College of Engineering & Technology
Mechanical Engineering Department

Graduation Project

Design and cost estimation of water supply drainage system , air conditioning system and treatment system of solid and waste water for 1049.07 m^2 for villa in Dura

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Abstract

Using supply system is provide the building for potable water by pumping it from well to the different fixtures throw tubes called risers and using boilers to heat the water

In drainage system which help the building to dispose the waste and sold water and by using water treatment in order to use gray water for flushing and irrigation.

For every store we will use different system:

Under floor heating system is a winter heating method that is considered are a part of what is known as panel heating , the heated panel in this case is part of the space floor to be heated .

Air conditioning system implies much more than the central of the inside temperature of a given space

It implies the controlling and maintaining of the following four atmospheric can that effect the human comfort

1. Temperature of the space
2. Humidity or the moisture contents of the air
3. Purity and quality of the inside air
4. Air velocity and air circulation within the space

Satisfy the human comfort we will provide the inner rooms by split units

The hot water heating system consist of the boiler or the solar panels system and the system of pipes connected to radiators , piping located in rooms to be heated .

So to make the estimation will be done for the system after design and it`s drawings on the real drawings to make the specifications dimensions and quantities for all mechanical parts used in this villa

This project is done as an applies for several engineering courses which has been studies in our Specialization .

Chapter One

Introduction

Introduction

1.1 introduction

in this project , at real is made to make the best air conditioning , heating , plumbing , water treatment systems to cover the requirements in villa at Dura .
a heating system consist of all the pipe work and radiators that are connected to the boiler . the boiler provides the heat by pump that moves the heated water from the boiler through the pipe work to the radiators and back to the boiler for reheating

The term air conditioning implies much more than the control of the inside temp of a given space.
The main goal of plumping design for building is to safely and reliably provide domestic water , cooking gas and water for fire fitting and to remove sanitary wastes .

1.2 project objectives

1. our project goal is to design air conditioning , heating , plumbing , water treatment systems
2. to prepare the required drawings for the above mentioned systems
3. to select the required equipments and parts

1.3 Project benefits

We chose this project to prepare a full document for mechanical systems in this villa which located in Dura .

Documentation :

1.cooling load calculation for air conditioning system

2.heating load calculations for heating system

3.calculations for flow and pipes for plumbing system

4.design for water treatment system

5.preparing the required drawings

6.selection of the required equipment`s and parts

1.4 Timing table

Table (1.1) First semester time table

week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Choosing the building plane															
Overview previous projects															
Water supply and plumbing system calculations and design															
Drainage system calculations															
Overall coefficient calculations for walls , ceiling , floor ,doors and windows															
Heating load calculations															
Air conditioning calculations															
Drawings															

Table (1.2) Second semester time table

week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Gather information	■	■	■	■	■										
Under floor heating calculations			■	■	■	■	■	■	■	■	■	■			
Design water treatment system			■	■	■	■	■	■	■	■	■	■			
Auditing our work in the project			■	■	■	■	■	■	■	■	■	■	■	■	■
Prepare the quantity tables													■	■	
Drawings											■	■	■	■	
Project documentation			■	■	■	■	■	■	■	■	■	■	■	■	■

Chapter 2

Air Conditioning by using VRV system

2.1 Introduction

Variable refrigerant volume (VRV) systems, which were introduced in Japan more than 20 years ago, have become popular in many countries; The technology has gradually expanded its market presence, reaching European markets in 1987, and steadily gaining market share throughout the world. VRV systems are used in approximately 50% of medium sized commercial buildings (up to 6,500 m^2).

VRV systems are larger in capacity, more complex versions of the ductless multisplit systems, with the additional capability of connecting ducted style fan coil units. They require many evaporators and complex oil and refrigerant management and control system. Also, they need a separate ventilation system.

The term variable refrigerant flow refers to the ability of the system to control the amount of refrigerant flowing to each of the evaporators. This enables the use of many evaporators of different capacities and configurations, individualized comfort control, simultaneous heating and cooling in different zones, and heat recovery from one zone to another. This refrigerant flow control lied at the heart of VRV systems and is the major technical challenge as well as the source of many of the systems advantages.

Many HVAC professionals are familiar with ductless mini split products. A variation of this product, often referred to as a multi split, includes multiple indoor evaporators connected to a single condensing unit see figure (5-1). Ductless products are fundamentally different from ducted systems. VRV air-conditioning system is in power air-conditioning system, by controlling the amount of circulating refrigerant compressor and access to indoor heat exchanger refrigerant flow in a timely manner to meet the requirements of indoor hot and cold load .

The main advantage of a VRV system is its ability to respond to fluctuations in space load conditions by allowing each individual thermostat to modulate its corresponding electronic expansion valve to maintain its space temperature set point.

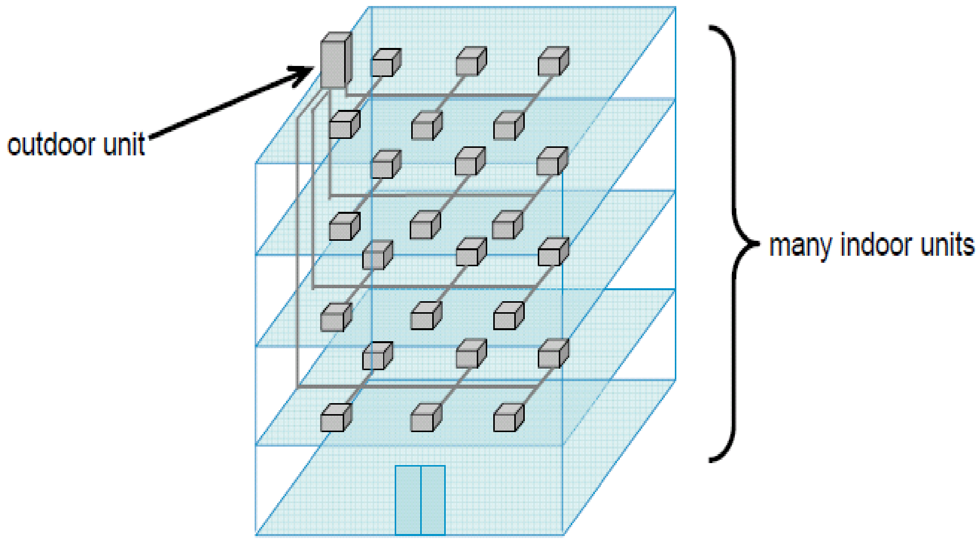

Figure 2.1: Distribution units,internal and external

Figure (2-2) shows main components of VRV system that includes outdoor unit that contains inverter compressor, heat exchanger and multiple indoor units that contain fan coil and electronic expansion valve.

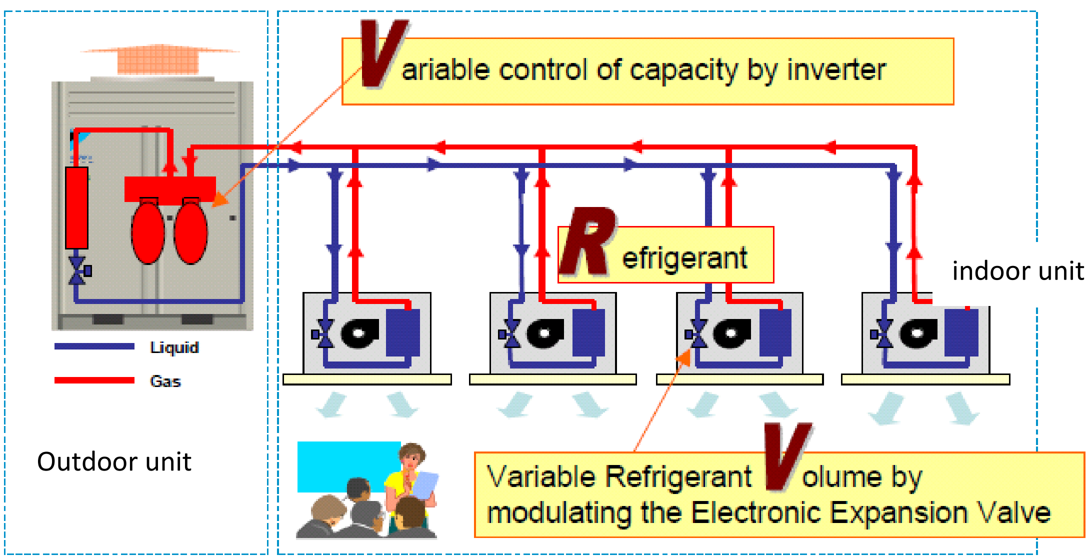

Figure1.2 : main components of VRV system

2.2 Refrigerant Cycle And Components

Figure (2.3) shows the concept of Basic Refrigeration Cycle for VRV system that includes either a two-pipe (liquid and suction gas) or three-pipe (liquid, suction gas, and discharge gas) configuration Using a control system, refrigerant is pumped through pipes to individually sized configured evaporators in each space, each of which can have its own thermostat. It's a closed-loop system so refrigerant is continuously circulated, VRV air conditioning systems need to use inverter compressor to achieve the combination of compressor capacity control and electronic expansion valve to regulate access to indoor unit refrigerant flow.

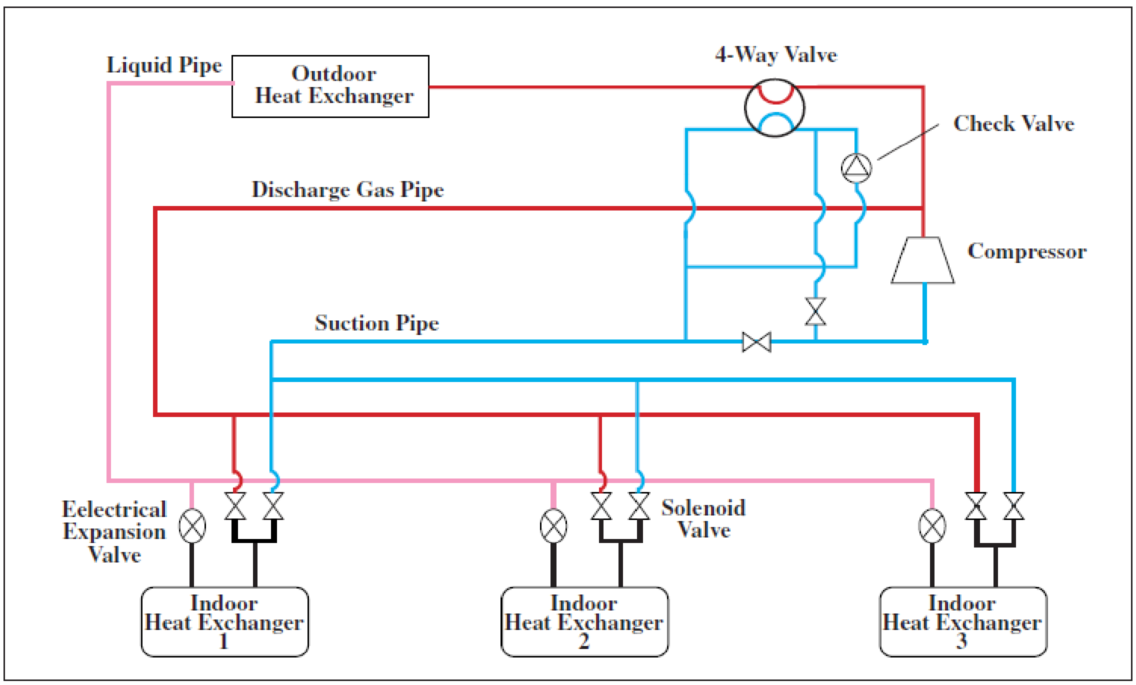

Figure 2.3 Basic Refrigeration Cycle for VRV

2.3 Inverter Compressor

VRV system use inverter controller that enables compressor speed to vary according to the cooling/heating load and therefore consume only the power necessary to match that load. The 50 Hz frequency of the power supply is inverted to a higher or lower frequency according to the required capacity to heat or cool the room. If a lower capacity is needed, the frequency is decreased and less energy is used. Under partial load conditions, the energy efficiency is higher. If the compressor rotates more slowly because less capacity is needed, the coil becomes virtually oversized. Improved efficiencies can therefore be achieved than are possible with non inverter compressors, which always run at the same speed.

2.4 Types Of VRV

There are two basic types of VRV multi-split systems: heat pump and heat recovery. Heat pumps can operate in heating or cooling mode. A heat-recovery system, by managing the refrigerant through a gas flow device, can simultaneously heat and cool, some indoor fan coil units in heating and some in cooling, depending on the requirements of each building zone.

2.4.1 Cooling Operation

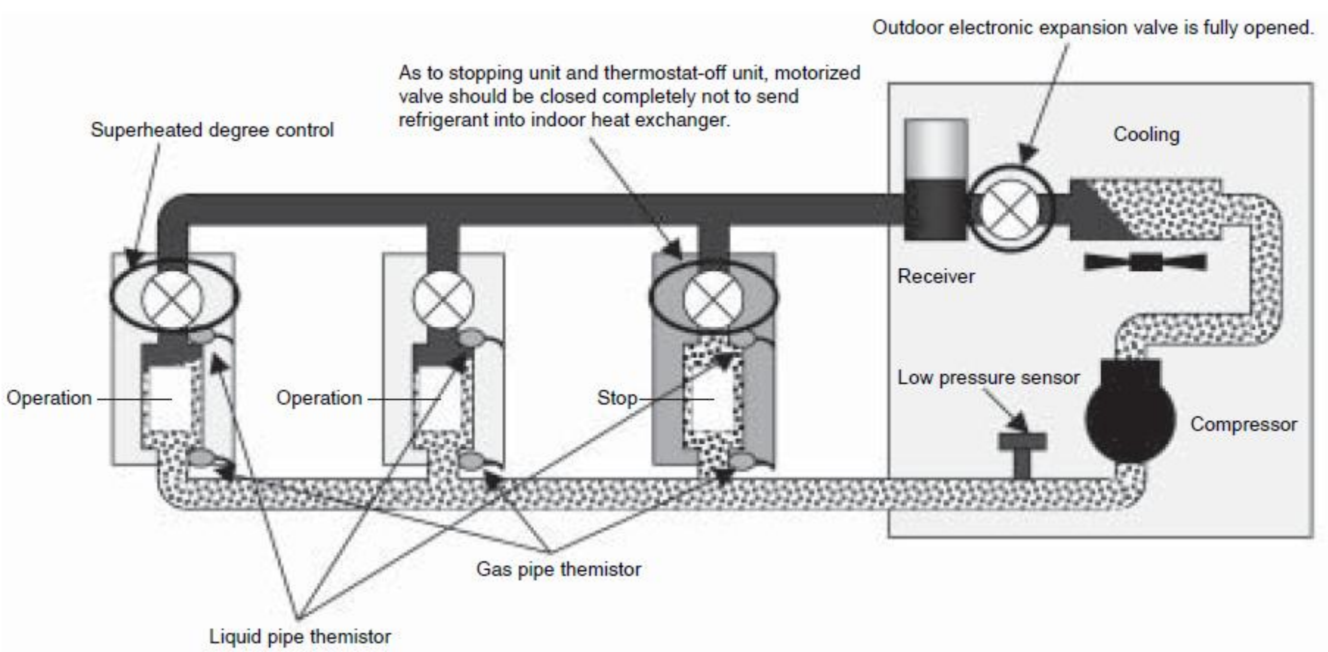

Figure 2.4: Schematic diagram for cooling operation

To maintain the cooling capacity corresponding to the capacity of evaporator and load fluctuation, based on the pressure detected by low pressure sensor of outdoor unit (Pe), the compressor capacity is so controlled to put the low pressure equivalent saturation temperatures (evaporation temperature = Te) close to target value. In order to maintain the superheated degree in evaporator and to distribute proper refrigerant flow rate in spite of different loads on every indoor unit, based on the temperature detected by thermostats of liquid pipes and gas pipes, indoor electronic expansion valve is so regulated as to put superheated degree at evaporator outlet close to target value. Superheated degree equal (indoor gas pipe temperature – indoor liquid pipe temperature).

2.4.2 Heating Operation

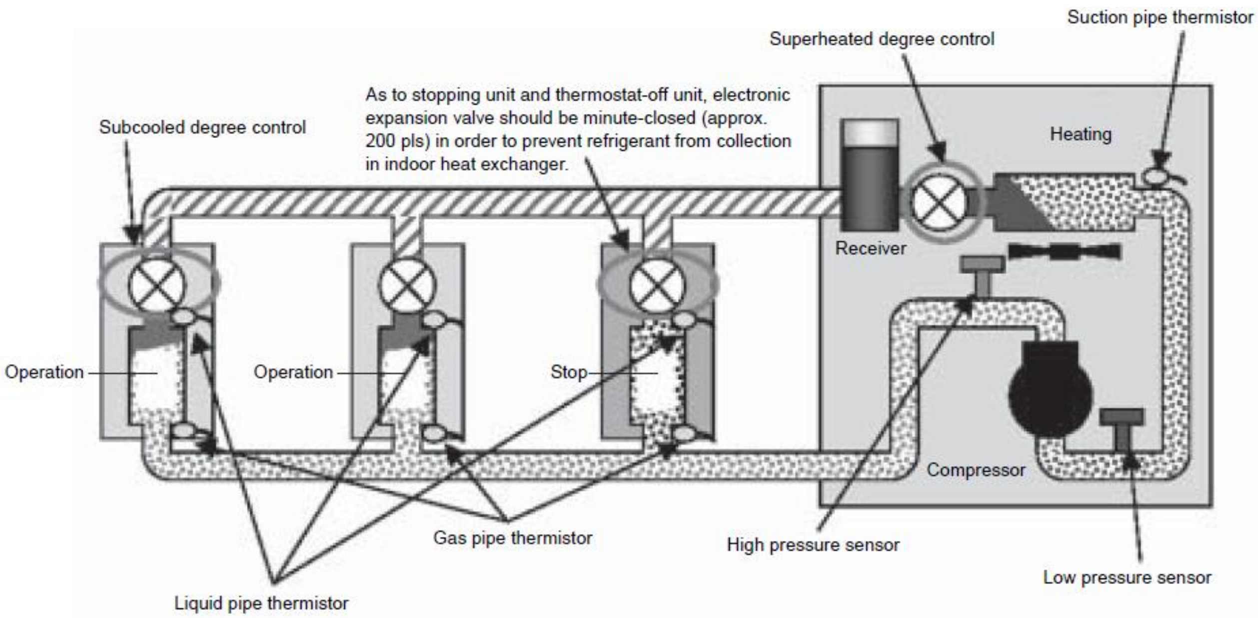

Figure 2.5: Schematic diagram for heating operation

To maintain the heating capacity against condenser capacity and load fluctuation, based on the pressure detected by high-pressure sensor control (Pc), compressor capacity is so controlled to put the high pressure equivalent saturation temperature (condensing temperature Tc) close to target value. In order to maintain the superheated degree in evaporator, based on the pressure detected by the low pressure sensor (Te) and the temperature detected by the thermostat of suction pipe, outdoor electronic expansion valve is so controlled as to put superheated degree at evaporator outlet close to target value. Superheated degree equal (outdoor suction pipe temperature – outdoor evaporating temperature).

In order to distribute proper refrigerant flow rate in spite of different loads on every indoor unit, based on the pressure detected by the high pressure sensor of outdoor unit (Tc) and the temperature detected by the thermostat of indoor liquid pipes, indoor electronic expansion valve is so controlled as to put subcooled degree at condenser outlet close to target value. Subcooled degree equal (outdoor condensing temperature – indoor liquid pipe temperature).

2.4.2.1 Heating And Defrost Operation

In heating mode, VRVsystems typically must defrost like any mechanical heat pump, using reverse cycle valves to temporarily operate the outdoor coil in cooling mode. Oil return and balance with the refrigerant circuit is managed by the microprocessor to ensure that any oil entrained in the low side of the system is brought back to the high side by increasing the refrigerant velocity using a high-frequency operation performed automatically based on hours of operation.

2.4.2.2 Heat Recovery Operation

Heat recovery operation is achieved using either 3 pipes or 2 pipes (depending on manufacturer). See figure. 5.6 and 5.7 . The 2 pipe heat recovery system has a central branch

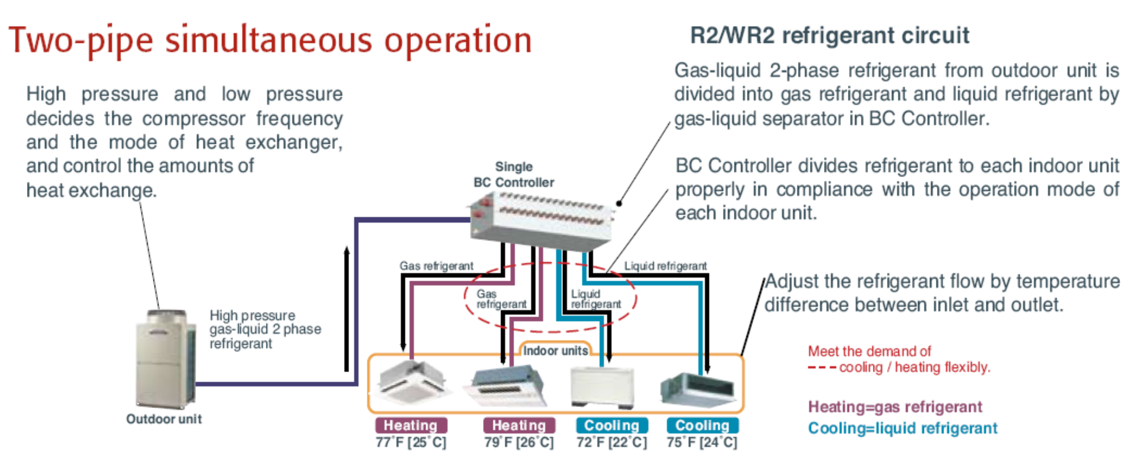

Figure 2.6 Two pipe heat recovery syste

controller with two pipes from the outdoor unit and 2 pipes to each indoor unit . For mixed mode operation the branch controller separates a mixture of saturated liquid and vapor delivered by the outdoor unit so that each indoor can receive high pressure liquid or vapor. In both cases the liquid produced by indoor units in heating mode is then used to serve indoor units in cooling mode and improved energy saving is possible.

