26.3	22.8	32.0
29	23.0	21.6	25.5	31.0	31.9	28.0	24.3	23.6	26.1	21.6	31.9
30	22.8	22.2	24.4	28.3	30.1	26.6	24.2	23.2	25.2	22.2	30.1
31	22.3	21.6	24.4	28.4	30.4	28.3	24.4	23.3	25.4	21.6	30.4
Avg	23.8	23.1	26.7	31.0	32.7	29.6	25.8	24.6			
Min	21.4	21.0	23.4	26.0	28.6	26.5	23.6	21.8			
Max	30.1	29.2	34.6	38.0	39.5	38.3	34.4	32.9			

Hourly Data Report

From date: 01/01/2015 To Date: 31/12/2015

Station Name: NAB00003 Nablus (Latitude: 32. 13 N) (Longitude: 35 .15 E) (Elv. 570)

Element Name: Dry bulb temp. ?c

Month: 09/2015

Time / Day	0	3	6	9	12	15	18	21	Avg	Min	Max
01	22.5	22.1	24.4	28.4	28.8	28.0	24.7	23.4	25.3	22.1	28.8
02	23.0	22.0	25.4	30.9	32.8	28.2	23.6	22.9	26.1	22.0	32.8
03	22.2	21.8	25.0	30.0	33.2	27.8	24.8	24.0	26.1	21.8	33.2
04	23.1	22.5	25.4	28.0	30.3	26.8	22.2	21.8	25.0	21.8	30.3
05	21.6	21.2	25.0	28.0	29.9	26.2	23.1	22.4	24.7	21.2	29.9
06	22.3	22.0	23.0	28.4	29.6	26.6	23.0	22.9	24.7	22.0	29.6
07	23.4	23.3	25.0	29.5	32.0	28.8	25.3	26.2	26.7	23.3	32.0
08	29.7	30.0	29.8	31.0	33.0	32.5	31.7	32.7	31.3	29.7	33.0
09	29.0	26.1	29.5	33.8	35.8	29.0	27.8	28.2	29.9	26.1	35.8
10	28.4	26.7	29.6	35.0	36.5	31.8	30.0	27.4	30.7	26.7	36.5
11	25.1	24.4	30.2	35.2	36.0	30.7	27.0	28.7	29.7	24.4	36.0
12	26.0	24.2	27.0	30.2	35.8	31.0	26.3	25.5	28.3	24.2	35.8
13	25.0	23.6	26.0	29.8	32.8	28.4	25.0	24.2	26.9	23.6	32.8
14	23.2	22.8	26.0	30.0	32.0	28.7	24.8	23.0	26.3	22.8	32.0
15	23.3	23.1	24.5	30.0	31.0	29.0	25.6	25.0	26.4	23.1	31.0
16	24.4	23.8	25.5	30.0	31.0	26.7	24.0	22.7	26.0	22.7	31.0
17	20.8	20.4	26.5	29.5	32.0	26.8	23.7	22.8	25.3	20.4	32.0
18	21.3	21.6	25.8	27.8	29.3	27.7	22.4	22.0	24.7	21.3	29.3
19	20.8	19.8	26.7	29.8	32.2	28.0	25.7	26.4	26.2	19.8	32.2
20	26.0	23.3	29.0	33.0	33.0	29.0	26.5	24.3	28.0	23.3	33.0
21	23.3	23.0	24.0	26.4	27.7	26.6	22.2	21.4	24.3	21.4	27.7
22	19.8	18.7	24.0	29.4	30.5	29.0	25.1	22.5	24.9	18.7	30.5
23	20.7	22.0	30.0	35.4	24.3	29.8	25.0	23.4	26.3	20.7	35.4
24	22.6	21.8	30.0	33.0	33.3	28.5	24.9	24.4	27.3	21.8	33.3
25	22.2	24.1	28.4	29.6	30.2	30.2	23.6	23.0	26.4	22.2	30.2
26	21.4	21.0	27.2	28.9	30.4	26.8	22.0	21.0	24.8	21.0	30.4
27	20.5	20.0	25.0	28.0	29.8	24.6	21.7	21.0	23.8	20.0	29.8
28	20.3	19.8	24.5	28.0	30.3	24.6	22.3	21.7	23.9	19.8	30.3
29	21.3	21.1	24.5	26.0	27.8	25.6	22.4	21.3	23.8	21.1	27.8
30	20.2	19.5	24.0	27.8	30.0	27.5	24.6	23.5	24.6	19.5	30.0
Avg	23.1	22.5	26.4	30.0	31.4	28.2	24.7	24.0			
Min	19.8	18.7	23.0	26.0	24.3	24.6	21.7	21.0			
Max	29.7	30.0	30.2	35.4	36.5	32.5	31.7	32.7			

جامعة النجاح الوطنية
كلية الدراسات العليا

مقارنة بين نظام VRF ونظام Chiller Air to Water من حيث استهلاك الطاقة ومن الناحية الاقتصادية في أنظمة تكييف الهواء، دراسة حالة: مبنى طفولة جامعة النجاح

إعداد
أمير محمد طاهر خليل

إشراف
د. عماد بريك
د. عبد الرحيم أبو صفا

قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة الطاقة النظيفة وترشيد الاستهلاك بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2018م

مقارنة بين نظام VRF ونظام Chiller Air to Water من حيث استهلاك الطاقة ومن الناحية الاقتصادية في أنظمة تكييف الهواء، دراسة حالة: مبنى طفولة جامعة النجاح

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الملخص

تحتل انظمة التكييف والتبريد مراتب عليا في نسبة استهلاك الطاقة في الضفة الغربية في الوقت الذي تعاني منه الضفة الغربية من شح و غلاء لموارد الطاقة والكهرباء، لذلك ترشيد الاستهلاك في الطاقة اصبح ضرورة ملحة فيها.

في هذا البحث تم مناقشة ودراسة نظامين للتكييف والتبريد، الاول هو نظام الجريان المتغيير للمبرد والنظام الثاني هو نظام التكييف المركزي التشيلر وذلك بهدف الخروج بالنظام الاكثر توفيرا للطاقة و توفيرا للمال. هذه المناقشة طبقت على مبنى مركز طفولة النجاح المكون من اربع طابق وحسبت الاحمال الحرارية في المبنى باستخدام برنامج التصميم الحراري وكان مجمل الحمل الحراري في المبنى 60 طن.

تخلل هذه الدراسة تحليل وتصميم للنظامين من ناحية ميكانيكية وحرارية للوحدات الخارجية والداخلية وحساباتها وايضا شبكات الانابيب والصاج الداخلي والمضخات وحساباتها. بعد ذلك تم طلب الاسعار الرسمية من الشركات المحلية ليتم بعد ذلك مقارنة الاسعار الرسمية باستخدام قاعدة ال القيمة الحالية، بحيث ان القيمة الاقل سالبية للنظامين تدل على ان هذا النظام افضل من ناحية اقتصادية و موفر للطاقة، وكانت القيمة الحالية لنظام التدفق المتغير للمبرد - 158,204 $ والقيمة الحالية لنظام التشيلر المركزي $ 182,654.0-، وحسب قاعدة القيمة الحالية فالقيمة الاقل سالبية تعبّر عن النظام المناسب والاقل كلفة و الاكثر توفيرا للطاقة وهو نظام الجريان المتغير للمبرد.