The three pipe heat recovery system has a liquid line, a hot gas line and a suction line from the outdoor unit. Each indoor unit is branched off from the 3 pipes using solenoid valves. An indoor unit requiring cooling will open its liquid line and suction line valves and act as an evaporator. An indoor unit requiring heating will open its hot gas and liquid line valves and will act as a condenser.

2.5 Features

2.5.1 High-Performance VRV System For Cold Climate

VRV system's energy efficiency is higher than that of normal duct systems. The VRV essentially eliminate duct losses, which are often estimated to be between 10%~20% of total airflow in a ducted system. VRV systems typically include two or three compressors. This approach yields high part-load efficiency, which translates into high seasonal energy efficiency, because HVAC systems typically spend most of their operating hours in the range of 40% to 80% of maximum capacity. For buildings requiring simultaneous heating and cooling, heat recovery VRV systems can be used. These systems circulate refrigerant between zones, transferring heat from indoor units of zones being cooled to those of zones being heated.

The most sophisticated VRV systems can have indoor units, served by a single outdoor unit, in both heating and cooling modes simultaneously. This mixed mode operation leads to energy savings as both ends of the thermodynamic cycle are delivering useful heat exchange. If a system has a cooling COP (Coefficient of Performance) of 3, and a heating COP of 4, then heat recovery operation could yield a COP as high as 7. It should be noted that this perfect balance of heating and cooling demand is unlikely to occur for many hours each year, but whenever mixed mode is used energy is saved. In mixed mode the energy consumption is dictated by the larger demand, heating or cooling, and the lesser demand, cooling or heating is delivered free. Units are now available to deliver the heat removed from space cooling into hot water for space heating, domestic hot water or leisure applications, so that mixed mode is utilized for more of the year.

2.5.2 Operation Range

VRV can be Installation in extreme temperature conditions is possible due to an increase in operational range cooling mode can be operated from : -15°C to 46°C and heating mode can be operated from -20°C to 21°C see figure 5.8 below.

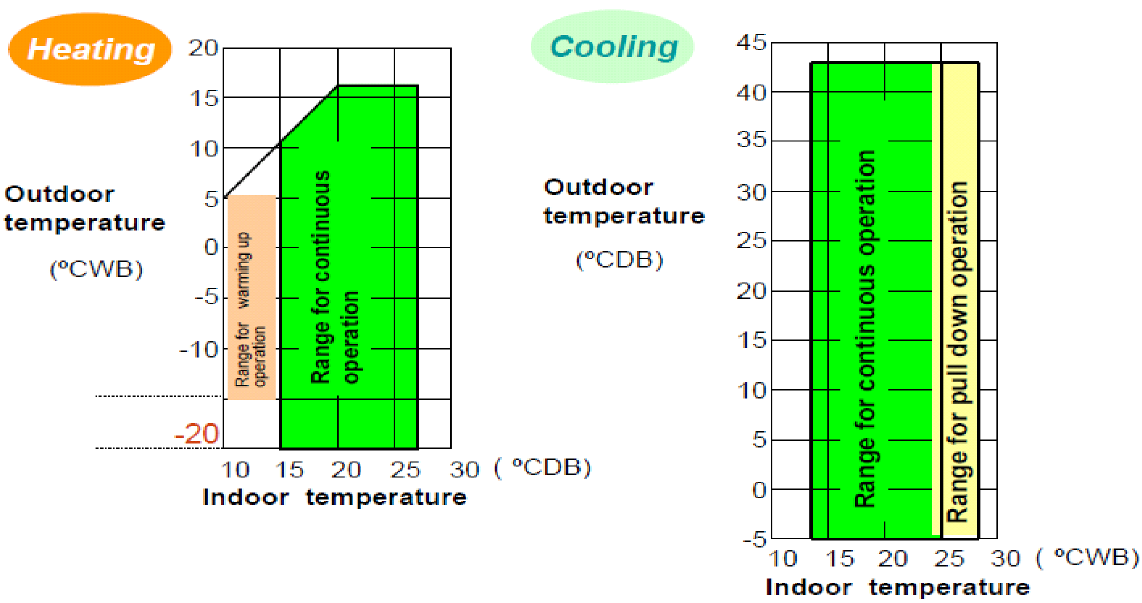

Figure 2.8 Operation Range

2.5.3 Low Noise Mode

Two low noise modes can be selected automatically by quiet priority setting and capacity priority setting depending on the usage environment and outside temperature load. Reductions in outdoor unit sound pressure levels have been achieved via:

- redesigned fan blades and inlet bell mouth

- a new high efficiency aero spiral fan with backward curved blade tips that reduce air turbulence and pressure loss.
- the redesigned bell mouth air inlet fitted with guide vanes at the intake that also reduces air turbulence around the blades.

  Using the latest technology, sound pressure levels down to 47 dB(A) in cooling (3 HP) are achieved. The sound pressure levels therefore up to 3 dB(A) lower than those of standard fixed speed models.

2.5.4 Precision Refrigerant Flow Control

Precision and Smooth refrigerant flow control is achieved by using a DC Inverter control in conjunction with individual indoor unit electronic expansion valve control. This allows for a high precision comfortable temperature control of ±0.5°C. Figure 5.9 shows the deference between inverter air condition and Traditional air condition , inverter air condition use PI controller (proportional and integral) that response to the temperature of the air deviating from the setpoint, the proportional and integral control signals occur simultaneously. The proportional component provides a relatively fast response to the deviation from the setpoint. The integral component is used to drive the controlled variable back toward the setpoint, eliminating the offset characteristic of proportional control. The two signals are additive.

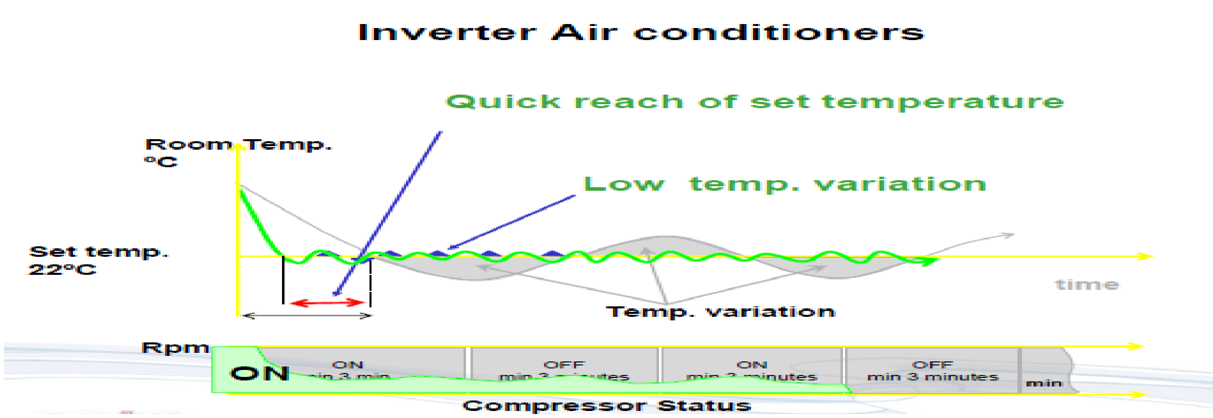

Figure 2.9 Inverter air conditioners

2.5.5 Individual Air Conditioning Control

The desired temperature conditions of each room are met due to the Individual thermostat control of each indoor unit see Figure (2.10)

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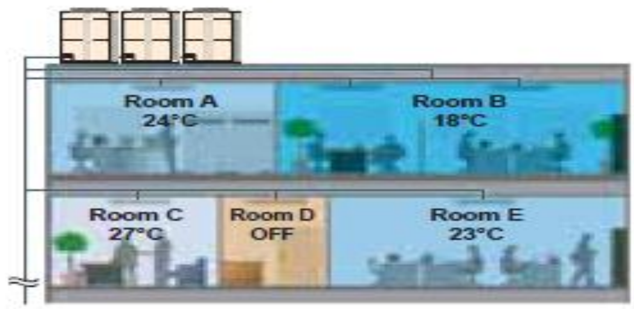


2.5.6 Continuous Operation During Maintenance

Non-stop operation When servicing a specific indoor unit, maintenance can be performed even without turning off the other indoor unitsfigure 5.11

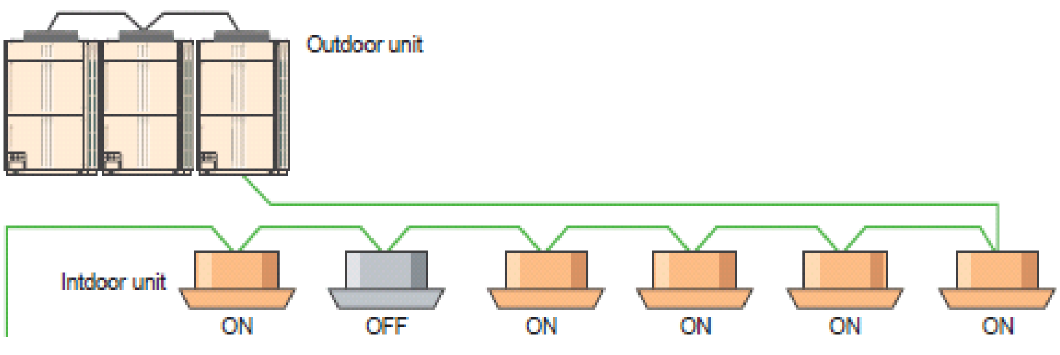


Figure 2.11 Continuous operation scheme

2.5.7 Space saving

The VRV system allows you to use the available space more efficiently. Instead of having to incorporate a machine room in to your building plans, you can use this space for other purposes, such as a garage.

2.6 General Design Consideration

2.6.1 User Requirements

The user primarily needs space conditioning for occupant comfort. Cooling, dehumidification, and air circulation often meet those needs, although heating, humidification, and ventilation are also required in many applications. Components other than the base outdoor and indoor units may need to be installed for VRVsystems to satisfy all requirements.

2.6.2 Diversity And Zoning

The complete specification of a VRV system requires careful planning. Each indoor section is selected based on the greater of the heating or cooling loads in the area it serves. In cold climates where the VRV system is used as the primary source for heating, some of the indoor sections will need to be sized based on heating requirements.

Once all indoor sections are sized, the outdoor unit is selected based on the load profile of the facility. An engineer can specify an outdoor unit with a capacity that constitutes anywhere between 70% and 130% of the combined indoor units capacities. The design engineer must review the load profile for the building so that each outdoor section is sized based on the peak load of all the indoor sections at any given time. Adding up the peak load for each indoor unit and using that total number to size the outdoor unit likely will result in an unnecessarily oversized outdoor section.

Although an oversized outdoor unit in a VRV system is capable of operating at lower capacity, avoid over sizing unless it is required for a particular project due to an anticipated future expansion or other criteria. Also, when indoor sections are greatly oversized, the modulation function of the expansion valve is reduced or entirely lost. Most manufacturers offer selection software to help simplify the optimization process for the system's components.

2.6.3 Installation

In deciding if a VRV system is feasible for a particular project, the designer should consider building characteristics; cooling and heating load requirements; peak occurrence; simultaneous heating and cooling requirements; fresh air needs; electrical and accessibility requirements for all system components; minimum and maximum outdoor temperatures; sustainability; and acoustic characteristics. The physical size of the outdoor section of a typical VRV is somewhat larger than that of a conventional condensing unit, with a height up to 6 ft. (1.8 m) excluding supports. The chosen location should have enough space to accommodate the condensing unit(s) and any clearance requirements necessary for proper operation.

5.6.4 Maintenance Considerations

Ductless VRV indoor units have some considerations in reference to maintenance:

- Draining condensate water from the indoor and outdoor units
- Changing air filters
- Repairs
- Cleaning

Ease of maintenance depends on the relative position of the indoor and outdoor units and the room to ensure access for changing filters, repairing, and cleaning. The installer must make sure there is enough slope to drain condensate water generated by both the indoor and outdoor units. Depending on the location where the indoor unit is installed, it may be necessary to install a pump so that water drains properly.

2.6.6 Sustainability

VRV systems feature higher efficiencies in comparison to conventional heat pump units. Less power is consumed by heat-recovery VRVsystems at part load, which is due to the variable speed driven compressors and fans at outdoor sections. The designer should consider other factors to increase the system efficiency and sustainability. Again, sizing should be carefully evaluated.

Environmentally friendly refrigerants such as R-410A should be specified. Relying on the heat pump cycle for heating, in lieu of electric resistance heat, should be considered, depending on outdoor air conditions and building heating loads. This is because significant heating capacities are available at low ambient temperatures (e.g., the heating capacity available at 5°F (– 15°C) can be up to 70% of the heating capacity available at 60°F (16°C), depending on the particular design of the VRV system).

2.7Advantages And Disadvantages Of VRV

VRV systems have many advantages over more traditional HVAC units. The advantages and disadvantages for a VRV system, when compared to a chilled system, are presented in Table (2.1)

Item	Description	Chilled Water AC System	Variable Refrigerant Flow AC System
1	Human Comfort	Partial – no humidity control, not so good air distribution	Good – true air conditioning
2	Process cooling, heating, humidification and dehumidification	Not applicable - no humidity control, not so good air distribution	Good - May by designed for any condition
3	Internal Air Quality	Partial – needs a auxiliary air make-up system and special filters No duct work is good	Good – may be designed for any condition. Ducts need to be cleanable
4	Initial Cost	Similar	Similar
5	Operational Cost	Little higher at full load 1.25 kW/ton	At full load 1.18 kW/ton
6	Cooling capacity	Good performance until 100 m equivalent length Poor performance above 100 m equivalent length	Distance is only a matter of pumps' selection and operational power consumption
7	Increasing cooling capacity	Not so easy, it may be necessary to change the refrigerant lines and the	It could be done by changing the control valves and or the coils. Chiller plant doesn't

		condensing unit	change or chilled water pipes
8	Operation at partial load	Good performance and control	Good performance and control
9	Customer or tenant control on the operational cost	Good - full control Very important	No control on the operational and maintenance cost
10	Compatibility with standards, guides and regulations	Partial. It is necessary to solve the compatibilities issue during the design	Fully compatible
11	Long distance pipes	Up to 100 m is OK, more there is a cooling capacity reduction up to 75%	No problem.
12	Refrigerant management	Difficult it depends on the design of the system for monitoring, identification and repair	Concentrate in a single equipment easy and simple – Good
13	Customer operation	Easy and simple – Good Very important	Not so clear to customer - Acceptable
14	Malfunction Possibility	To many parts and components and long refrigerant lines – Acceptable	More reliable, just a few parts and equipment – Good
15	Operational life expectation	Up to 15 years - Acceptable	Up to 25 years – Good
16	Maintenance	Depends on the design, access may be a problem	No problem - Good
17	Sales strategy	It is necessary to verify, the say what the customer would like to listen, but not all is true	Too much engineering stuff, difficult for the costumer to understand

2.2 Heating & Cooling Load Calculations

Cooling System

The rate at which heat energy must be removed from a space in order to maintain a given inside design condition is called the cooling load.

The cooling load is expressed in units of watt (Joule per second) or in kilowatts (kW) or in tons refrigeration (T.R) where 1 T.R. = 3.517 kW. Sometimes, the metric units of kilocalorie per hour (kcal/h) are used where 1 W = 0.8601 kcal/h.

The heat gain of a given space or its cooling load can be removed by mean of cooling equipment which supply cold air o the space in adequate amounts to maintain a given inside design temperature. The heat gain is the rate at which energy is transferred to or generated within the space. The heat gains may be external or internal gains.

Buildings and building spaces gain and loose sensible heat as well as latent heat. Both sensible heat and latent heats are produced inside the spaces by occupants, lights and equipment. Sensible heat causes temperatures to raise while latent heat does not cause temperature rise but it changes the condition of the air in the space such that it results in a higher humidity.

The cooling load of a given space consists of the following heat gains :

1- Heat gains that are transmitted through shaded building structures such as walls, floors and ceilings and that adjacent to unconditioned space.

2- Heat gains due to solar effects which include:

> **a-** Solar radiation transmitted through the glass into the air conditioned space and absorbed by inside space surfaces and furniture.
>
> **b-** Solar radiation absorbed by walls, glass windows, glass doors, and roofs that are exposed to solar radiation.

3- Sensible and latent heat gains brought into the space as a result of infiltration of air through windows and doors.

4- Sensible heat produced in the space by lights, appliances, motors and other miscellaneous heat gains.

5- Latent heat produced from cooking, hot baths, or any other moisture producing equipment.

6- Sensible and latent heat gains due to occupants.

2.1.1 Heat Gain Through Sunlit Walls And Roofs:

Direct and diffused solar radiation that is absorbed by walls and roof result in rising the temperature of these surface .amount of radiation absorbed by walls and roofs depends upon time of the day, building orientation, types of wall construction and presence of shading.

The calculation of this type of heat gain be obtain by using the following relation for heat transmission through walls.

$$Q = U * A * CLTDcorr \qquad (2.1)$$

But we find the magnitude of heat transfer throw inside walls is relation by :

$$Q = U * A * \Delta T \qquad 2.2)$$

Where:

$CLTDcorr$**:** cooling load temperatures difference for sunlit roofs and walls since:

$$CLTDcorr = (CLTD + LM)k + (25 - Ti) + (To, m - 29.4)$$

LM: is latitude correction factor .

K**:** is color adjustment factor where it equal 1 then dark colored roof or 0.5 then it permanently light colored roofs.

Ti: indoor design temperature =24^{o}C

To,m: outdoor mean temperature.

$$To,m = To - \frac{DR}{2}$$

To: outdoor design temperature =35^{o}C

DR: the daily rang temperature =($T_{ave.\ max} - T_{ave.\ min}$) in July =(35-17)= 18^{o}C

$To,m = 35 - \frac{18}{2} = 26^{o}C$

f; is attic or roof fan factor which is equal 1 if there is no roof fan , and equal 0.75 if there is an attic or roof fan .

Q : the rate of heat transferred in watts (W).

A : the inside surface area of the wall (m^2).

U : the overall coefficient of heat transmission in watts per square meter per callous.

ΔT : The temperature differential across the wall in callous.

2.1.2 Heat Transmitted through glass:

Solar radiation which falls on glass has three component which are:

1- Transmitted component: it represents the largest component, which is transmitted directly into the interior of the building or the space. This component represents about 42% to 87% of incident solar radiation, depending on the glass transmissibility value.

2- Absorbed component: this component is absorbed by the glass itself and raises its temperature. About 5 to 50% of solar radiation it absorbed by the glass, depending on the absorptive value of the glass.

3- Reflected component: this component is reflected by the glass to the outside of the building. About 8% of the solar energy is reflected back by the glass.

The amount of solar radiation that can be transmitted through glass depends upon the following factors:

1- Type of glass (single, double or insulation glass) and availability of inside shading.

2- Hour of the day, day of the month, and month of the year.
3- Orientation of glass area. (North, northeast, east orientation, etc).
4- Solar radiation intensity and solar incident angle.
5- Latitude angle of the location.

2.1.3 Transmission Heat Gain:

Heat gain due to solar transmission through glass windows and glass doors is estimate by using equation:

$$Q = A(SHG)(SC)(CLF) \qquad (2.5)$$

Where is:

(SHG):is factor represents the amount of solar energy that would be received by floor, furniture and inside walls of the room.

(SC): shading coefficient represented at finding the shading at windows.

(CLF): Cooling load factor represent effect of the internal walls floor, and furniture on the instantaneous cooling load.

In our project we choose the windows is clear insulation glass (glass wool) with thickness = 4mm with interior shading type of interior shading venetian blinds light then (shading coefficient) SC = 0.51

2.1.4 Convection Heat Gain:

The convicted cooling load by the glass is calculated from the equation:

$$Q = A * U * (CLTD)corr \qquad (2.6)$$

Where $(CLTD)corr$. is calculated by using equation (2.3).

2.1.5 Door Gain Load:

1- External doors:

Heat gain through external doors can be calculated by equation (2.7):

$$Q = U * A * CLTDcorr \qquad (2.7)$$

Where:

U: Overall heat transfer coefficients for doors.

CLTDcorr: varies with difference Orientation of doors area.

2- Inner doors:

Heat gain through inner doors can be calculated by equation (2.8):

$$Q = U * A * \Delta T \qquad (2..8)$$

2.1.6 Heat Gain Due To Equipment:

Sensible and latent heat loads arising from various equipment and appliances that are installed in conditioned space. The indicated heat dissipation rates from such equipment and appliances should be included when the cooling load is estimated.

2.1.7 Heat Gain Due To Lights:

Heat gains due to lights are sensible loads. And can be found by use following equation:

$$Q_{light} = \dot{w} * CLF \qquad (2.9)$$

$\dot{w}$: Power of light use.

CLF: the light cooling load factor.

2.1.8Heat Gain Due To Ventilation:

Ventilation is required for places in which the inside air is polluted due to activates that take place in these space such as factories, restaurants, closed parking area. this type of load calculated by equation :

$$Q = \left(\frac{V * N}{3600}\right) * \rho * cp * \Delta T \qquad (2.10)$$

Where is :

V: volume of room.

N: number of air change per hour.

ρ: density of air.

ΔT: difference in temperature.

2.1.9 Heat Gain Due To Infiltration:

Infiltration is the leakage of outside air through cracks or clearances around the windows and doors .It provides fresh outside air needed for living comfort and health. The amount of this infiltrated air depends mainly on the tightness of the window and door and on the outside wind speed and its direction or the pressure difference between the outside and inside of the room.

The heat loss due infiltration $Qt.f$, is calculated as follows:

$$Qt.f = \left(\frac{V_{inf}}{v_o}\right) * (h_i - h_o) \qquad (2.11)$$

Where is:

h_i: Inside enthalpy of infiltrated air in$({}^{kj}/_{kg})$

h_o: outside enthalpy of infiltrated air in$({}^{kj}/_{kg})$.

v_o : Specifics volume in($\frac{m^3}{kg}$)

V_{inf} :The volumetric flow rate of infiltrated air in ($\frac{m^3}{s}$)

$$V_{inf} = V_f * L \qquad (2.12)$$

Where is :

L: crack length (m).

V_f: The infiltration rate per unit length of crack.

2.3 Overall coefficient of heat transfer:

1)External wall:

Outside wall of building we have consists of the following material in table (3.1) (the arrangement of material in table from outside to inside)**.**

Table (2.2) types of material for outside walls

	Type of material	**Thickness (m)**	**Thermal conductivity W/m. ^{0}C**
١	Stone	0.07	1.7
٢	Concrete	0.2	1.75
٣	Insulation	0.02	0.04
٤	Cement block with air gap	0.1	1
٥	Cement Plaster	0.02	0.8

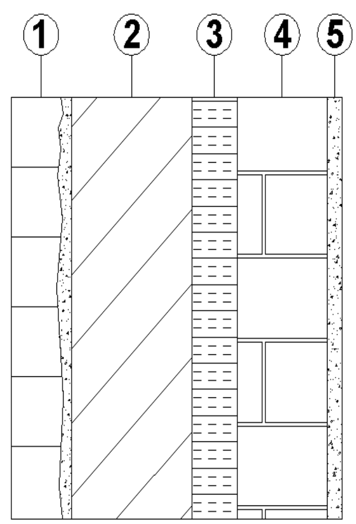


Figure (2.11) arrangement of material for outside walls

$$U = \frac{1}{\left(\frac{1}{hfin}\right) + \left(\frac{\Delta x}{Ks}\right) + \left(\frac{\Delta x}{Kc}\right) + \left(\frac{\Delta x}{Ki}\right) + \left(\frac{\Delta x}{Kb}\right) + \left(\frac{\Delta x}{Km}\right) + \left(\frac{1}{hfout}\right)}$$

Where,

ks : Thermal conductivity of stone .

kc : Thermal conductivity of concrete.

ki: Thermal conductivity of insulation.

kb: Thermal conductivity of block .

km : Thermal conductivity of cement plaster.

h_{Fin}: convection coefficient of inside air.

h_{Fout}: convection coefficient of outside air.

$$u = \frac{1}{\left(\frac{1}{9.37}\right)+\left(\frac{0.07}{1.7}\right)+\left(\frac{0.2}{1.75}\right)+\left(\frac{0.03}{0.04}\right)+\left(\frac{0.07}{1}\right)+\left(\frac{0.03}{0.8}\right)+\left(\frac{1}{22.7}\right)} = 1.2\ W/m^2.^oC$$

2) internal wall:

consists of four parts:

A)in general as table 2.2) and figure 2.2) below which represent the construction of internal wall:

Table (2.3) types of material for internal walls

	Type of material	Thickness m)(	Thermal conductivity W/m. ^{0}C)(
1	Cement plaster	0.02	0.8
2	block	0.07	1

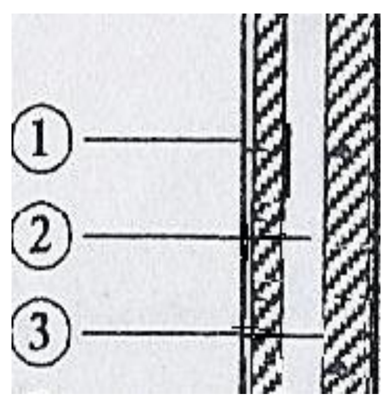


Figure (2.12) arrangement of material for internal walls

3	Cement plaster	0.02	0.8

$$U = \frac{1}{\left(\frac{2}{hfin}\right) + \left(\frac{\Delta x}{Kb}\right) + 2 * \left(\frac{\Delta x}{Km}\right)} \quad (2.)$$

Then we substitute the magnitude in previous equation to get:

$$u = \frac{1}{\left(\frac{2}{9.37}\right)+\left(\frac{0.1}{1}\right)+2*\left(\frac{0.02}{0.8}\right)} = 2.15\ W/m^2.^oC$$

3) Ceiling:

We choose the ceiling construction for four floors as shown in figure (2.4) below:

Table (2.4) types of material for ceiling

NO.	Type of material	Thickness (m)	R_{th} ($m^2.\ ^oC/W$)
١	Asphalt mix	0.02	0.028
٢	concrete	0.05	0.029
٣	insulation	0.02	0.5
٤	Reinforced concrete	0.06	0.034
٥	Cement block	0.18	0.189
6	plaster	0.02	0.017

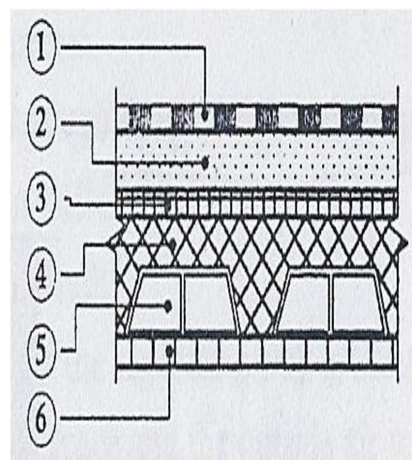


Figure (2.13) arrangement of material for ceiling

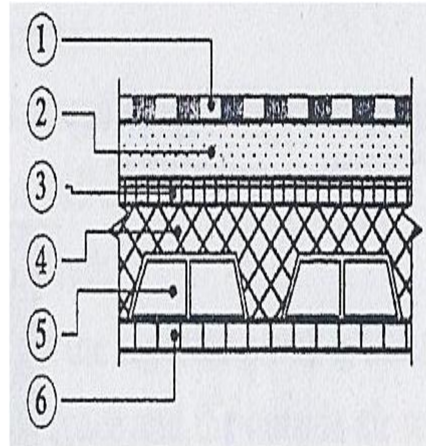
So: $U_{ceiling} = 1.08\ W/m^2.\ ^oC$

4) Floor:

We choose the floor construction as shown in figure (2.5) below

Table (2.5) types of material for floor

NO.	Type of material	Thickness (m)	Thermal conductivity (W/m. °C)
1	concrete	0.05	1.72
2	insulation	0.02	0.04
3	Reinforce concrete	0.06	1.75
4	plaster	0.02	0.8
5	Ceramic tile	0.025	1.1
6	sand	0.05	1.72
7	Cement block	0.18	1



So:

$$U = \frac{1}{\left(\frac{2}{hfin}\right) + \left(\frac{\Delta x}{Kt}\right) + \left(\frac{\Delta x}{Ks}\right) + \left(\frac{\Delta x}{Kc}\right) + \left(\frac{\Delta x}{Ki}\right) + \left(\frac{\Delta x}{Krf}\right) + \left(\frac{\Delta x}{Kb}\right) + \left(\frac{\Delta x}{Kp}\right)}$$

$$U = \frac{1}{\left(\frac{2}{9.37}\right) + \left(\frac{0.025}{1.1}\right) + \left(\frac{0.05}{1.72}\right) + \left(\frac{0.05}{1.72}\right) + \left(\frac{0.02}{0.04}\right) + \left(\frac{0.06}{1.75}\right) + \left(\frac{0.18}{1}\right) + \left(\frac{0.02}{0.8}\right)}$$

$U_{floor} = 0.97\ W/m^2.\ ^oC$

2.4 cooling load calculations

2.4.1 For Ground Floor

2.4.1.1 Wall Gain Load

Table (2.6) heat gain from bed room walls

Surface	**Area (m^2)**	**U** W/m^2. ^{o}C	**ΔT** **C**	**Q watt**
Interior	**12.92**	**2.08**	**17.6**	**472.97**
East	**12.6**	**2.15**	**17.6**	**476.78**
Ceiling	**17.64**	**1.08**	**17.6**	**335.3**
Floor	**17.64**	**1.08**	**17.6**	**335.3**
Q total				**1620.355**

Table (2.7) CLTD from bedroom

surface	**CLTD**	**LM**	**Area**	**U**	**Corrected (clt d**	**Q total**
S- wall	**9**	**-1.6**	**10.85**	**1.16**	**16.91**	**212.83**
W- wall	**6**	**0**	**9.45**	**1.16**	**16**	**175.4**
						388.23

2.4.1.3 Windows Gain Load:

W at south wall:

$A_{\text{south window}} = 1.75\ m^2$

Q_w = A(SHG)(SC)(CLF)= 1.75 * 227 * 0.25* 0.21 = 20.8 W

2.4.1.4 Doors Gain Load:

1. *External door heat gain:*

The all of outdoor made is aluminum (D)

the overall heat transfer coefficients (U= 7 W/m^2.C^o)

$Q = U * A * CLTD_{corr.}$

- *Q from door to bedroom:*

A= 2.466 m^2

Q = U * A_{D13} * $CLTD_{corr.west}$ = 7 * 2.466 * 11.6 = **200.2 W**

2. *Inner door heat gain:*

$$Q = A * U * \Delta T$$

$u = \frac{1}{\left(\frac{2}{9.37}\right)+\left(\frac{0.04}{0.11}\right)}$ =1.733 W/m^2. °C

ΔT= 6 C°

- *Q from D to bedroom:*

A_{D5} = 1.89 m^2

Q = U * A_D *ΔT = 1.733 * 1.89 * 6 = **19.652 W**

2.4.1.5Heat Gain Due To Lights:

Heat gains due to light are sensible load, we find used this equation:

Q_{light} = ẇ* CLF

Clf: cooling load factor = 0.88

Power of one light=50 W

The heat transfer of two light (Q_{light}) = 2*50*0.88 =**88W**

Total heat gain for room: $Q_{cooling}$ = **2.337 kW**

2.5 Tables of Results:

The results of cooling calculations for each floor are tabulated below:

Table (2.8):Cooling Load for ground floor

No. of Room	Cooling Load kW
Bed room	2.88
kitchen	3.675
living room	4.521
Saloon	4.22
Eating room 1	3.12
Eating room 2	3.45
Sum.	21.866

DUCT DESIGN

Bed room

Q @ bed room =2.88

Q=Cp *ρ*ΔT

$\dot{V}$1=Qs/11.25 =2.88/11.25 =0.256 $\frac{m^3}{s}$

$\dot{V}$ kitchen $= 0.326$

$\dot{V}$ living room $= 0.4$

$\dot{V}$ saloon $= 0.375$

$\dot{V}$ eating room 1 $= 0.277$

$\dot{V}$ living room2 $= 0.3066$

$\dot{V}\,\text{total} = 0.109$

$\dot{V}\,\text{AB} = .109\ \text{m}^3/\text{s}$ and v =3 m/s

$\frac{\Delta p}{El} = 1.25$

$\dot{V} = AV$

A =0.109/4 =0.027 m^2

D a-b = $\sqrt{\frac{4*0.027}{\pi}}$= 0.185 m

Duct section	$\dot{V}$	$\frac{\Delta p}{El}$	**d**	**v**
A-B	**0.109**	**0.15**	**0.76**	**3**
B-C	**0.0871**	**0.15**	**0.63**	**2.8**
C-D	**0.06833**	**0.15**	**0.57**	**2.5**
D-E	**0.051**	**0.15**	**0.5**	**2.4**
E-F	**0.038**	**0.15**	**0.46**	**2.2**
F-G	**0.027**	**0.15**	**0.40**	**2.1**
B-1	**0.0219**	**0.15**	**0.37**	**1.8**
C-2	**0.188**	**0.15**	**0.35**	**1.7**
D-3	**0.173**	**0.15**	**0.34**	**1.6**
E -4	**0.13**	**0.15**	**0.30**	**1.5**
G-5	**0.11**	**0.15**	**0.28**	**1.3**

VRV Components Selection

Introuction

VRV system contains several important components ,one of these elements outdoor units ,which its capacity must be suit with the loads and it contains indoor units,and there is many models of outdoor and indoor units and the system consists of copper piping and control equipment.

All VRV system components for this project have been selected from SAMSUNG company catalogs because it provides the specifications and conditions that achieve the desired objectives of the air conditioning system in addition to availability in the local market.

The selection components of VRV System consist of :

a. Selection indoor units.
b. Selection outdoor units of VRV system.
c. Selection refrigerant copper pipes.
d. Selection Y- joint .

Indoor Units

VRV indoor units are modern, technologically advanced and come in ceiling mounted cassette, concealed ceiling,ceiling suspended, wall mounted and floor standing models. Recently, the range has been extended by the visuallystriking and much acclaimed round flow ceiling mounted cassette with its unique 360° air flow distribution pattern.

Designed to fit rooms of any size and shape, SAMSUNG indoor units are also user friendly, quiet running, ultra reliable, easy tocontrol and supply users with that relaxing ‘extra something’ to the indoor climate.

VRV air conditioning brings summer freshness and winter warmth to offices, hotels, department stores and many othercommercial premises. It enhances the indoor environment and creates a basis for increased business prosperity andwhatever the air conditioning requirement.

Outdoor unit with a capacity that constitutes anywhere between 70% and 130% of the combined indoor units capacities. The design engineer must review the load profile for the building so that each outdoor section is sized based on the max load of all the indoor sections at any given time. Although an oversized outdoor unit in a VRV system is capable of operating at lower capacity, avoid oversizing unless it is required for a particular project due to an anticipated future expansion or other criteria. Also, when indoor sections are greatly oversized, the modulation function of the expansion valve is reduced or entirely lost. Most manufacturers offer selection software or catalogue to help simplify the optimization process for the system's components, Figure(6.2) show outdoor units shape.

Figure (2.15) Outdoor unit

Outdoor unit selection

Outdoor unitselection depends on the total cooling and heating loads capacity of the building as following :

- Total cooling outdoor capacity = cooling indoor capacity / capacity ratio = 21.044 / 1.3 = **16.8 Kw**

And refer to outdoor capacity tables from catalogue of outdoor units **(Table A-8/ Appendix A)**we selected 20hp unit consists of two units each one has 10hp with model type (RVXVHT100GE).

Figure (2.16) Outdoor unit (20 hp)

6.4 General Pipes Design

The pipes which used in VRV system is copper pipes. VRV offers an extended piping length of 165m (190m equivalentpiping length) with a total system piping length of 1,000m.

In case the outdoor unit is located above the indoor unit the heightdifference is 50m standard. It can be extended to 90m.In case the outdoor unit is located below the indoor unit, the heightdifference is 40m standard. Height differences up to maximum 90more possible.After the first branch, the difference between the longest pipinglength and the shortest piping length can be maximum 40m,provided that the longest piping length amounts to maximum 90m.

The figure below show the length of the pipes between outdoor units and indoor units**.**

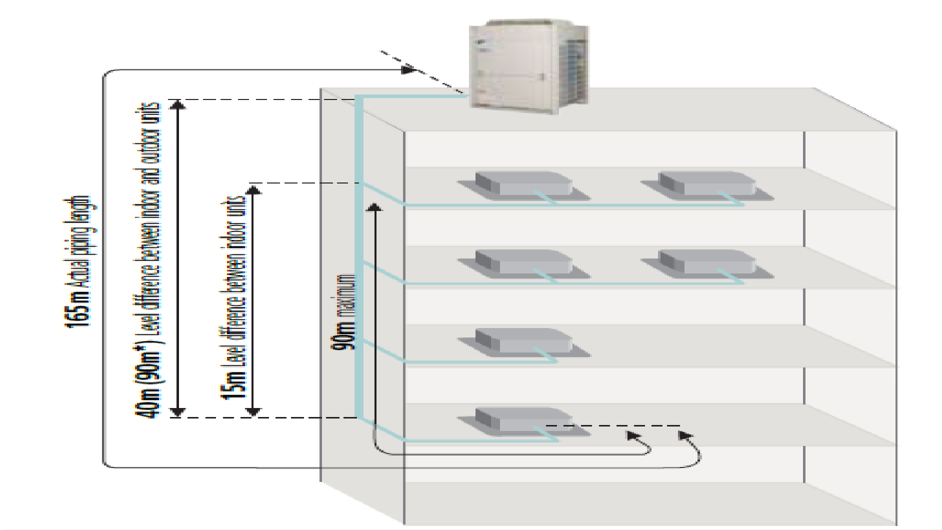


Figure (2.17) Pipes length between outdoor &indoor units

The VRV piping of the refrigeration system is one of the most important designs of the VRV system, i.e. the VRV piping should assure many purposes such as:

1. Ensure adequate velocity to return oil to compressor at all steps of unloading.
2. Avoid excessive noise.
3. Minimize system capacity and efficiency loss and pipe erosion.

The VRV piping design of the system requires designing the liquid line that supplies the indoor cooling unit with liquid refrigerant, and the refrigerant suction line; which returns refrigerant from the indoor unit to the compressor.

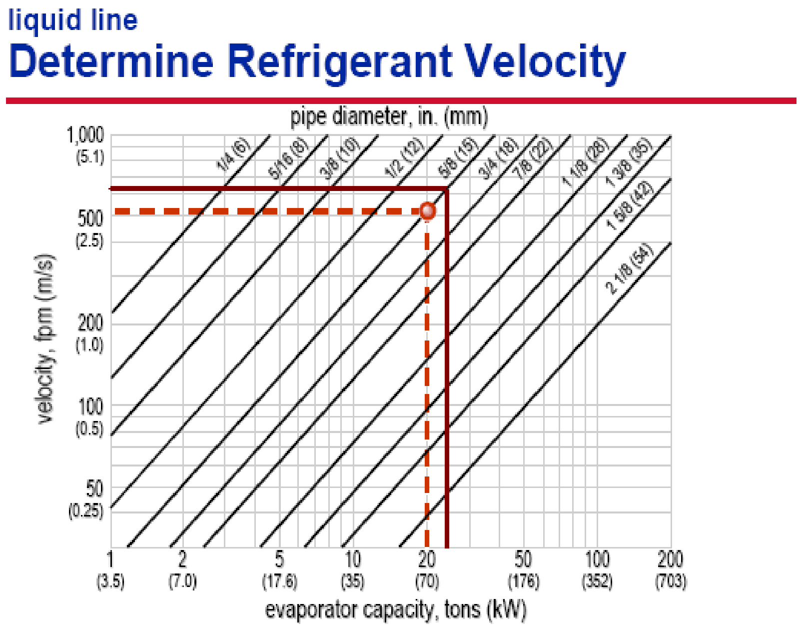
6.4.1 Liquid Line

This section of pipe conducts warm, high-pressure liquid refrigerant from the condenser to the expansion device and indoor unit .

The liquid line must be designed and installed to ensure that only liquid refrigerant (no vapor) enters the expansion device. The presence of refrigerant vapor upstream of a expansion valve can result in erratic valve operation and reduced system capacity. In order to meet this requirement, the condenser must provide adequate subcooling, and the pressure drop through the liquid line and accessories must not be high enough to cause flashing upstream of the expansion device. Subcooling allows the liquid refrigerant to experience some pressure drop as it flows through the liquid line, without the risk of flashing.

The diameter of the liquid line must be as small as possible to minimize the refrigerant charge, therefore improving reliability and minimizing installed cost. However, if the pipe is too small, the increased pressure drop may cause flashing upstream of the expansion device.

The refrigerant velocity in the liquid line shouldn't exceed 3 m/s to prevent noise and large pressure drops. And no under limit since the refrigerant will solute the oil and carry it by the way. As shown in Figure (6-5); the refrigerant velocity is about 2.8 m/s at the recommended liquid line diameter from the condensation unit manufacturer.



Evaporator capacity and velocity diagram for liquid line

Suction Line

This pipe conducts low pressure refrigerant vapor from the evaporator to the compressor.The diameter of the suction line must be small enough that the resulting refrigerant velocity is sufficiently high to carry oil droplets, at all steps of compressor unloading. The refrigerant velocity inside a pipe depends on the mass flow rate and density of the refrigerant if the velocity in the pipe is too high, however, objectionable noise may result. Also, the pipe diameter should be as large as possible to minimize pressure drop and thereby maximize system capacity and efficiency.

All pipes selection done by using refrigerant piping works catalogue**(Table A-9 / Appendix A),** depends on the capacity of units or joints the pipes that supply them refrigerant.

Unified REFNET piping

The unified SAMSUNGrefnet piping system is especially designed for simple installation.The use of refnet piping in combination with electronic expansion valves, results in adramatic reduction in imbalance in refrigerant flowing between indoor units, despite thesmall diameter of the piping.

refnet joints and headers (both accessories) can cut down on installation work andincrease system reliability.Compared to regular T-joints, where refrigerant distribution is far from optimal, the SAMSUNG refnet joints have specifically been designed to optimize refrigerant fl. The figure below show type ofrefnet.

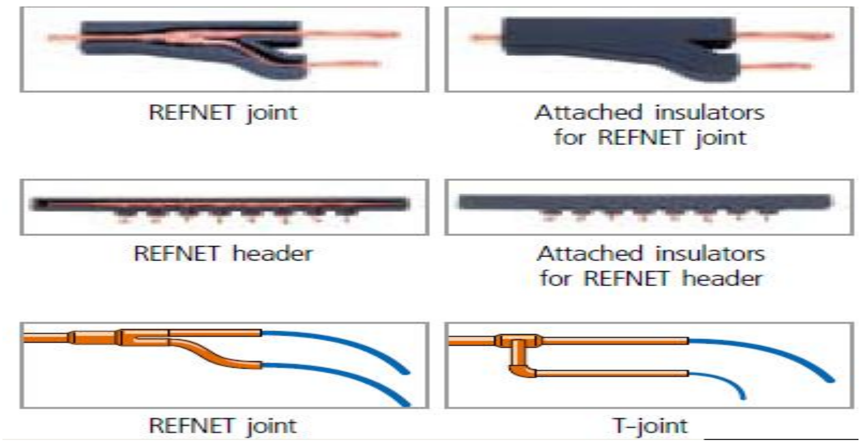


Figure () Types of REFNET

All REFNETS selection done by using refrigerant piping works catalogue

6.5 Limitation of VRV system

Although the high installation cost of the VRV systems and limitation bellow:

- There is a limitation on the indoor coil maximum and minimum entering dry- and wet-bulb temperatures, which makes the units unsuitable for 100% outside air applications especially in hot and humid climates.
- The cooling capacity available to an indoor section is reduced at lower outdoor temperatures. This limits the use of the system in cold climates to serve rooms that require year-round cooling.

It has many features such as high efficiency operation design versatility high reliability easy installation comfort and convenience easy service and maintenance .

Chapter Three

Heating system

Heating system

3.1 Introduction

Water is especially favoured for central-heating systems because its high density allows it to hold more heat and because its temperature can be regulated more easily.

A hot-water heating system consists of the boiler and a system of pipes connected to radiators, piping, or other heat emitters located in rooms to be heated. The pipes, usually of steel or copper, feed hot water to radiators or convectors, which give up their heat to the room. The water, now cooled, is then returned to the boiler for reheating.

Two important requirements of a hot-water system are (1) provision to allow for the expansion of the water in the system, which fills the boiler, heat emitters, and piping, and (2) means for allowing air to escape by a manually or automatically operated valve.

Early hot-water systems, like warm-air systems, operated by gravity, the cool water, being more dense, dropping back to the boiler, and forcing the heated lighter water to rise to the radiators. Neither the gravity warm-air nor gravity hot-water system could be used to heat rooms below the furnace or boiler.

In this project we divide the building to two parts A,B and we calculate the heat losses and then we design boiler, burner , pump, pipes ,…ect .

And we show sample for each part of the calculation and arrange the result in tables , and in the appendix we show some drawing for our project.

3.2 General procedure

In estimating the heating load of the villa , the necessary steps can be outlined as follows :

1. Design value for outdoor winter is selected
2. Indoor design conditions are selected on the activities to be carried out in the space .
3. The temperature in the un conditioned adjacent space is estimated . usually the avarege temperature between inside and out side is taken

4. Heat transfer coefficient and areas for the villa components are calculated form the villa planes and specifications. Surfaces between conditioned space must be omitted .
5. Rate of infiltration is estimated.
6. Rate of outside air required is estimated.
7. From the previous data transmission heat losses and infiltration hat losses are computed these values are summed.

3.3 Procedure in details

3.3.1 Outdoor design conditions selection

These include dry-bulb temperature (T_{out}) , relative humidity out (Φ_{out}) and average air speed (v) . these values are usually tabulated weather station reports

To obtain these values from psychometric chart (see appendix B) figure (1)

Table (3.1) values for outdoor design conditions

Season	T_{out} (℃)	Φ_{out} %	v_{out} $(m^3/Kg\ dry\ air)$	h_{out} $(KJ/Kg$
Heating	5	40	0.86	32.9

3.3.2 indoor design conditions selection

Table (3.2) values for indoor design conditions

Season	T_{in} (℃)	Φ_{in} %	h_{in} $(KJ/Kg$
Heating	25	60	10

3.4 heat gain calculations

The heat gain can be found from walls , roof , ceiling , and interior walls, windows , doors .

$$Q = U * A * \Delta t \tag{3.1}$$

Where:

Q = the rate at which heat transfer in watts.

A = Area of the layer (m²) which heat flow through, which in our project may be an area of wall, window, or ceiling…

Δ**t** = the temperature difference in °C or °K.

U = the overall heat transfer coefficient (W/m^2. °C), which depend on the type of the material of the layer which heat transfer through.

Table (3.3) show values of heat gain for bed room (1)

walls	**U** (W/m^2. °C)	A (m²)	**Δt** °C	**Q (watt)**
North	2.08	13.44	10	279.5
South	1.2	13.37	20	320.88
East	2.15	10.45	10	224.67
West	1.2	7.3	20	175.2
Ceiling	1.08	20.9	10	225.7
Floor	1.08	20.9	10	225.7
Window	3.5	1.75	20	122.5
Door	5.8	3.15	20	365.4
Interior door	2.4	1.68	10	40.32

Table (3.4) show values of heat gain for bed room (2)

walls	**U** (W/m^2. °C)	A (m²)	**Δt** °C	**Q (watt)**
North	2.08	13.44	10	279.5
South	1.2	13.37	20	320.88
East	2.15	7.3	20	175.2
West	1.2	10.45	10	224.67
Ceiling	1.08	20.9	10	225.7
Floor	1.08	20.9	10	225.7
Window	3.5	1.75	20	122.5
Door	5.8	3.15	20	365.4
Interior door	2.4	1.68	10	40.32

Table (3.5) show values of heat gain for kitchen

walls	**U** (W/m^2. °C)	A (m²)	**Δt** °C	**Q (watt)**
North	1.2	6.325	20	151.8
South	2.08	6.075	10	131.56
East	1.2	7.055	20	169.8
West	2.08	6.075	10	126.36
Ceiling	1.08	6.49	10	70.09
Floor	1.08	6.49	10	70.09
Window	3.5	0.7	20	49
Interior door	2.4	1.47	10	35.28

Table (3.6) show values of heat gain for bathroom

walls	**U** (W/m^2. °C)	A (m²)	**Δt** °C	**Q (watt)**
North	1.2	6.325	20	151.8
South	2.08	6.325	10	131.56
East	2.08	6.075	10	126.36
West	1.2	7.055	20	169.8
Ceiling	1.08	6.49	10	70.09
Floor	1.08	6.49	10	70.09
Window	3.5	0.7	20	49
Interior door	2.4	1.47	10	35.28

Table (3.7) show values of heat gain for living room

walls	**U** (W/m^2. °C)	A (m²)	**Δt** °C	**Q (watt)**
North	1.2	9.29	20	222.96
North-West	1.2	5.4	20	129.6
North-East	1.2	5.4	20	129.6
East-Interior	2.08	6.28	10	130.6
East - Exterior	1.2	7.29	20	174.96
West-Interior	2.08	6.28	10	130.6
West - Exterior	1.2	7.29	20	174.96
South	2.08	18.24	10	379.39
Ceiling	1.08	55.35	10	597.78
Floor	1.08	55.35	10	597.78
Window #2	3.5	0.625	20	43.75
Window #2	3.5	0.625	20	43.75
Window #1	3.5	1.75	20	122.5
Window #1	3.5	1.75	20	122.5
Door #1	5.8	3.15	20	365.4
Door #4	2.4	1.47	10	35.3

Door #4	2.4	1.47	10	35.3
Door #3	2.4	1.68	10	40.3
Door #3	2.4	1.68	10	40.3

3.5 infiltration rate calculations

The air flow due to infiltration is calculated from the equation below

$$Q_{inf} = \frac{V_{inf}}{V_{outside}} * (h_o - h_i) \tag{3.2}$$

$$V_{inf} = k\ l\ [0.613\ (s_1 s_2 V_o)^2]^{2/3} \tag{3.3}$$

Where

Q_{inf} is the infiltration heat load [w]

V_{inf} is the volumetric flow rate of infiltrated air [m^3/s]

$V_{outside}$ is the outside volumetric flow rate [$\frac{m^3}{Kg\ \ dry\ air}$]

h_o , h_i *are the outside and inside enthapies of infiltrated air ,respectively* [KJ/Kg]

k is the coefficient of infiltration air for windows

l is the crack length [m].

s_1 is the factor that depends on the topography of the location of the building

$s_2$is another coefficient that depends on the height of the building and terrain of it`s location

V_o the measured wind speed [m/s]

to obtaining the values of these factors see appendix (B) Tables (1),(2),(3) Table (3.8) heat gain by infiltration For bedroom (1)

Window type	Area $[m^2]$	k	s_1	s_2	l	V_o	V_{inf}	Q_{inf}
Aluminum Window #1	1.75	0.43	1	0.85	6.55	5	0.0038	101.2

$l_1 = (1.4 * 2) + (1.25 * 3)$ = 6.55 m , for sliding window

V_{inf}= 0.43*6.55$[0.613(1 * 0.85 * 5)^2]^{2/3}$ = 0.0038 m^3/s

$Q_{inf} = \left(\frac{0.038}{0.86}\right) * 1000(32.9 - 10)$ = 101.2 w

For door (1) : Q_{inf} = 106.5 w

For door (3) : Q_{inf} = 90.5 w

Table (3.9) heat gain by infiltration For bedroom (2)

Window type	Area $[m^2]$	k	s_1	s_2	l	V_o	V_{inf}	Q_{inf}
Aluminum Window #1	1.75	0.43	1	0.85	6.55	5	0.0038	101.2

For door (1) : Q_{inf} = 106.5 w

For door (3) : Q_{inf} = 90.5 w

Table (3.10) heat gain by infiltration For kitchen

Window type	Area $[m^2]$	k	s_1	s_2	l	V_o	V_{inf}	Q_{inf}
Aluminum Window #3	0.7	0.43	1	0.85	3.4	5	0.002	53

For door (4) : Q_{inf} = 85.2 w

Table (3.11) heat gain by infiltration For living room

Window type	Area $[m^2]$	k	s_1	s_2	l	V_o	V_{inf}	Q_{inf}
(2) Aluminum Window #1	1.75	0.43	1	0.85	6.55	5	0.0038	202.4
(2) Aluminum Window #2	0.625	0.43	1	0.85	3.5	5	0.0027	143.8

For door (1) : Q_{inf} = 106.5 w

3.6 The total heat loss from roof rooms

Table (3.12) heat loss from roof rooms

Room type	Q total [watt]
Bedroom (1)	2280
Bedroom (2)	2280
kitchen	941.98
Bathroom	941.98
Living room	3988.03
Total Q [w]	10431.99 = 10.432 KW

3.7 Radiators calculation and selection

Using radiators of the type “ Die cast aluminum radiators “ GB 600/100 “ which capacity of one section = 145.5 w/section (see appendix A) , catalogue (1)

so in order to calculate the number of sections of each radiator for any room :

No. of section = heat load from room / heat capacity of radiator per section (3.4)

No. of sections (Bedroom (1)) = 2280/145.5 = 16 section

Width of radiator =(No. section X width of each section) + valves for both sides (3.5)

width of each section = 8cm

valves for both sides = 12cm

Width of radiator = (16X8)+12 = 140 cm = 1.4 m

Table (3.13) No. of sections of each radiators in the roof floor

RAD. NO.	NO. of section	RAD. Length (cm)	Type
1	8	70	AL 600/100
2	8	70	AL 600/100
3	8	70	AL 600/100
4	8	70	AL 600/100
5	7	68	AL 600/100
6	7	68	AL 600/100
7	13	110	AL 600/100
8	13	110	AL 600/100
Total =	72		

3.8 collector capacity calculation and selection

There are 72 sections for roof floor , so

Collector capacity = No. sections X heat transfer per section (3.6)

Collector capacity = 72 X 145.5 = 10476 w = 10.476 kw

3.8.1 flow rate and collector size calculations

Q = $\dot{m}\ c_p\ \Delta t$ (3.7)

Where :

$\dot{m}$: flow rate [littre/sec]

c_p : specific heat = 4.18 [J/kg.℃] for water

Δt : the Temperature diffreance between inlet and outlet water flow rate [℃]

$\dot{m}$ = (Q/$c_p\ \Delta t$)

$\dot{m}$ = 10.476/(4.18*15) = 0.167 L/s

Flow rate = V x A (3.8)

Where :

V : flow rate velocity , assuming it 0.9 [m/s]

A : cross sectional area , A = $\pi \frac{D^2}{4}$,

where D : the diameter of the collector

0.167 = 0.9 x $\pi \frac{D^2}{4}$, then D = 1 "

Chapter Four

Under floor Heating

Under floor heating

4.1 introduction

most under floor heating systems are either warm water (wet) systems or electric (dry) systems . wet under floor heating systems operate by heat transferring from the water passing through the pipe directly into the floor . because the whole area of the floor is warm , it heats the room more evenly . unlike radiators , under floor heating system don't need to run high temperatures .

typically, the temp. of the water in an under floor heating system pipe is 45-60 C .

for dry system , the principle is the same . the difference is that instead of imparting heat from water passing through a pipe . using an electric heating elements as the heat source .

4.1.2 Advantages of the system :

The main advantages offered by panel systems relate to :

-heat comfort

-Air quality

-Hygiene conditions

-environmental impact

-energy saving

4.1.3 Floor Temperature :

According to the International standard Association (ISO 7730) , the most comfortable floor temperatures should range between 19-26 C , it is also important to ensure that the heating effect is dimensioned so that the temperature drop across the floor is higher than 5 C , A higher temperature drop giving an uneven floor temperature could be perceived by the human foot as uncomfortable , (floor surface temperature are generally feigned to remain at or below 29 C)

Under floor Vs. Radiators Heating

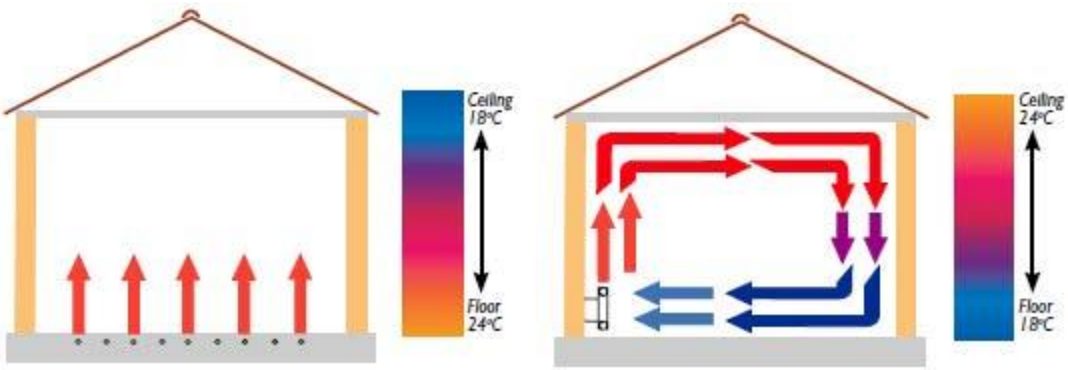


Fig (4.1)

Under floor Vs. Radiators Heating

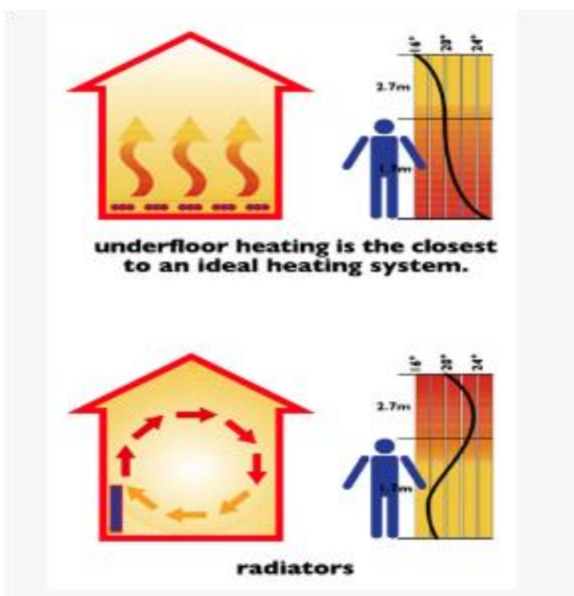


Fig (4.2)

4.1.4 Pipe loops configuration :

There are three main types of loop configuration for under floor heating can be used but we select single serpentine configuration .

single serpentine configuration :

This method yield easy installation of pipes and it can be used for all kind of floor structures . Temperatures variations on the floor surface are kept to minimum values within small area. The pipe layout can be easily modified to produce different energy requirements by changing the pipe loop pitch . the pipe loop arrangement of this method is shown in figure (5.3) this configuration is used in residences and required very flexible pipe **.**

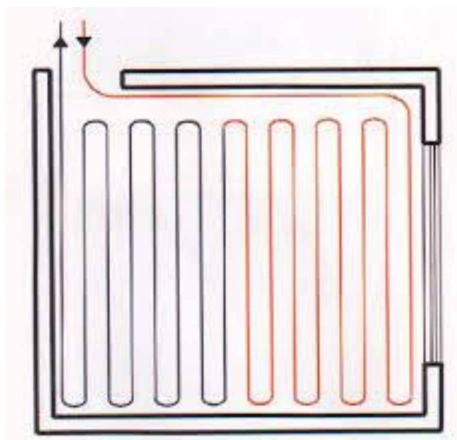


Fig (4.3) **single serpentine pipe Arrangement**

4.2 Design Considerations :

1.pipe loop configuration : A single serpentine pipes is usually used for residences concrete floors , so we will use it in the project .

2.Circulation of water temperature : the design water temperature used in water flowing through PEX plastic pipe is usually (40-45)C . on other hand ASHRE standard required that the maximum water temperature in floor heating is (54.4 C) . And there is n rigid limitation on the drop of water temperature in the loop , however , an optimum design value is (5-10) C .

4.3 Under floor design Procedure :

The design procedure for under floor heating system is summarized as follows :

1. Calculate the heat load for each space and obtain the total heat load for the house . the heating load depend on infiltration and heat transfer (loss) due to walls , ceiling , floor , doors and windows .

2.Sellect the location of supply and return manifold and layout the pipe loops for all spaces .

Measure the loop length for each space to determine the space that has the longest loop length

3.Calculate the pressure drop for the longest pipe loop by using 'diagram B2' , we select pipe diameter of 20x2.0mm

And mass flow rate used value for each loop. the pressure drop in loop is obtained by multiply the value of the pressure drop in kpa/m obtained from the 'diagram B1' and loop pipe length

4.Estmate the pressure drop in the main supply and main return pipe from the boiler to the manifold value (0.2-0.5) kpa/m is usually used for estimation .

5.Balance the pressure drop for all loops .

6.Thee pump of under floor system is selected from the manufacturer catalogues (Biral pump 'diagram B3')

By using the total pressure drop of the longest pipe loop and the total flow rate for all loop

7.boiler selection by using the total demand for all loops and domestic hot water we will use 'Fondital catalogue A-7'

4.4 PEX Pipes

PEX material has features common to most plastic and some which are unique:

1.not effected by corrosion or erosion

2.not affected by additives in concrete

3.low friction force

4.flexible

4.4.2 Selection of the pipe:

pipes depth 30-70 mm related to equation

$(\Delta Tst = q_t * R_{th})$

ΔTst : structure temperature diffrance

q_t: heating load

R_{th}: thermal resistance of structure material

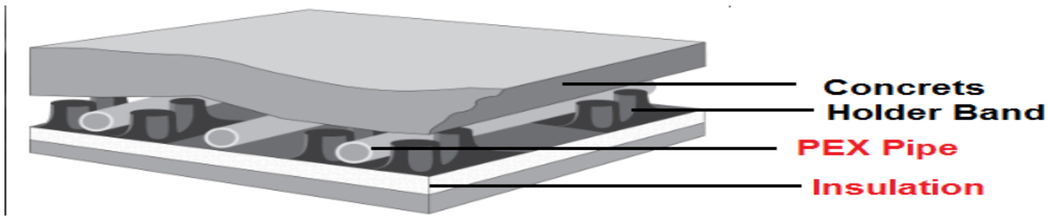


Fig (5.4) concrete floor on insulation. Pipe loops laid on plastic holder band

4.5 Manifolds:

Manifolds can serve until 12 loops, the following consideration:

1. Manifolds should be located as near as possible a center point of the building so that the pipe loops lengths are minimum.

2. manifolds location should be selected such that maintenance can be easily accessible .

3. selected location should result in minor damage if water leakage occurs .

Fig (5.6) Manifolds

4.6 System design calculations

4.6.1 Heating load calculations

Table (4.1) Heating load for Bed Room No.1

Area	A (m^2)	U ($W/_{m^2 °C}$)	ΔT (°C)	Q (Kw)
Floor	25.74	1.2	11	0.339
Ceiling	25.74	1.08	2	0.0556
SE-interior	11.52	2.15	8.5	0.274
NW	10.05	1.16	17	0.198
NE	15.8	1.16	17	0.3115
SW	15.8	1.16	17	0.3115
Infiltration				0.4
Q total				1.986

Table (4.2) Heating load for Bed Room No.2

Area	A (m^2)	U ($W/_{m^2 °C}$)	ΔT (°C)	Q (Kw)
Floor	25.74	1.2	11	0.339
Ceiling	25.74	1.08	2	0.0556
SW-interior	11.52	2.15	8.5	0.274
NE	10.05	1.16	17	0.198
SE	15.8	1.16	17	0.3115
NW	15.8	1.16	17	0.3115
Infiltration				0.4
Q total				1.986

Table (4.3) Heating load for Bed Room No.3

Area	A (m^2)	U ($W/_{m^2 °C}$)	ΔT (°C)	Q (Kw)
Floor	24.8	1.2	11	0.327
Ceiling	24.83	1.08	2	0.053
interior	14.82	2.15	8.5	0.270
South	16.2	1.16	17	0.319
East	15	1.2	8.5	0.153
West	11.85	1.16	17	0.233
Infiltration				0.2982
Q total				1813

Table (4.4) Heating load for Bed Room No.4

Area	A (m^2)	U ($^{W}/_{m^2 °C}$)	ΔT (°C)	Q (Kw)
Floor	24.8	1.2	11	0.327
Ceiling	24.83	1.08	2	0.053
interior	14.82	2.15	8.5	0.270
South	16.2	1.16	17	0.319
East	15	1.2	8.5	0.153
Infiltration				0.2982
West	11.85	1.16	17	0.233
Q total				1813

Table (4.5) Heating load for Hall

Area	A (m^2)	U ($^{W}/_{m^2 °C}$)	ΔT (°C)	Q (Kw)
Floor	106	1.2	11	1.3992
Ceiling	113.09	1.08	2	0.244
South	30.84	2.15	8.5	0.563
North	5.94	1.16	17	0.117
SW-interior	11.52	2.15	8.5	0.210
E-interior	17.7	2.15	8.5	0.323
NW-interior	21.12	2.15	8.5	0.380
West	6.16	1.16	17	0.122
Infiltration				0.8092
Q total				4.1674

Infiltration heat gain : the same calculation of heating system for roof floor

Q total = 12.456 * SF(1.2) = 14.94 KW

4.6.2 Under floor heating system calculations

1. Heat demand for under floor system :

$$\dot{q}_t = \frac{\dot{Q}_{t,room}}{A_{room,floor}} = \frac{2386.17}{25.74} = 92.7\ ^{W}/_{m^2} \quad (4.1)$$

2. flow surface room temperature (T_f) :

$$\dot{q}_t = \mathrm{h}(T_f - T_i) \quad (4.2)$$

92.7=12*($T_f - 23$) = 28.7°C

3. Hot water temperature entering the room T_w :

The floor consist of concrete construction , we will use 20mm pipe diameter .

There a concrete, soil and wall to wall carpet upon the pipes .

R_{th} structure =$(R_{th}\ concret + R_{th}\ soil + R_{th}\ tail\ ) = 00.075\ {(m^2°C}/_{w})$ (4.3)

$R_{th} = 0.08\ {(m^2°C}/_{w})$

Where :

R_{th} carpet from 'Wirsbo catalogue'.

$R_{th}\ structure\ from\ palstinain\ code$.

$\overline{T}_W = T_f + \Delta Tst + \Delta T_{COV}$ (4.4)

Sample : For Bed Room 1:

$\overline{T}_W$= 28.7+(92.7*0.075)+(92.7*0.08) = 43°C

T_w=$\overline{T}_W$+2.5 = 45.5°C

4. mass flow rate of water ($\dot{m}_{water}$) :

$\dot{m}_{water} = \frac{Q_{t,room}}{c_p * \Delta T\ \ _w}$ (4.5)

$\dot{m}_{water}\ = \frac{1.98617}{20.9}$ = 0.095 kg/s

5.loops pressure drop :

From' Wirsbo pipe diagram (B-1)', for 0.095 L/s flow rate and 20 mm diameter :

Pressure drop per meter = 0.2 kpa/m

The pitch between pipes 30cm (from center to center)

Total length of pipe = loops in room + distance to manifold

The loop layout using single serpentine pipe arrangement . each 1 m^2 reqiured (3-4) meter length

Total length loop = 54+9.5 = 63.5 m

By using 'Wirsbo diagram' $\Delta P/_m$ = 0.2 kpa

Pressure drop through the loop = $\Delta P/_m$ * length = 0.2*63.5 = 12.7 KPa (4.6)

6. valve pressure drop :

we estimate it by intersection flow rate (m^3/h) with totally open line in 'Gioacomini manifold diagram (B-3)' :

valve pressure drop (VPD) = 2.1 kpa

totally pressure drop = 2.1 + 12.7 = 14.8 kpa

- total loops length = 337 m

4.7 Boiler selection

boiler capacity = (total heat losses + heat required for DHW+ Radiators heat)*1.15 = 47.6 KW

From table A7 we select has capacity of 47.9 KW (cast iron) , 'Fonditial company'

-the expansion tank capacity = 200 L from table 13

4.7.1 Boiler chimney

$$A_{\ chimney} = \frac{\dot{m}_g}{\rho_g * v} \ , \quad (4.7)$$

where

$\dot{m}_g$: mass flow rate of the fuel gas leaving the chimney

v : average velocity = 4 m/s

$m_f = \frac{\dot{Q}_{boiler}}{CV * \eta}$ = 47.9/ (39000*0.909) = 0.00135 kg/s

$\dot{m}_g$ = 0.00135* 25.2 = 0.0340 kg/s fuel gas

ρ_{gas} = 1.1 kg/m^3

$A_{\ chimney} = \frac{0.0\dot{3}40}{1.1*4.4}$ = 0.00727 m^2

$A_{\ chimney} = \frac{\pi\ D^4}{4}$, (4.8)

D= "6

4.8 pump selection

'Biral pump diagram (B-5)' to select the circulating pump for radiators and under floor heating system .

$(\dot{m}_{total} = 0.619\ \ L/s)^{\cdot}$

Total pressure drop (TPD) = 12.7 kpa for critical loop

Equivalent length (EL) for main supply and return pipe = 30*1.5 = 45 m

Pump head = friction loss + TPD (4.9)

Friction loss range should be (0.2-0.5) kpa

Friction loss = 0.29 kpa

Friction loss during the range , the circulating pump M12 is selected .

Table (4.6) Design Parameter For Under floor System

Room	Bed room 1	Bed room 2	Bed room 3	Bed room 4	Hall
$\dot{Q}$ (W)	1986.17	1986.17	1813	1813	4167.4
A (m^2)	25.74	25.74	24.83	24.83	106
$\dot{q}(w/m^2)$	92.7	92.7	85	85	46.63
T_f ℃	28.7	28.7	28	28	24.8
T_w ℃	43	43	41.18	41.18	32
T_{wi} ℃	45.5	45.5	43.6	43.6	34.5
$\dot{m}_w\ l/h$	342	342	312.12	312.12	514
$\dot{m}_w\ l/s$	0.095	0.095	0.0867	0.0867	0.199
P (KPa/m)	0.15	0.15	0.14	0.14	0.35
L (m)	63.5	63.5	51	51	108
LDP (KPa)	12.7	12.7	7.14	7.14	15.5
VPD (KPa)	2.1	2.1	1.5	1.5	2.5
TPD (KPa)	14.8	14.8	8.64	8.64	17.5

Chapter Five

Plumping system

Plumbing system

5.1 Water supply system

5.1.1 Introduction

The main goal of plumping design for building is to safely and reliably provide domestic water , cooking gas and water for fire fitting and to remove sanitary wastes .

Plumping consist of two things which are water supply system and drainage distribution system

Water supply system , there are two basic types of water distribution systems for building :

1. up feed distribution system
2. down feed distribution system

in this project we will use the down feed distribution system . the supply of water for the building is received from a public street main usually 35 psi for residential buildings , this water enters the well of the villa and then by using pumps which pumping the water to the tanks called gravity tanks which located on the roof .

the water from the gravity tank on the roof surface provides the fixtures that are located in the floors below .

minimum pressure required in the top floor is usually 15 psi for flush tank and maximum pressure on the lowest floor should not exceed 50 psi other wise pressure reducing valves are used to reduce the pressure

5.1.2 calculations for hot and cold water

to determine the pipe size for cold and hot water we must calculate the water supply fixture unit (WFSU) for each fixture and fixture unit total on each pipeing run out and determined the minimum flow pressure required at the most remote out let , we can determine the required pipe in each section using the friction head loss data calculated and the friction head chart .

This table will show the water supply fixture unit for the roof plane :

Table (5.1) WSFU for roof plane

Fixture unit	No. of units	WSFU from table 9-3	Total No. of WSFU for cold water	Total No. of WSFU for hot water	Total No. of WSFU for cold& hot water
Lavatory (private)	1	1*3/4	3/4	3/4	1.5
Shower (privet)	1	2*3/4	1.5	1.5	3
WC (private) flush tank	1	3	3	-------	3
kitchen sink (private)	1	2*3/4	1.5	1.5	3
Total			∑ 6.75	∑ 3.75	∑ 10.5

For roof floor by using table(5) for estimating demand : (see appendix (B)) ,
By using interpolation the required flow is 8.3 gpm for hot and cold water
For cold water by interpolation the required flow is 5.56 gpm
For hot water by interpolation the required flow is 5 gpm
The total cold and hot water demand needed = 8.3 gpm

Table (5.2) WSFU for first floor plane

Fixture unit	No. of units	WSFU from table 9-3	Total No. of WSFU for cold water	Total No. of WSFU for hot water	Total No. of WSFU for cold & hot water
Lavatory (private)	3	1*3/4	3*0.75 = 2.25	2.25	4.5
Shower (privet)	3	2*3/4	3*1.5 = 4.5	4.5	9
WC (private) flush tank	3	3	3*3=9	-------	9
kitchen sink (private)	1	2*3/4	1.5	1.5	3
Total			∑ 17.25	∑ 7.25	∑ 25.5

For first floor by using Table(5)for estimating demand : (see appendix (B)) Table(5)
By using interpolation the required flow is 17.3 gpm for hot and cold water
For cold water by interpolation the required flow is 12.35 gpm
For hot water by interpolation the required flow is 5.93 gpm
The total cold and hot water demand needed = 17.3 gpm

Table (5.3) WSFU for ground floor plane

Fixture unit	No. of units	WSFU from table 9-3	Total No. of WSFU for cold water	Total No. of WSFU for hot water	Total No. of WSFU for cold&hotwater
Lavatory (private)	1	1*3/4	3/4	3/4	1.5
Shower (privet)	1	2*3/4	1.5	1.5	3
WC (private) flush tank	1	3	3	-------	3
kitchen sink (private)	1	2*3/4	1.5	1.5	3
Total			∑ 6.75	∑ 3.75	∑ 10.5

For ground floor by using Table (5) for estimating demand : (see appendix (B))
By using interpolation the required flow is 8.3 gpm for hot and cold water
For cold water by interpolation the required flow is 5.56 gpm
For hot water by interpolation the required flow is 5 gpm
The total cold and hot water demand needed = 8.3 gpm

Table (5.4)WSFU for basement plane

Fixture unit	No. of units	WSFU from table 9-3	Total No. of WSFU for cold water	Total No. of WSFU for hot water	Total No. of WSFU for cold&hotwater
Lavatory (private)	3	1*3/4	3*0.75 = 2.25	2.25	4.5
WC (private) flush tank	1	3	3	-------	3
kitchen sink (private)	1	2*3/4	1.5	1.5	3
Total			∑ 6.75	∑ 3.75	∑ 10.5

For basement floor by using Table(5) for estimating demand : (see appendix (B))

By using interpolation the required flow is 8.3 gpm for hot and cold water
For cold water by interpolation the required flow is 5.56 gpm
For hot water by interpolation the required flow is 5 gpm
For supply outlets likely to impose continuous demand , we estimate continous sperately and add it to the total demand for fixtures
We estimate that the lawn sprinklers use 4 gpm
The total cold and hot water demand needed = 8.3+4 = 12.3 gpm

To calculate static head for basement floor

From basement floor to ground floor : highet = 3 m = 9.84 ft
1m = 3.28 ft
From ground floor to first floor : highet = 3.25 m = 10.66 ft
From first floor to roof floor : highet = 3 m = 9.84 ft

Lavatory outlet above basement level = 1m = 3.28 ft
tank outlet above roof surface = 17m = 55.76 ft
So the static head in this case = floor to floor hight + tank aoutlet hight – lavatory outlet hight
static head = 55.76 – 3.28 = 52.48 ft
So then the static pressure = static head * 0.433 psi = 52.48 *0.433 = 22.72 psi

total equivalent length

to calculate the equivalent length , we will calculate the equivalent length at roof surface to the farthest outlet (lavatory) at the basement floor at farthest collector

For cold water :
total length from tank outlet to the basement floor through risers = 17 m = 55.76 ft
Total length from riser to the collector = 13.2 m = 43.29 ft
Total length from collector to lavatory outlet = 4.35 m = 14.268 ft
So the total length from tank outlet to the farthest outlet at the basement floor = 17+13.2+4.35 = 34.55 m = 113.324 ft
To calculate total equivalent length we assumed 50% additional equivalent length to account for fittings therefore the total equivalent length as follow :
Total equivalent length = total length * 1.5 = 34.55*1.5 = 51.825m = 170 ft

and the minimum flow pressure in the lavatory fixture is(8 psi) for flush valve
Friction head = static pressure – minimum flow pressure
Friction head = 22.72 – 8 = 14.72 psi

For hot water

total length from tank outlet to the basement floor through risers = 17 m = 55.76 ft
Total length from riser to the collector = 13.2 m = 43.29 ft
Total length from collector to lavatory outlet = 4.35 m = 14.268 ft
So the total length from tank outlet to the farthest outlet at the basement floor = 17+13.2+4.35 = 34.55 m = 113.324 ft

To calculate total equivalent length we assumed 50% additional equivalent length to account for fittings therefore the total equivalent length as follow :
Total equivalent length = total length * 1.5 = 34.55*1.5 = 51.825m = 170 ft

The minimum flow pressure

and the minimum required flow pressure at the most remote outlet on the basement floor (lavatory) is 8 psi

to calculate the friction head
for cold water :
we can calculate the friction head from the following equation :
static pressure = Friction head + minimum flow
Friction head = 22.72 – 8 = 14.72 psi

for hot water :
we can calculate the friction head from the following equation :
static pressure = Friction head + minimum flow pressure
Friction head = 8 psi

the usual design aims for uniform friction loss along the inter pipe length to do this we established a friction loss per 100 ft by dividing total loss by total length and then size the pipe accordingly
uniform design friction loss in psi/100ft is : 8psi/100ft

for cold water

friction/100ft = available friction head/ total equivalent length

friction/100ft = 14.72 psi /170*100 ft = 8.65 psi/100ft
so for basement flow rate (12.3 gpm) and friction head loss (8.65 psi/100ft) , from figure 9.5 for for steel pipes (see appendix (B)) figure (2)

Table (5.5) sizing pipe for cold water

Distance between floor and branches	Flow rate (gpm)	Pipe size (inch)	Friction (psi/100)	Velocity (fps)
From tank to roof floor	29	1 1/2”	8.65	5
Branch roof floor	5.56	3/4	8.65	3.5
From roof to first floor	23.44	1 1/4	8.65	5
Branch first floor	12.35	1	8.65	4
From first to ground floor	17.88	1 1/4	8.65	4.5
Branch ground floor	5.56	3/4	8.65	3.5
From ground to basement floor	12.32	1 1/4	8.65	4
Branch basement floor	5.56	3/4	8.65	3.5

Table (5.6) sizing pipe for Hot water

Distance between floor and branches	Flow rate (gpm)	Pipe size (inch)	Friction (psi/100)	Velocity (fps)
From tank to roof floor	29	1 1/2	8	5.2
Branch roof floor	5	3/4	8	3.5
From roof to first floor	24	1 1/4	8	5
Branch first floor	5.93	1	8	4
From first to ground floor	18.07	1 1/4	8	4.5
Branch ground floor	5	3/4	8	3.5
From ground to basement floor	13.07	1 1/4	8	4
Branch basement floor	5	3/4	8	3.5

5.2 Sanitary drainage system

5.2.1 Introduction

5.2.2 Manhole Design

We design the manhole around the building so as that the sewage comes from the stacks flows in then the sewage flows from one manhole to another so as reaching the septic tank .
the design of manholes depend on the round and it`s nature around the building and so as the first manhole height should not be less than 50 cm and then we calculate the hight of other manholes depending on the spaceing between manholes and the slope of drainage pipes between manholes to be 1.5% .
As a result of these calculations we estimate the invert level of the manhole that is the depth of the pipe entering the manhole and we choose the diameter of the manhole depending on the depth of the manhole as below

ᶲ 60 cm for manhole depth (50-100) cm
ᶲ 80 cm for manhole depth (100-150) cm
ᶲ 100 cm for manhole depth (150-250) cm
ᶲ 120 cm for manhole depth > 250 cm

5.2.3 Manholes calculations

We assume the depth of the first manhole to be (60 cm) and we calculate the second manhole according to it and so on

For manhole No.2 :
The distance between manhole No.1 and manhole No.2 is (4.28 m)
Depth = (length between manholes * slope% * scale + (hight for previous manhole + 0.05 m))
where : scale = 1:1 , slope = 1.5%
D1 = 0.6 m
D2 = (4.28*1.5%+(0.6 + 0.05)) = 0.60m , 60 cm

Table (5.7) manhole levels

Manhole NO#	S = distance between manholes(m)	Slope %	D = Depth (m)	Invert level (m)	Top level (m)	Diameter (m)
1	4.28	1.5	0.6	-0.6	-1.1	0.6
2	10.69	1.5	0.71	-0.71	-1.1	0.6
3	6.4	1.5	0.92	-0.92	-1.1	0.6
4	4.79	1.5	1.066	-1.066	-1.1	0.8
5	1.78	1.5	1.35	-1.35	-1.1	0.8
6	2.16	1.5	1.4267	-1.4267	-1.1	0.8
7	5.20	1.5	1.5	-1.5	-1.1	0.8
8	7.16	1.5	1.63	-1.63	-1.1	1.0
9	4.93	1.5	1.79	-1.79	-3.10	1.0
10	7.66	1.5	0.6	-0.6	-1.1	0.6
11	7.65	1.5	0.76	-0.76	-1.1	0.6
12	8.03	1.5	0.92	-0.92	-3.10	0.6
13	5.42	1.5	1.09	-1.09	-3.10	0.8
14	5.54	1.5	1.22	-1.22	-3.10	0.8

5.2.4 Selection the diameter and the slope of the drainage pipe system

1.we will use pipes (sewage) between manholes with diameter 6" and with slope 1.5% and the waste water will transfer between manholes until it reach the main manhole and then goes to the septic tank

2.we will use floor trap (FT) at the end of the branch as a collection box for this pipes and in order to provide a water seal to prevent odors , sewage gases and vermin`s from entering building

3.we will use clean out (CO) at the end of the branch in order to clean the pipes from any things that can blockage and close the pipes

4. for the pipes that will include the grease and oil the recommended slope 1.5%

5.2.5 Drainage Piping sizing

The required pipe sizing are calculated by using a concept of fixture unit instead of using gpm of drainage water we use drainage fixture units (dfu) .
This unit takes into account not only the fixtures water use but also it`s frequency of use, that is, the dfu has a built – in diversity factor . this enable us , exactly as for water supply to add the dfu of varies fixtures to obtain the maximum expected drainage flow . drainage pipes are then sized for particular number of drainage fixtures units , according to tables .(see appendix (B)) Table(6) Built into these tables are the fill factors that are :

1.branche (horizontal pipes) to run maximum of 50% fill

2.stacks (vertical Pipes) are designed to run at maximum of 25~33 % fill

3.building drain and sewar drains may run some what higher (over 50%) fill

This table will show the drainage fixture unit (dfu) for the roof plane
Table (5.8) dfu for roof plane

Fixture unit	dfu value table 10-2 Horizontal branch	Diameter of pipe (inch) Table 10.4
Bath tub group (wc , lavatory , shower) stack B	6	2
kitchen sink (private) Stack A	2	1 1/2

Table (5.9) dfu for first plane

Fixture unit	dfu value table 10-2 Horizontal branch	Diameter of pipe (inch) Table 10.4
Bath tub group (wc , lavatory , shower) Stack A	6	2
Bath tub group (wc , lavatory , shower) Stack c	6	2
Bath tub group (wc , lavatory , shower) Stack d	6	2
kitchen sink (private) Stack B	2	1 1/2

Table (5.10) dfu for ground plane

Fixture unit	dfu value table 10-2 Horizontal branch	Diameter of pipe (inch) Table 10.4
Bath tub group (wc , lavatory , shower) Stack A	6	2
kitchen sink (private) Stack E	2	1 1/2

Table (5.11) dfu for basement plane

Fixture unit	dfu value table 10-2 Horizontal branch	Diameter of pipe (inch) Table 10.4
wc Stack C	4	2
kitchen sink (private) Stack C	2	1 1/2
Lavatory (private) stack C	3*1	1 1/2

Table (5.12) sizing of stack A

Stack A	Total dfu value horizontal branches	Diameter of Stack (inch) Table 10.4
From roof to first floor	2	1 1/2
From first floor to ground floor	8	2
from ground floor to basement	14	3

Table (5.13) sizing of stack B

Stack B	Total dfu value horizontal branches	Diameter of Stack (inch) Table 10.4
From roof to first floor	6	2
From first floor to ground floor	8	2
from ground floor to basement	--	2

Table (5.14) sizing of stack C

Stack C	Total dfu value horizontal branches	Diameter of Stack (inch) Table 10.4
From roof to first floor	--	1 1/2
From first floor to ground floor	6	2
from ground floor to basement	15	3

Table (5.15) sizing of stack D

Stack D	Total dfu value horizontal branches	Diameter of Stack (inch) Table 10.4
From roof to first floor	--	1 1/2
From first floor to ground floor	6	2
from ground floor to basement	--	2

Table (5.16) sizing of stack E

Stack E	Total dfu value horizontal branches	Diameter of Stack (inch) Table 10.4
From roof to first floor	--	1 1/2
From first floor to ground floor	--	1 1/2
from ground floor to basement	2	1 1/2

Table (5.17) design of Branch slope of building

Branch of building drain from stack	Total dfu value from stacks	Diameter of building drain (inch) Table 10.4	Slope % table 10.5	Velocity ft/s table 10.1
Building drain A1 from stack A	14	3	¼	3
Building drain B1 from stack B	8	2	¼	3
Building drain C1 from stack C	15	3	¼	3
Building drain D1 from stack D	6	2	¼	3
Building drain E1 from stack E	2	1 1/2	¼	3

Recommendation for Velocities :

1.for branches , the recommended velocity is (2ft/s)

2.for building drains , the recommended velocity is (3ft/s)

3.for the pipes that will include the grease and oil the recommended velocity (4 ft/s)

The flow in vertical pipes (stacks) depends on :

- pipes size
- the amount of fluid (flow rate)
- velocity
- direction of the fluid entering the stacks
- pipe wall friction (roughness of the pipe wall)

velocity of water flow through drainage pipe depends on :

- pipe size
- slope

for pipes with diameter ≤ 3" the minimum slope is ¼ inch/ft
for pipes with diameter ≥ 4" the minimum slope is 1/8 inch/ft

Chapter Six

Water treatment system

Water treatment

6.1 Introduction

Water can be classified as freshwater, grey water and black water based on characteristics and potential for (re)/use as presented in this table

Table (1) : Type of Water and Possible Uses

Water	Sources	Possible uses
Fresh water	Ground & surface water	Drinking, cooking, bathing
Greywater	Bathing, cloth washing	Toilet cleaning, irrigation, floor washing, construction after treatment
Black water	Toilet, urinal	No use in majority of the cases and requires extensive treatment - ECOSAN toilet can be an option

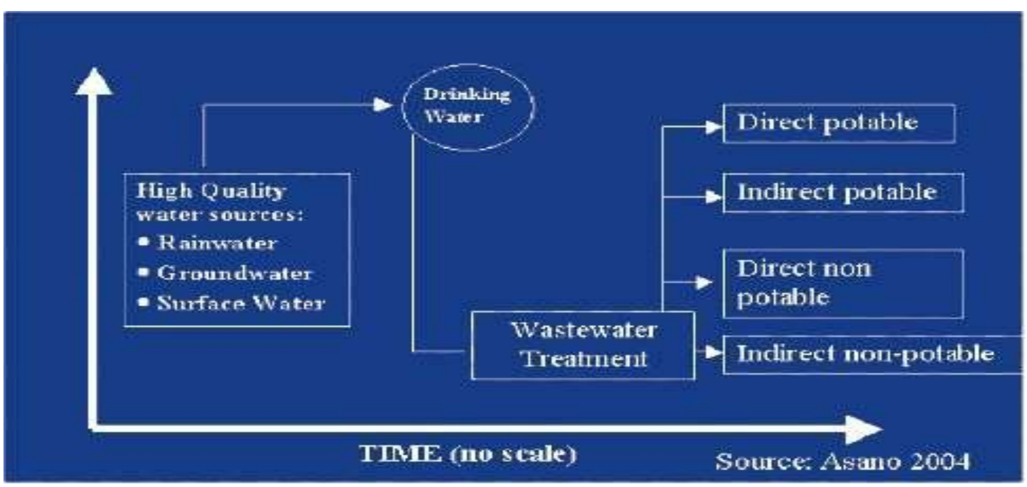


Figure 1 : Wastewater as a Substitute for Higher Quality Water Resources

6.1.2 Potential of Grey water Reuse

Reuse of grey water serves two purposes:

●Reduces fresh water requirement

●Reduces sewage generation

The amount and quality of grey water will in part determine how it can be reused. Irrigation and toilet flushing are two common uses, but nearly any non-contact use is a possibility. Toilet flushing can be done either by direct bucketing or by pumping treated grey water to an overhead tank connected by suitable piping to the toilets

Possible uses of treated grey water are presented in Table 2

Table 2 : Use of Grey water

Use of Greywater	Purpose
● Individual household	● Toilet flushing
● School	● Floor cleaning
● Government/ non government office	● Irrigation
● Hospital	● Gardening
● Theatre	● Car washing
● Hotel	● Construction
● Airport	
● Railway station	
● Apartment/colony	

6.2 Site selection

In the process of assessing the suitability of sites for constructing grey water treatment system, important considerations are as below:

●Approximate size of 15 – 20 m^2 land in the Villa campus for reuse system has been considered

●Topography and natural slope : the topography of the sites and contours can be established using standard surveying procedures. The slope of the site is an important factor in controlling surface pounding, runoff and erosion. A minimum of 2% slope of area is recommended.

●Soil type : Soil type and properties are the key factors in the design and operation of grey water reuse systems. The main characteristics necessary for the evaluation of the soil for the purpose of grey water reuse are soil texture, soil structure, submergence, infiltration rate through.

6.3 Composition of Grey water

Grey water from Bathroom

Water used in hand washing and bathing generates around 50-60% of total greywater and is considered to be the least contaminated type of grey water. Common chemical contaminants include soap, shampoo, hair dye, toothpaste and cleaning products.

Grey water from Cloth Washing

Water used in cloth washing generates around 25-35% of total grey water. Wastewater from the cloth washing varies in quality from wash water to rinse water to second rinse water. Grey water generated due to cloth washing can have parasites such as bacteria.

Grey water from Kitchen

Kitchen grey water contributes about 10% of the total grey water volume. It is contaminated with food particles, oils, fats and other wastes. It readily promotes and supports the growth of micro-organisms. Kitchen grey water also contains chemical pollutants such as cleaning agents which are alkaline in nature and contain various chemicals. Therefore kitchen wastewater may not be well suited for reuse in all types of grey water systems.

Table 3 : **Characteristics of Grey water**

Water Source	Bacteria	Chlorine	Foam	Food Particles	Hair	High pH	Nitrate	Odor	Oil & Grease	Organics matter	Oxygen demand	Phosphate	Salinity	Soaps	Sodium	Suspended solids	Turbidity
Cloth washing			*			*	*		*		*	*	*	*	*	*	*
Washing of utensils	*		*	*		*		*	*	*	*			*	*	*	*
Bathing	*				*			*	*		*			*		*	*
Kitchen	*			*				*	*	*	*			*		*	*

6.4 Grey water Treatment Options

Grey water reuse methods can range from low cost methods such as the manual bucketing of grey water from the outlet of bathroom, to primary treatment methods that coarsely screen oils, greases and solids from the grey water before irrigation via small trench systems, to more expensive secondary treatment systems that treat and disinfect the grey water to a high standard before using for irrigation. The choice of system will depend on a number of factors including whether a new system is being installed or a disused wastewater system is being converted because the household has been connected to sewer. Options for reusing grey water are listed below. The grey water treatment option as shown in Figure

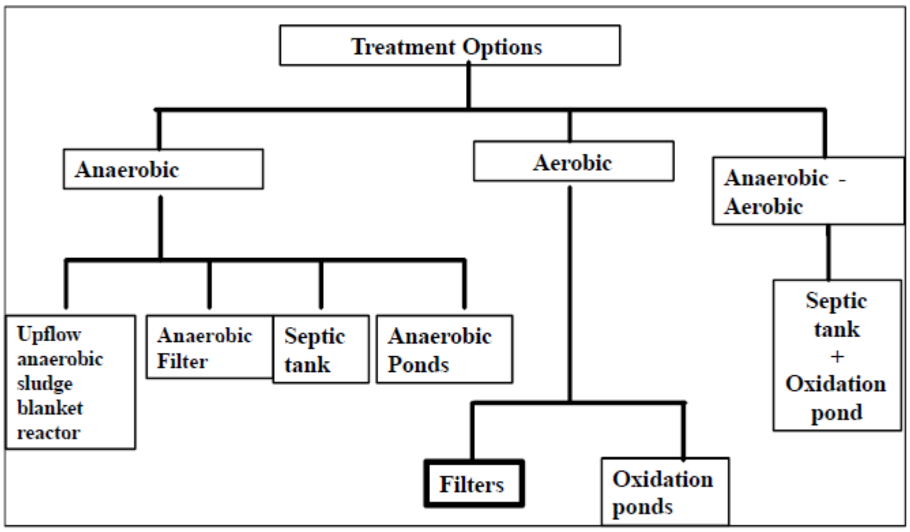


Figure 2 : Grey water Treatment Options

6.4.1 Primary Treatment System

In primary treatment system, a sedimentation tank is used to coarsely screen out oils/greases and solids prior to reuse. This system is recognized as an economically attractive option for grey water reuse because it requires minimal maintenance, and chemicals.

6.4.2 Secondary Treatment System

In secondary treatment system, Chemical and Biological treatment process are used to remove most of the organic matter. This reduces health risk at end use with human contact and provides additional safety for reuse. This system is generally more expensive, due to the initial establishment costs associated with the further treatment needs and the periodic maintenance costs.

6.4.3 Tertiary Treatment System

Tertiary treatment processes further improves the quality of grey water or polish it for reuse applications. Fixed film biological rotating drums, membrane bioreactors, biologically aerated filters, activated sludge and membrane treatment systems are all included in this category.

6.4.4 Biological Treatment System

This level of treatment involves utilizing the biological content in grey water to reduce microbial contamination, suspended solids, turbidity and nutrients (nitrogen and phosphorous).

Table 4 : Grey water Treatment Options

Option of greywater treatment		Advantage	Disadvantage
Primary Treatment		• Provides extensive physical treatment • Comparatively higher safety and lower health risk	• Maintenance and monitoring required • Costly
Secondary Treatment		• Quality of greywater is good • Directly put to irrigation • Besides removing BOD, N and P they are very efficient at removing/inactivating microorganisms and helminth eggs	• Treated greywater for any other purpose is not available • Skilled persons required

2.4.5 Odor and Color

There is a possibility of odor generation in grey water treatment system due to the following:

1. a slime layer will develop on the submerged walls of filters, collection sump and possibly in sedimentation tank and as velocity of the grey water through the system sometime is too low to scour the sides
2. If aeration is not sufficient dissolved oxygen will reduce substantially and only anaerobic bacteria will attach to the slime layer

6.5 Design of Grey water Treatment System

Determination of grey water generation and flow rate is the first requirement in the design of grey water collection, treatment and reuse system.

Following methods are proposed for quantification of grey water:

Method	Type
Direct method	Water meter Bucket method
Indirect method	Water consumption Types of uses

6.5.1 Direct Method

6.5.1.1 Water Meter

In the water meter method, a meter is provided at the outlet of the drain connecting bathrooms, kitchen and cloth washing place (laundry). If not possible, the meter can be placed at the inlet of the grey water collection tank which can be connected to bathroom, kitchen and laundry.

6.5.1.2 Bucket Method

This is the simplest form of grey water quantification wherein grey water is collected in a bucket of known volume at the outlet of bathroom, laundry or kitchen. This method is cheap and suitable where grey water quantity remains almost constant for a substantial time period. The method is manual and precautions are required to avoid any human contact with grey water

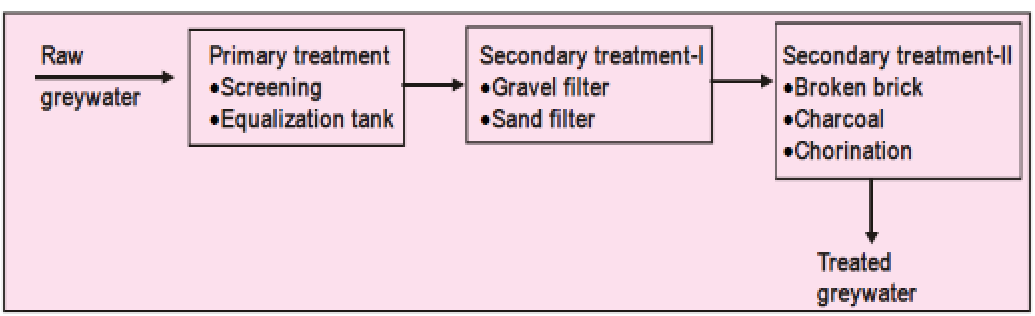


Figure 3 : Grey water Treatment Scheme

The function of various treatment units are presented in Table 6

Table 5 : Treatment Units and Functions

Unit of treatment system	Removal
1. Screen	Floating matter, suspended matter
2. Junction chamber	Odour, some of settleable solids
3. Equalization Tank (Holding)	Settleable solids
4. Horizontal Roughing Filter	Turbidity, suspended solids, some amount of BOD
5. Slow Sand Filter	Colour, bacteria, suspended solids and some amount of BOD
6. Disinfection	Bacteria, odour

6.5.2 Filter

The filter types are as below:

1. Up flow –down flow filter
2. Multi Media Filter
3.Slow Sand Filter
4. Horizontal Roughing Filter

Up flow-down flow filter

As the name suggests, raw grey water is put into the bottom of first column of filter and collected at the top of second column. This water is again fed to the third column of filter from the bottom and is collected at the top of fourth column. The number of columns depends on quality of grey water and expected use of grey water and optimally up flow-down flow filter contains four columns. The filter media varies with the column and may contain gravel, coarse sand, fine sand and other material such as wood chips etc. The up flow – down flow filter is shown in **Figure 4**

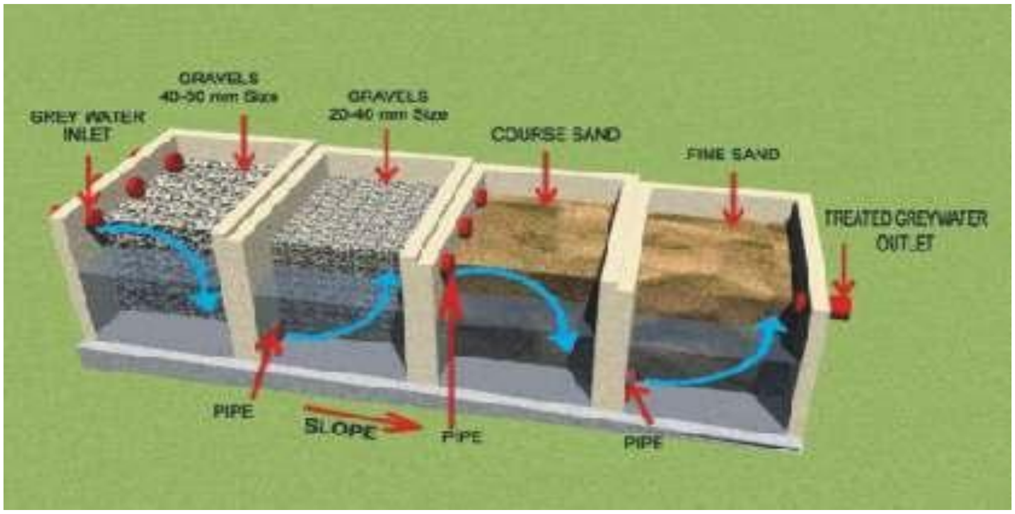


Figure 4 : Up flow Down flow Filter

Multi-media filter

Multi-media filters are filled with a variety of media in order of increasing size, The inlet is provided at the top so that the filtered water is collected through outlet in the bottom. A vent is provided at the top for letting out odorous emissions, if generated in the filter. Media can be taken out for washing periodically depending on the grey water characteristics and quantity.

6.5.3 Odor Control

Good design and maintenance practices will reduce odor problems in grey water treatment system without the use of chemical addition or air treatment. However, the following measures are recommended to minimize odor problem:

1. A minimum slope of 2-3 % should be provided so as to ensure sufficient flow through system when in operation
2. The closed conduit system should be avoided
3. Deposited solids should periodically be removed from sedimentation tank
4. Addition of chemicals such as calcium nitrate
5. Filters should be washed with clean water and filter media should be periodically replaced
6. Chlorination also helps in minimizing odor .

Table 6 : Maintenance of Grey water Treatment System

Treatment Units	Activity	Frequency of Cleaning	Purpose
Equalization cum settling tank	De-sludging	Every week	Maintain the volume of equalization tank
Horizontal filter	Cleaning of filter media	Every10 days	Maintain the efficiency of sand filter
Coarse sand filter	Cleaning of filter media	Every week	Maintain the efficiency of sand filter
Sand filter	Refill the upper layer	Every week	Overcome chocking problem
	Cleaning of filter media	Every 10 days	Maintain effective filtration
Filter Broken bricks	Cleaning of filter media	Every 10 days	Colour removal
Wetland	Removal of unwanted grass & plants	Every 2 months	Maintain the efficiency of system
Chlorination	Maintain proper dose	Every day	Disinfection
Collection tank	Reuse of water	Every 2 days	Maintain the quality of greywater

Pumping system

The pumping requirement for grey water reuse system is to lift the water from the storage tank to the overhead tank. The pumps for grey water reuse system are power operated electric motors. These pumps are popular because they are relatively easy to operate, require low maintenance cost.

References

[1] Mohammad A.hammad .1996 , Heating and Air conditioning , 3rd edition,Mohammad A.Alsaad , Jordan .

[2] Mcgraw-Hill.2000, Building design and construction hand book , 6th edition , Frederick S.Merritt & Jonathan T. Ricketts , New York .

[3] Amell.N.1996, Plumbing System, 1st edition

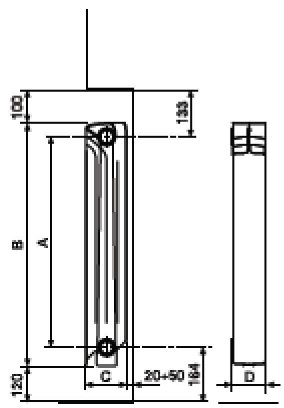
[4] Ezat Hamdan , Hussain Naser .2007 , Design of mechanical systems in residential villa Tira/ Ram Allah , Palestine .

[5] internet .

APPENDIX (A)

Fondital presents the new **Astor S4** die-cast aluminium radiator.
This model features high thermal output and mechanical resistance, guaranteeing considerable cost saving.

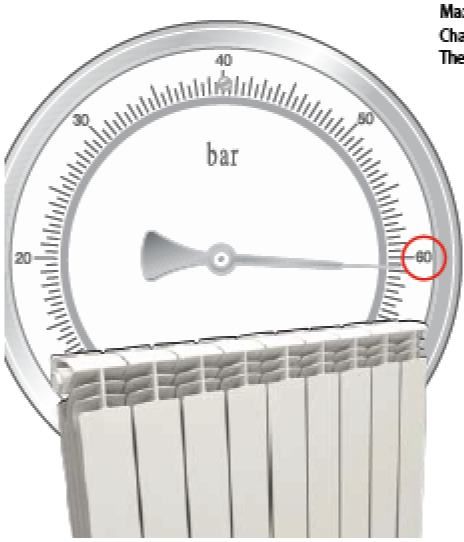
Great care has been taken over the tiniest detail, resulting in a superior-quality, attractive-looking radiator. Each radiator is painted in two stages: the first coat is applied by anaphoresis to provide total protection; then epoxy powders are applied to give a perfect finish.
The **Astor S4** is designed to operate up to 16 bar, but the ultimate bursting pressure exceeds 60 bar. Each radiator is tested at 24 bar before going on the market.

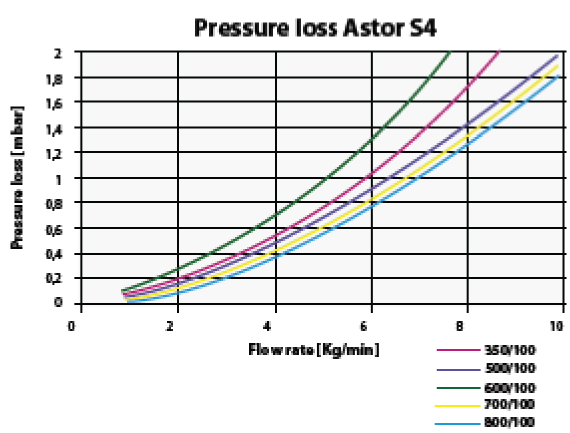


Technical data

Model	Depth (C)	Height (B)	Centre distance (A)	Length (D)	Connection diameters	Water capacity	Weight	Heat output 50K	Heat output 30K	Exponent n	Coefficient K_m
	mm	mm	mm	mm	inches	litres/sect.	Kg/sect.	W/sect.	W/sect.		
350/100	97	428	350	80	G1	0.26	1.16	94.8	48.6	1.3079	0.5686
500/100	97	577	500	80	G1	0.31	1.46	125.1	63.8	1.3169	0.7243
600/100	97	677	600	80	G1	0.37	1.73	145.5	73.3	1.3416	0.7646
700/100	97	778	700	80	G1	0.44	1.98	159.1	79.6	1.3543	0.7954
800/100*	97	876	800	80	G1	0.48	2.20	173.8	86.3	1.3703	0.8164

* *Provisional data, certification pending.*
Maximum working pressure: 1600 kPa (16 bar)
Characteristic equation of the model $\Phi = K_m \Delta T^n$ (reference EN 442-1).
The thermal output values published are in compliance with the European Standard EN 442-2.





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Catalogue (2)

Catalogue (3) VRV selection unit

10-2. Specifications

1) Technical specifications

Model				AVXWNH022E✳	AVXWNH028E✳	AVXWNH036E✳	AVXWNH056E✳	AVXWNH071E✳
Power Supply			ø/V/Hz	1/220~240/50	1/220~240/50	1/220~240/50	1/220~240/50	1/220~240/50
Mode*1)				HP / HR	HP / HR	HP / HR	HP / HR	HP / HR
Performance	Capacity	Cooling*2)	kW	2.2	2.8	3.6	5.6	6.8
			Btu/h	7,500	9,500	12,200	19,100	23,200
		Heating*3)	kW	2.5	3.2	4.0	6.3	7.0
			Btu/h	8,500	10,900	13,600	21,400	23,800
	Condensate (with High fan speed)		Liters/h	1.12	1.44	1.91	2.87	3.51
Power	Input		W	25	25	30	45	50
	Running Current		A	0.16	0.16	0.18	0.27	0.30
Sound Level	Sound Pressure (High/Low)*4)		dB(A)	32 / 23	32 / 23	36 / 23	40 / 30	41 / 30
Fan	Type		-	Crossflow fan	Crossflow fan	Crossflow fan	Crossflow fan	Crossflow fan
	Motor	Model	-	KSFD-18SX	KSFD-18SX	KSFD-18SX	YDK-045S42213-02	YDK-045S42213-02
		Type	-	Feedback SSR	Feedback SSR	Feedback SSR	Feedback SSR	Feedback SSR
		Output	W	23*5)	23*5)	23*5)	40*5)	40*5)
Airflow Rate	Cooling (High)		m³/min	7.8	7.8	9.3	12.0	14.0
	Heating (High)		m³/min	8.2	8.2	9.5	13.0	15.0
Refrigerant	Type		-	R410A	R410A	R410A	R410A	R410A
	Control Method		-	EEV (Optional)	EEV (Optional)	EEV (Optional)	EEV (Optional)	EEV (Optional)
Temperature Control			-	Micom&Thermistors	Micom&Thermistors	Micom&Thermistors	Micom&Thermistors	Micom&Thermistors
Safety Devices			-	Fuse	Fuse	Fuse	Fuse	Fuse
Option Code			-	027602-1120FA	027602-1320FA	027602-15224D	026602-1A226F	026602-1C228F
Piping Connections	Liquid (Flare)		ø, mm	6.35	6.35	6.35	6.35	9.52
	Gas (Flare)		ø, mm	12.70	12.70	12.70	12.70	15.88
	Drain		ø, mm	ID 18 hose	ID 18 hose	ID 18 hose	ID 18 hose	ID 18 hose
Weight	Net Weight		kg	7.8	7.8	7.8	13.0	13.0
	Shipping Weight		kg	9.4	9.4	9.4	16.0	16.0
Dimensions	Net Dimensions (W x H x D)		mm	825x285x189	825x285x189	825x285x189	1,065x298x218	1,065x298x218
	Shipping Dimensions (W x H x D)		mm	900x349x252	900x349x252	900x349x252	1,137x377x299	1,137x377x299
Functions	Auto Restart		-	O	O	O	O	O
	Auto Swing		-	O	O	O	O	O
	Group/Individual Control		-	O	O	O	O	O
	External Contact Control		-	O	O	O	O	O
	Trouble Shooting by LED		-	O	O	O	O	O
Standard Accessories	Installation Manual		-	O	O	O	O	O
	Operation Manual		-	O	O	O	O	O
	Pattern Sheet for Installation		-	X	X	X	X	X
	Flexible Drain Hose		-	O	O	O	O	O
	Filter / Safety Grille		-	Filter (Washable)	Filter (Washable)	Filter (Washable)	Filter (Washable)	Filter (Washable)
	Wireless Remote Controller		-	ARH-465	ARH-465	ARH-465	ARH-465	ARH-465
Optional Accessories	Wireless Remote Controller		-	MR-CH01	MR-CH01	MR-CH01	MR-CH01	MR-CH01
	Wired Remote Controller	Multi function	-	MWR-WE00	MWR-WE00	MWR-WE00	MWR-WE00	MWR-WE00
		Premium	-	MWR-WS0✳	MWR-WS0✳	MWR-WS0✳	MWR-WS0✳	MWR-WS0✳
		Standard	-	MWR-TH01	MWR-TH01	MWR-TH01	MWR-TH01	MWR-TH01
		Simplified	-	MWR-SH00	MWR-SH00	MWR-SH00	MWR-SH00	MWR-SH00
	External Contact Interface Module		-	MIM-B14	MIM-B14	MIM-B14	MIM-B14	MIM-B14
	EEV Kits			MXD, MEV Series	MXD, MEV Series	MXD, MEV Series	MXD, MEV Series	MXD, MEV Series

10 Neo Forte

10-3. Capacity tables

1) Cooling

TC : Total Capacity(kW), SHC : Sensible Heat Capacity(kW)

Model	Outdoor temperature (°C, DB)	Indoor temperature (°C, WB)													
		20 (°C, DB) 14 (°C, WB)		23 (°C, DB) 16 (°C, WB)		26 (°C, DB) 18 (°C, WB)		27 (°C, DB) 19 (°C, WB)		28 (°C, DB) 20 (°C, WB)		30 (°C, DB) 22 (°C, WB)		32 (°C, DB) 24 (°C, WB)	
		TC	SHC	TC	SHC	TC	SHC	TC	SHC	TC	SHC	TC	SHC	TC	SHC
022	10	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.5	1.6	2.6	1.4
	12	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.5	1.6	2.6	1.4
	14	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.5	1.6	2.6	1.4
	16	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	18	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	20	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	21	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	23	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	25	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	27	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	29	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	31	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	33	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	35	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	37	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.6	1.4
	39	1.5	1.3	1.8	1.5	2.1	1.5	2.2	1.5	2.3	1.5	2.4	1.5	2.5	1.3
	42	1.5	1.3	1.8	1.5	2.1	1.5	2.1	1.4	2.2	1.7	2.3	1.4	2.4	1.2
	44	1.5	1.3	1.8	1.5	2.0	1.4	2.1	1.4	2.1	1.6	2.2	1.3	2.2	1.1
028	10	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.4	1.9
	12	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	14	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	16	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	18	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	20	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	21	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	23	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	25	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	27	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	29	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	31	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	33	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	35	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	37	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.1	1.9	3.3	1.8
	39	1.9	1.6	2.3	1.8	2.6	2.0	2.8	1.9	2.9	1.9	3.0	1.8	3.2	1.7
	42	1.9	1.6	2.3	1.8	2.6	2.0	2.7	1.8	2.8	1.8	2.9	1.7	3.0	1.6
	44	1.9	1.6	2.3	1.8	2.5	1.9	2.7	1.8	2.7	1.7	2.7	1.6	2.8	1.5
036	10	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.3	2.3
	12	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.3	2.3
	14	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.3	2.3
	16	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.3	2.3
	18	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.3	2.3
	20	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.2	2.3
	21	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.2	2.3
	23	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.2	2.3
	25	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.2	2.3
	27	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.2	2.3
	29	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.2	2.3
	31	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.2	2.3
	33	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.2	2.3
	35	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	4.0	2.4	4.2	2.3
	37	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	3.9	2.3	4.2	2.3
	39	2.5	2.1	2.9	2.2	3.4	2.3	3.6	2.4	3.7	2.4	3.9	2.3	4.1	2.2
	42	2.5	2.1	2.9	2.2	3.4	2.3	3.5	2.3	3.6	2.3	3.7	2.2	3.9	2.1
	44	2.5	2.1	2.9	2.2	3.2	2.2	3.4	2.2	3.5	2.2	3.5	2.1	3.6	1.9
056	10	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.3	3.9	6.7	3.6
	12	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.3	3.9	6.7	3.6
	14	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.7	3.6
	16	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	18	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	20	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	21	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	23	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	25	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	27	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	29	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	31	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	33	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	35	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.2	3.8	6.6	3.5
	37	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.1	3.7	6.5	3.4
	39	3.9	3.0	4.6	3.4	5.3	3.7	5.6	3.8	5.8	3.8	6.1	3.7	6.4	3.3
	42	3.9	3.0	4.6	3.4	5.3	3.7	5.4	3.7	5.6	3.7	5.8	3.6	6.0	3.2
	44	3.9	3.0	4.6	3.4	5.0	3.6	5.3	3.6	5.4	3.6	5.5	3.5	5.6	3.0
071	10	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.1	4.6	7.6	4.6	8.2	4.4
	12	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.1	4.6	7.6	4.6	8.1	4.3
	14	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.1	4.6	7.6	4.6	8.1	4.3
	16	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.1	4.6	7.6	4.6	8.1	4.3
	18	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	20	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	21	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	23	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	25	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	27	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	29	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	31	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	33	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	35	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	8.0	4.2
	37	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.5	4.5	7.9	4.1
	39	4.7	3.7	5.5	4.1	6.4	4.5	6.8	4.6	7.0	4.6	7.4	4.4	7.7	4.0
	42	4.7	3.7	5.5	4.1	6.4	4.5	6.6	4.5	6.7	4.4	7.0	4.2	7.3	3.8
	44	4.7	3.7	5.5	4.1	6.1	4.4	6.5	4.4	6.5	4.3	6.7	4.1	6.8	3.6

2) Heating

TC : Total Capacity(kW)

Model	Outdoor temperature (°C)		Indoor temperature (°C, DB)				
			16.0	18.0	20.0	22.0	24.0
			TC	TC	TC	TC	TC
	DB	WB	kW	kW	kW	kW	kW
022	-20	-21	1.5	1.5	1.5	1.5	1.5
	-17	-18	1.6	1.6	1.6	1.6	1.6
	-15	-16	1.7	1.6	1.6	1.6	1.6
	-12	-13	1.8	1.8	1.8	1.8	1.7
	-10	-11	2.0	2.0	1.9	1.9	1.9
	-7	-8	2.3	2.2	2.2	2.0	2.0
	-5	-6	2.4	2.3	2.3	2.2	2.2
	-3	-4	2.5	2.5	2.4	2.3	2.2
	0	-1	2.6	2.5	2.5	2.3	2.2
	3	2.2	2.7	2.6	2.5	2.3	2.2
	5	4.1	2.8	2.7	2.5	2.3	2.2
	7	6	2.8	2.7	2.5	2.3	2.2
	9	7.9	3.0	2.7	2.5	2.3	2.2
	11	9.8	3.0	2.7	2.5	2.3	2.2
	13	12	3.0	2.7	2.5	2.3	2.2
	15	14	3.0	2.7	2.5	2.3	2.2
028	-20	-21	1.9	1.9	1.9	1.9	1.9
	-17	-18	2.0	2.0	2.0	2.0	1.9
	-15	-16	2.1	2.1	2.0	2.0	1.9
	-12	-13	2.2	2.2	2.2	2.1	2.1
	-10	-11	2.3	2.3	2.3	2.3	2.2
	-7	-8	2.5	2.4	2.4	2.4	2.3
	-5	-6	2.6	2.6	2.5	2.5	2.4
	-3	-4	2.8	2.7	2.7	2.6	2.5
	0	-1	2.9	2.8	2.8	2.7	2.6
	3	2.2	3.0	3.0	2.9	2.8	2.7
	5	4.1	3.2	3.1	3.1	2.9	2.7
	7	6	3.3	3.2	3.2	3.0	2.7
	9	7.9	3.4	3.3	3.2	3.0	2.7
	11	9.8	3.5	3.3	3.2	3.0	2.7
	13	12	3.6	3.4	3.2	3.0	2.7
	15	14	3.7	3.4	3.2	3.0	2.7
036	-20	-21	2.4	2.4	2.3	2.3	2.3
	-17	-18	2.6	2.5	2.4	2.4	2.3
	-15	-16	2.7	2.6	2.5	2.5	2.4
	-12	-13	2.8	2.7	2.7	2.6	2.6
	-10	-11	2.9	2.9	2.9	2.8	2.8
	-7	-8	3.1	3.1	3.0	3.0	2.9
	-5	-6	3.3	3.2	3.2	3.1	3.0
	-3	-4	3.4	3.4	3.3	3.2	3.1
	0	-1	3.6	3.6	3.5	3.4	3.2
	3	2.2	3.8	3.7	3.7	3.5	3.4
	5	4.1	3.9	3.9	3.8	3.6	3.4
	7	6	4.1	4.1	4.0	3.7	3.4
	9	7.9	4.2	4.1	4.0	3.7	3.4
	11	9.8	4.4	4.2	4.0	3.7	3.4
	13	12	4.5	4.2	4.0	3.7	3.4
	15	14	4.6	4.3	4.0	3.7	3.4
056	-20	-21	3.9	3.8	3.8	3.7	3.7
	-17	-18	4.0	4.0	3.9	3.8	3.8
	-15	-16	4.2	4.1	4.0	3.9	3.8
	-12	-13	4.4	4.3	4.2	4.2	4.1
	-10	-11	4.6	4.6	4.5	4.4	4.4
	-7	-8	4.9	4.8	4.8	4.7	4.5
	-5	-6	5.2	5.1	5.0	4.9	4.7
	-3	-4	5.4	5.3	5.3	5.1	4.9
	0	-1	5.7	5.6	5.5	5.3	5.0
	3	2.2	5.9	5.9	5.8	5.6	5.3
	5	4.1	6.2	6.1	6.0	5.7	5.3
	7	6	6.5	6.4	6.3	5.8	5.3
	9	7.9	6.7	6.5	6.3	5.8	5.3
	11	9.8	6.9	6.6	6.3	5.8	5.3
	13	12	7.1	6.7	6.3	5.8	5.3
	15	14	7.3	6.8	6.3	5.8	5.3
071	-20	-21	4.4	4.3	4.2	4.2	4.2
	-17	-18	4.5	4.4	4.3	4.3	4.2
	-15	-16	4.7	4.6	4.4	4.3	4.2
	-12	-13	4.9	4.8	4.7	4.6	4.5
	-10	-11	5.1	5.1	5.0	4.9	4.9
	-7	-8	5.4	5.4	5.3	5.2	5.1
	-5	-6	5.7	5.6	5.6	5.4	5.2
	-3	-4	6.0	5.9	5.9	5.6	5.4
	0	-1	6.3	6.2	6.1	5.9	5.6
	3	2.2	6.6	6.5	6.4	6.2	5.9
	5	4.1	6.9	6.8	6.7	6.3	5.9
	7	6	7.2	7.1	7.0	6.5	5.9
	9	7.9	7.4	7.2	7.0	6.5	5.9
	11	9.8	7.6	7.3	7.0	6.5	5.9
	13	12	7.9	7.4	7.0	6.5	5.9
	15	14	8.1	7.5	7.0	6.5	5.9

(2) Compact combinations

<table>
<tr><td colspan="4">Type</td><td colspan="6"></td><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td rowspan="6">Model</td><td colspan="3">Compact Combinations</td><td colspan="6">18 HP</td><td colspan="6">20 HP</td><td colspan="6">22 HP</td></tr>
<tr><td colspan="2" rowspan="5">Basic</td><td>RVXVHT080GE</td><td colspan="6">1</td><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td>RVXVHT100GE</td><td colspan="6">1</td><td colspan="6">2</td><td colspan="6">1</td></tr>
<tr><td>RVXVHT120GE</td><td colspan="6"></td><td colspan="6"></td><td colspan="6">1</td></tr>
<tr><td>RVXVHT140GE</td><td colspan="6"></td><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td>RVXVHT160GE</td><td colspan="6"></td><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td colspan="3">Power Supply</td><td>ø/V/Hz</td><td colspan="6">3/ 380~415/ 50</td><td colspan="6">3/ 380~415/ 50</td><td colspan="6">3/ 380~415/ 50</td></tr>
<tr><td colspan="3">Mode*1)</td><td>-</td><td colspan="6">HP</td><td colspan="6">HP</td><td colspan="6">HP</td></tr>
<tr><td rowspan="5">Performance</td><td colspan="2">Horse Power</td><td>HP</td><td colspan="6">18</td><td colspan="6">20</td><td colspan="6">22</td></tr>
<tr><td rowspan="4">Capacity</td><td rowspan="2">Cooling*2)</td><td>kW</td><td colspan="6">50.4</td><td colspan="6">56.0</td><td colspan="6">61.6</td></tr>
<tr><td>Btu/h</td><td colspan="6">171,900</td><td colspan="6">191,000</td><td colspan="6">210,100</td></tr>
<tr><td rowspan="2">Heating*3)</td><td>kW</td><td colspan="6">56.7</td><td colspan="6">63.0</td><td colspan="6">69.3</td></tr>
<tr><td>Btu/h</td><td colspan="6">193,500</td><td colspan="6">215,000</td><td colspan="6">236,500</td></tr>
<tr><td rowspan="5">Power</td><td rowspan="2">Nominal input</td><td>Cooling</td><td>kW</td><td colspan="6">13.54</td><td colspan="6">15.56</td><td colspan="6">18.18</td></tr>
<tr><td>Heating</td><td>kW</td><td colspan="6">12.67</td><td colspan="6">14.32</td><td colspan="6">16.56</td></tr>
<tr><td rowspan="2">Nominal running current</td><td>Cooling</td><td>A</td><td colspan="6">26.1</td><td colspan="6">27.8</td><td colspan="6">34.9</td></tr>
<tr><td>Heating</td><td>A</td><td colspan="6">25.0</td><td colspan="6">26.0</td><td colspan="6">32.2</td></tr>
<tr><td colspan="2">Circuit Breaker (MCCB/ELB)</td><td>A</td><td colspan="6">50</td><td colspan="6">60</td><td colspan="6">60</td></tr>
<tr><td rowspan="2">COP</td><td colspan="2">Cooling</td><td>-</td><td colspan="6">3.72</td><td colspan="6">3.60</td><td colspan="6">3.39</td></tr>
<tr><td colspan="2">Heating</td><td>-</td><td colspan="6">4.48</td><td colspan="6">4.40</td><td colspan="6">4.18</td></tr>
<tr><td rowspan="7">Compressor</td><td colspan="2">Model</td><td>-</td><td>ZPJ61*</td><td>ZPJ72*</td><td>ZPJ83*</td><td>ZPI61*</td><td>ZPI72*</td><td>ZPI83*</td><td>ZPJ61*</td><td>ZPJ72*</td><td>ZPJ83*</td><td>ZPI61*</td><td>ZPI72*</td><td>ZPI83*</td><td>ZPJ61*</td><td>ZPJ72*</td><td>ZPJ83*</td><td>ZPI61*</td><td>ZPI72*</td><td>ZPI83*</td></tr>
<tr><td colspan="2">Type</td><td>-</td><td colspan="3">Digital scroll</td><td colspan="3">Fixed scroll</td><td colspan="3">Digital scroll</td><td colspan="3">Fixed scroll</td><td colspan="3">Digital scroll</td><td colspan="3">Fixed scroll</td></tr>
<tr><td colspan="2">Number</td><td>EA</td><td>2</td><td></td><td></td><td>2</td><td></td><td></td><td>2</td><td></td><td></td><td>2</td><td></td><td></td><td>1</td><td></td><td>1</td><td>1</td><td></td><td>1</td></tr>
<tr><td colspan="2">Piston Displacement</td><td>cc/Rev</td><td>58.1</td><td></td><td></td><td>58.1</td><td></td><td></td><td>58.1</td><td></td><td></td><td>58.1</td><td></td><td></td><td>58.1</td><td></td><td>77.2</td><td>58.1</td><td></td><td>77.2</td></tr>
<tr><td colspan="2">Output</td><td>kW</td><td>4.93</td><td></td><td></td><td>4.93</td><td></td><td></td><td>4.93</td><td></td><td></td><td>4.93</td><td></td><td></td><td>4.93</td><td></td><td>8.02</td><td>4.93</td><td></td><td>8.02</td></tr>
<tr><td rowspan="2">Lubricant</td><td>Type</td><td>-</td><td colspan="6">3MAF POE</td><td colspan="6">3MAF POE</td><td colspan="6">3MAF POE</td></tr>
<tr><td>Charging</td><td>cc</td><td>1,890</td><td></td><td></td><td>1,890</td><td></td><td></td><td>1,890</td><td></td><td></td><td>1,890</td><td></td><td></td><td>1,890</td><td></td><td>1,990</td><td>1,890</td><td></td><td>1,990</td></tr>
<tr><td rowspan="5">Fan</td><td colspan="2">Type/Control</td><td>-</td><td colspan="6">Propeller/BLDC</td><td colspan="6">Propeller/BLDC</td><td colspan="6">Propeller/BLDC</td></tr>
<tr><td colspan="2">Motor Output</td><td>W</td><td colspan="6"></td><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td colspan="2">Airflow Rate</td><td>m³/min</td><td colspan="6">170 x 2</td><td colspan="6">170 x 2</td><td colspan="6">170 x 1 + 180 x 1</td></tr>
<tr><td rowspan="2">External Static Pressure</td><td rowspan="2">Max.</td><td>mmAq</td><td colspan="6">8</td><td colspan="6">8</td><td colspan="6">8</td></tr>
<tr><td>Pa</td><td colspan="6">78.5</td><td colspan="6">78.5</td><td colspan="6">78.5</td></tr>
<tr><td rowspan="6">Safety Devices</td><td colspan="2" rowspan="3">Mechanical Type</td><td>-</td><td colspan="6">High pressure switch</td><td colspan="6">High pressure switch</td><td colspan="6">High pressure switch</td></tr>
<tr><td>-</td><td colspan="6">Crank Case Heater</td><td colspan="6">Crank Case Heater</td><td colspan="6">Crank Case Heater</td></tr>
<tr><td>-</td><td colspan="6">Fuse for PCB</td><td colspan="6">Fuse for PCB</td><td colspan="6">Fuse for PCB</td></tr>
<tr><td colspan="2" rowspan="3">Electronic Type</td><td>-</td><td colspan="6">Over voltage protection</td><td colspan="6">Over voltage protection</td><td colspan="6">Over voltage protection</td></tr>
<tr><td>-</td><td colspan="6">Current Transformer</td><td colspan="6">Current Transformer</td><td colspan="6">Current Transformer</td></tr>
<tr><td>-</td><td colspan="6">Fan over heat/current protector</td><td colspan="6">Fan over heat/current protector</td><td colspan="6">Fan over heat/current protector</td></tr>
<tr><td rowspan="5">Piping Connections</td><td colspan="2">Liquid</td><td>ø, mm</td><td colspan="6">15.88</td><td colspan="6">15.88</td><td colspan="6">15.88</td></tr>
<tr><td colspan="2">Gas</td><td>ø, mm</td><td colspan="6">28.58</td><td colspan="6">28.58</td><td colspan="6">28.58</td></tr>
<tr><td colspan="2">Oil (Flare)</td><td>ø, mm</td><td colspan="6">6.35</td><td colspan="6">6.35</td><td colspan="6">6.35</td></tr>
<tr><td rowspan="2">Installation Limitation</td><td>Max. Length</td><td>m</td><td colspan="6">200</td><td colspan="6">200</td><td colspan="6">200</td></tr>
<tr><td>Max. Height</td><td>m</td><td colspan="6">50 (40)</td><td colspan="6">50 (40)</td><td colspan="6">50 (40)</td></tr>
<tr><td rowspan="2">Refrigerant</td><td colspan="2">Type</td><td>-</td><td colspan="6">R410A</td><td colspan="6">R410A</td><td colspan="6">R410A</td></tr>
<tr><td colspan="2">Factory Charging</td><td>kg</td><td colspan="6">7.5 x 2</td><td colspan="6">7.5 x 2</td><td colspan="6">7.5 x 2</td></tr>
<tr><td>Sound*4)</td><td colspan="2">Sound Pressure</td><td>dB(A)</td><td colspan="6">60</td><td colspan="6">61</td><td colspan="6">62</td></tr>
<tr><td rowspan="4">Set Size</td><td colspan="2">Net Weight</td><td>kg</td><td colspan="6">240 x 2</td><td colspan="6">240 x 2</td><td colspan="6">240 x 2</td></tr>
<tr><td colspan="2">Shipping Weight</td><td>kg</td><td colspan="6">253 x 2</td><td colspan="6">253 x 2</td><td colspan="6">253 x 2</td></tr>
<tr><td colspan="2">Net Dimensions (WxHxD)</td><td>mm</td><td colspan="6">(880 x 1,703 x 765) x 2</td><td colspan="6">(880 x 1,703 x 765) x 2</td><td colspan="6">(880 x 1,703 x 765) x 2</td></tr>
<tr><td colspan="2">Shipping Dimensions (WxHxD)</td><td>mm</td><td colspan="6">(948 x 1,868 x 832) x 2</td><td colspan="6">(948 x 1,868 x 832) x 2</td><td colspan="6">(948 x 1,868 x 832) x 2</td></tr>
<tr><td rowspan="2">Cable</td><td colspan="2">Main Power (Below 50m)</td><td>mm²</td><td colspan="6">CV 6</td><td colspan="6">CV 10</td><td colspan="6">CV 10</td></tr>
<tr><td colspan="2">Communication</td><td>mm²</td><td colspan="6">0.75~1.50</td><td colspan="6">0.75~1.50</td><td colspan="6">0.75~1.50</td></tr>
<tr><td rowspan="2">Operating Temp. Range</td><td colspan="2">Cooling</td><td>℃</td><td colspan="6">-5~43</td><td colspan="6">-5~43</td><td colspan="6">-5~43</td></tr>
<tr><td colspan="2">Heating</td><td>℃</td><td colspan="6">-20~24</td><td colspan="6">-20~24</td><td colspan="6">-20~24</td></tr>
</table>

Catalogue (4)

SPECIFICATIONS SUMMARY AOY36VMNM4

	ASY/ARY-VM Series Indoor Unit Combinations (x1,000BTU)				Capacity of each indoor unit (kW) rated at 230V											
					8.5A				11A				16.5A			
					A	B	C	D	A	B	C	D	A	B	C	D
1 indoor unit operation for all systems	9	–	–	–	2.70	–	–	–	2.70	–	–	–	2.70	–	–	–
	12	–	–	–	3.50	–	–	–	3.50	–	–	–	3.50	–	–	–
	18	–	–	–	5.20	–	–	–	5.20	–	–	–	5.20	–	–	–
	24	–	–	–	5.80	–	–	–	6.50	–	–	–	6.80	–	–	–
SMIGHTY V-2 *Or 2 indoor units operation for SMIGHTY V-3 and V-4*	* 9	9	–	–	2.70	2.70	–	–	2.70	2.70	–	–	2.70	2.70	–	–
	* 12	9	–	–	3.15	2.50	–	–	3.50	2.70	–	–	3.50	2.70	–	–
	18	9	–	–	4.05	2.05	–	–	4.55	2.30	–	–	5.05	2.55	–	–
	24	9	–	–	4.40	1.90	–	–	5.00	2.15	–	–	5.55	2.35	–	–
	12	12	–	–	3.00	3.00	–	–	3.30	3.30	–	–	3.50	3.50	–	–
	18	12	–	–	3.90	2.45	–	–	4.40	2.80	–	–	4.90	3.10	–	–
	24	12	–	–	4.30	2.20	–	–	4.90	2.50	–	–	5.50	2.90	–	–
**:Except for SMIGHTY V-2*	18	18	–	–	3.25	3.25	–	–	3.70	3.70	–	–	4.15	4.15	–	–
	24	18	–	–	3.55	3.00	–	–	4.10	3.45	–	–	4.60	3.90	–	–
SMIGHTY V-3 *Or 3 indoor units operation for SMIGHTY V-4*	9	9	9	–	2.10	2.10	2.10	–	2.30	2.30	2.30	–	2.60	2.60	2.60	–
	12	9	9	–	2.40	1.95	1.95	–	2.75	2.20	2.20	–	3.10	2.45	2.45	–
	18	9	9	–	3.25	1.65	1.65	–	3.70	1.90	1.90	–	4.20	2.15	2.15	–
	24	9	9	–	3.55	1.55	1.55	–	4.05	1.75	1.75	–	4.65	2.00	2.00	–
	12	12	9	–	2.30	2.30	1.85	–	2.60	2.60	2.10	–	2.95	2.95	2.30	–
	18	12	9	–	3.10	1.95	1.60	–	3.55	2.25	1.80	–	4.00	2.55	2.05	–
	24	12	9	–	3.40	1.80	1.80	–	3.90	2.10	1.70	–	4.50	2.40	1.95	–
	18	18	9	–	2.70	2.70	1.40	–	3.10	3.10	1.60	–	3.55	3.55	1.80	–
	24	18	9	–	3.00	2.50	1.30	–	3.40	2.90	1.50	–	3.95	3.30	1.70	–
	12	12	12	–	2.20	2.20	2.20	–	2.45	2.45	2.45	–	2.75	2.75	2.75	–
	18	12	12	–	3.00	1.90	1.90	–	3.40	2.15	2.15	–	3.80	2.45	2.45	–
	24	12	12	–	3.30	1.75	1.75	–	3.80	1.95	1.95	–	4.30	2.30	2.30	–
	18	18	12	–	2.60	2.60	1.65	–	2.95	2.95	1.85	–	3.40	3.40	2.15	–
	24	18	12	–	2.90	2.45	1.55	–	3.30	2.80	1.75	–	3.80	3.20	2.05	–
	18	18	18	–	2.20	2.20	2.20	–	2.65	2.65	2.65	–	3.05	3.05	3.05	–
	24	18	18	–	2.45	2.05	2.05	–	2.95	2.50	2.50	–	3.40	2.90	2.90	–
SMIGHTY V-4	9	9	9	9	1.65	1.65	1.65	1.65	1.85	1.85	1.85	1.85	2.15	2.15	2.15	2.15
	12	9	9	9	1.90	1.55	1.55	1.55	2.20	1.80	1.80	1.80	2.50	2.00	2.00	2.00
	18	9	9	9	2.65	1.35	1.35	1.35	3.05	1.55	1.55	1.55	3.50	1.80	1.80	1.80
	24	9	9	9	2.90	1.30	1.30	1.30	3.35	1.45	1.45	1.45	3.90	1.70	1.70	1.70
	12	12	9	9	1.85	1.85	1.50	1.50	2.10	2.10	1.70	1.70	2.40	2.40	1.95	1.95
	18	12	9	9	2.55	1.60	1.30	1.30	2.95	1.85	1.50	1.50	3.35	2.15	1.75	1.75
	24	12	9	9	2.80	1.50	1.25	1.25	3.25	1.75	1.40	1.40	3.75	2.00	1.60	1.60
	18	18	9	9	2.15	2.15	1.10	1.10	2.60	2.60	1.35	1.35	3.00	3.00	1.55	1.55
	24	18	9	9	2.40	2.00	1.05	1.05	2.85	2.45	1.25	1.25	3.35	2.85	1.45	1.45
	12	12	12	9	1.75	1.75	1.75	1.45	2.00	2.00	2.00	1.65	2.30	2.30	2.30	1.85
	18	12	12	9	2.45	1.55	1.55	1.30	2.80	1.80	1.80	1.45	3.25	2.05	2.05	1.65
	24	12	12	9	2.70	1.45	1.45	1.20	3.10	1.65	1.65	1.35	3.60	1.95	1.95	1.55
	18	18	12	9	2.20	2.20	1.40	1.15	2.50	2.50	1.60	1.30	2.90	2.90	1.85	1.50
	12	12	12	12	1.70	1.70	1.70	1.70	1.95	1.95	1.95	1.95	2.20	2.20	2.20	2.20
	18	12	12	12	2.40	1.50	1.50	1.50	2.75	1.75	1.75	1.75	3.10	2.00	2.00	2.00
	24	12	12	12	2.70	1.40	1.40	1.40	3.05	1.65	1.65	1.65	3.50	1.90	1.90	1.90

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APPENDIX (B)

Table(1)

TABLE 6–2 Values of infiltration air coefficient K.[2] for windows.

Window Type	Infiltration Air Coefficient K		
	Average	Minimum	Maximum
Sliding			
Iron	0.36	0.25	0.40
Aluminum	0.43	0.25	0.70
Hung			
Iron	0.25	0.10	0.60
Aluminum (side pivoted)	0.36	0.07	0.70
Aluminum (horizontal pivoted)	0.30	0.07	0.50
PVC	0.10	0.03	0.15

Table(2)

TABLE 6–4 Values of the factor S_2 of Eq. (6–7).

Location Class	Class 1			Class 2			Class 3			Class 4		
Building Height, m	A	B	C	A	B	C	A	B	C	A	B	C
3	0.47	0.52	0.56	0.55	0.60	0.64	0.63	0.67	0.72	0.73	0.78	0.83
5	0.50	0.55	0.60	0.60	0.65	0.70	0.70	0.74	0.79	0.78	0.83	0.88
10	0.58	0.62	0.67	0.69	0.74	0.78	0.83	0.88	0.93	0.90	0.95	1.00
15	0.64	0.69	0.74	0.78	0.83	0.88	0.91	0.95	1.00	0.94	0.99	1.03
20	0.70	0.75	0.79	0.85	0.90	0.95	0.94	0.98	1.03	0.96	1.01	1.06
30	0.79	0.85	0.90	0.92	0.97	1.01	0.98	1.03	1.07	1.00	1.05	1.09
40	0.89	0.93	0.97	0.95	1.00	1.05	1.01	1.06	1.10	1.03	1.08	1.12
50	0.94	0.98	1.02	1.00	1.04	1.08	1.04	1.08	1.12	1.06	1.10	1.14
60	0.98	1.02	1.05	1.02	1.06	1.10	1.06	1.10	1.14	1.08	1.12	1.15
80	1.03	1.07	1.10	1.06	1.10	1.13	1.09	1.13	1.17	1.11	1.15	1.18
100	1.07	1.10	1.13	1.09	1.12	1.16	1.12	1.16	1.19	1.13	1.17	1.20
120	1.10	1.13	1.15	1.11	1.15	1.18	1.14	1.18	1.21	1.15	1.19	1.22
140	1.12	1.15	1.17	1.13	1.17	1.12	1.16	1.19	1.22	1.17	1.20	1.24
160	1.14	1.17	1.19	1.15	1.18	1.21	1.18	1.21	1.24	1.19	1.22	1.25
180	1.16	1.19	1.20	1.17	1.20	1.23	1.19	1.22	1.25	1.20	1.23	1.26
200	1.18	1.21	1.22	1.18	1.21	1.24	1.21	1.24	1.26	1.21	1.24	1.27

Table(3)

TABLE 5–4 Overall Heat Transfer Coefficient for Windows, W/m[2].°C

Material Type and Frames	Wind Speed, m/s					
	Single Glass			Double Glass, 6mm air gap		
	< 0.5	0.5 - 5.0	> 5.0	< 0.5	0.5 - 5.0	> 5.0
Wood	3.8	4.3	5.0	2.3	2.5	2.7
Aluminum	5.0	5.6	6.7	3.0	3.2	3.5
Steel	5.0	5.6	6.7	3.0	3.2	3.5
PVC	3.8	4.3	5.0	2.3	2.5	2.7

Table(4)

TABLE 7–8 Performance and technical data for commercial cast iron boilers of low and medium heating capacities (Selected from different manufacturers catalogues).

Output kW	No. of Sections	Water Content Liter	Mass kg	Depth mm
Low Heating Capacity Boilers				
26	4	17	140	520
34	5	21	160	520
42	6	25	190	686
50	7	29	210	686
56	8	33	245	686
Medium Heating Capacity Boilers				
49	4	32	280	510
64	5	40	330	615
79	6	47	380	720
91	7	55	430	825
110	8	62	480	930
128	9	70	530	1,035
139	10	77	580	1,140

Table (5)

566 / DRAINAGE AND WASTEWATER DISPOSAL

Table 10.1 Approximate Discharge Rates and Velocities[a] in Sloping Drains Flowing Half Full[b]

Actual Inside Diameter of Pipe, in.	1/16 in./ft Slope		1/8 in./ft Slope		1/4 in./ft Slope		1/2 in./ft Slope	
	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps	Discharge, gpm	Velocity, fps
1¼							3.40	1.78
1⅜					3.13	1.34	4.44	1.90
1½					3.91	1.42	5.53	2.01
1⅝					4.81	1.50	6.80	2.12
2					8.42	1.72	11.9	2.43
2½			10.8	1.41	15.3	1.99	21.6	2.82
3			17.6	1.59	24.8	2.25	35.1	3.19
4	26.70	1.36	37.8	1.93	53.4	2.73	75.5	3.86
5	48.3	1.58	68.3	2.23	96.6	3.16	137.	4.47
6	78.5	1.78	111.	2.52	157.	3.57	222.	5.04
8	170.	2.17	240.	3.07	340.	4.34	480.	6.13
10	308.	2.52	436.	3.56	616.	5.04	872.	7.12
12	500.	2.83	707.	4.01	999.	5.67	1413	8.02

Table(6)

Table 10.4 Horizontal Fixture Branches and Stacks

	Maximum Number of Fixture Units That May Be Connected to			
			Stacks with More Than Three Branch Intervals	
Diameter of Pipe, in.	*Any Horizontal Fixture Branch,[a] dfu*	*One Stack of Three Branch Intervals or Less, dfu*	*Total for Stack, dfu*	*Total at One Branch Interval, dfu*
1½	3	4	8	2
2	6	10	24	6
2½	12	20	42	9
3	20[b]	48[b]	72[b]	20[b]
4	160	240	500	90
5	360	540	1100	200
6	620	960	1900	350
8	1400	2200	3600	600
10	2500	3800	5600	1000
12	3900	6000	8400	1500
15	7000			

Table (7)

North Latitude Wall Facing	Solar Time h																								Hour of Max. CLTD	Min. CLTD	Max. CLTD	Difference CLTD
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24				
NW	14	13	12	11	10	9	8	7	6	6	5	5	6	6	6	7	9	10	12	14	15	15	15	15	22	5	15	10
	Group D Walls																											
N	8	7	7	6	5	4	3	3	3	3	4	4	5	6	6	7	8	9	10	11	11	10	10	9	21	3	11	8
NE	9	8	7	6	5	5	4	4	6	8	10	11	12	13	13	13	14	14	14	13	13	12	11	10	19	4	14	10
E	11	10	8	7	6	5	5	5	7	10	13	15	17	18	18	18	18	18	17	17	16	15	13	12	16	5	18	13
SE	11	10	9	7	6	5	5	5	5	7	10	12	14	16	17	18	18	18	17	17	16	15	14	12	17	5	18	13
S	11	10	8	7	6	5	4	4	3	3	4	5	7	9	11	13	15	16	16	16	15	14	13	12	19	3	16	13
SW	15	14	12	10	9	8	6	5	5	4	4	5	5	7	9	12	15	18	20	21	21	20	19	17	21	4	21	17
W	17	15	13	12	10	9	7	6	5	5	5	5	6	6	8	10	13	17	20	22	23	22	21	19	21	5	23	18
NW	14	12	11	9	8	7	6	5	4	4	4	4	5	6	7	8	10	12	15	17	18	17	16	15	22	4	18	14

Table (8)

TABLE 9-2 Latitude-Month correction factor LM, as applied to walls and horizontal roofs, north latitudes.

Lat.	Month	N	NNE NNW	NE NW	ENE WNW	E W	ESE WSW	SE SW	SSE SSW	S	Horizontal Roofs
16	December	−2.2	−3.3	−4.4	−4.4	−2.2	−0.5	2.2	5.0	7.2	−5.0
	Jan./Nov.	−2.2	−3.3	−3.8	−3.8	−2.2	−0.5	2.2	4.4	6.6	−3.8
	Feb./Oct.	−1.6	−2.7	−2.7	−2.2	−1.1	0.0	1.1	2.7	3.8	−2.2
	Mar/Sept.	−1.6	−1.6	−1.1	−1.1	−0.5	−0.5	0.0	0.0	0.0	−0.5
	Apr./Aug.	−0.5	0.0	−0.5	−0.5	−0.5	−1.6	−1.6	−2.7	−3.3	0.0
	May/July	2.2	1.6	1.6	0.0	−0.5	−2.2	−2.7	−3.8	−3.8	0.0
	June	3.3	2.2	2.2	0.5	−0.5	−2.2	−3.3	−4.4	−3.8	0.0
24	December	−2.7	−3.8	−5.5	−6.1	−4.4	−2.7	1.1	5.0	6.6	−9.4
	Jan./Nov.	−2.2	−3.3	−4.4	−5.0	−3.3	−1.6	−1.6	5.0	7.2	−6.1
	Feb./Oct.	−2.2	−2.7	−3.3	−3.3	−1.6	−0.5	1.6	3.8	5.5	−3.8
	Mar/Sept.	−1.6	−2.2	−1.6	−1.6	−0.5	−0.5	0.5	1.1	2.2	−1.6
	Apr./Aug.	−1.1	−0.5	0.0	−0.5	−0.5	−1.1	−0.5	−1.1	−1.6	0.0
	May/July	0.5	1.1	1.1	0.0	0.0	−1.6	−1.6	−2.7	−3.3	0.5
	June	1.6	1.6	1.6	0.5	0.0	−1.6	−2.2	−3.3	−3.3	0.5
32	December	−2.7	−3.8	−5.5	−6.1	−4.4	−2.7	1.1	5.0	6.6	−9.4
	Jan./Nov.	−2.7	−3.8	−5.0	−6.1	−4.4	−2.2	1.1	5.0	6.6	−8.3
	Feb./Oct.	−2.2	−3.3	−3.8	−4.4	−2.2	−1.1	2.2	4.4	6.1	−5.5
	Mar/Sept.	−1.6	−2.2	−2.2	−2.2	−1.1	−0.5	1.6	2.7	3.8	−2.7
	Apr./Aug.	−1.1	−1.1	−0.5	−1.1	0.0	−0.5	0.0	5.0	0.5	−0.5
	May/July	0.5	0.5	0.5	0.0	0.0	−0.5	−0.5	−1.6	−1.6	0.5
	June	0.5	1.1	1.1	0.5	0.0	−1.1	−1.1	−2.2	−2.2	1.1

Table (9)

TABLE 5–5 Overall heat transfer coefficients for wood and metal doors, W/m^2·°C.

Door Type	Without Storm Door	With Wood Storm Door	With Metal Storm Door
25 mm-wood	3.6	1.7	2.2
35 mm-wood	3.1	1.6	1.9
40 mm-wood	2.8	1.5	1.8
45 mm-wood	2.7	1.5	1.8
50 mm-wood	2.4	1.4	1.7
Aluminum	7.0	—	—
Steel	5.8	—	—
Steel with:			
Fiber core	3.3	—	—
Polystyrene core	2.7	—	—
Polyurethane core	2.3	—	—

Table (10)

TABLE 5–4 Overall Heat Transfer Coefficient for Windows, W/m²·°C

Material Type and Frames	Wind Speed, m/s					
	Single Glass			Double Glass, 6mm air gap		
	< 0.5	0.5 - 5.0	> 5.0	< 0.5	0.5 - 5.0	> 5.0
Wood	3.8	4.3	5.0	2.3	2.5	2.7
Aluminum	5.0	5.6	6.7	3.0	3.2	3.5
Steel	5.0	5.6	6.7	3.0	3.2	3.5
PVC	3.8	4.3	5.0	2.3	2.5	2.7

Table (11)

TABLE 9-16 Cooling load factor due to occupants $(CLF)_{occ}$, for sensible heat gain.[5]

Hours after each entry into space	Total hours in space							
	2	4	6	8	10	12	14	16
1	0.49	0.49	0.50	0.51	0.53	0.55	0.58	0.62
2	0.58	0.59	0.60	0.61	0.62	0.64	0.66	0.70
3	0.17	0.66	0.67	0.67	0.69	0.70	0.72	0.75
4	0.13	0.71	0.72	0.72	0.74	0.75	0.77	0.79
5	0.10	0.27	0.76	0.76	0.77	0.79	0.80	0.82
6	0.08	0.21	0.79	0.80	0.80	0.81	0.83	0.85
7	0.07	0.16	0.34	0.82	0.83	0.84	0.85	0.87
8	0.06	0.14	0.26	0.84	0.85	0.86	0.87	0.88
9	0.05	0.11	0.21	0.38	0.87	0.88	0.89	0.90
10	0.04	0.10	0.18	0.30	0.89	0.89	0.9	0.91
11	0.04	0.08	0.15	0.25	0.42	0.91	0.91	0.92
12	0.03	0.07	0.13	0.21	0.34	0.92	0.92	0.93
13	0.03	0.06	0.11	0.18	0.28	0.45	0.93	0.94
14	0.02	0.06	0.10	0.15	0.23	0.36	0.94	0.95
15	0.02	0.05	0.08	0.13	0.20	0.30	0.47	0.95
16	0.02	0.04	0.07	0.12	0.17	0.25	0.38	0.96
17	0.02	0.04	0.06	0.10	0.15	0.21	0.31	0.49
18	0.01	0.03	0.06	0.09	0.13	0.19	0.26	0.39

Table (12)

TABLE 4–2 Instantaneous heat gain from occupants in units of Watts[a].

Type of Activity	Typical Application	Total Heat Dissipation Adult Male	Total Adjusted[a] Heat Dissipation	Sensible Heat, W	Latent Heat, W
Seated at rest	*Theater*:				
	Matinee	111.5	94.0	64.0	30.0
	Evening	111.5	100.0	70.0	30.0
Seated, very light work	Offices, hotels, apartments, restaurants	128.5	114.0	70.0	44.0
Moderately active office work	Offices, hotels, apartments	135.5	128.5	71.5	57.0
Standing, light work, walking	Department store, retail store, supermarkets	157.0	143.0	71.5	71.5
Walking, seated	Drug store	157.0	143.0	71.5	71.5
Standing, walking slowly	Bank	157.0	143.0	71.5	71.5
Sedentary work	Restaurant	168.5	157.0	78.5	78.5
Light bench work	Factory	238.0	214.0	78.0	136.0
Moderate work	Small-Parts assembly	257.0	243.0	87.0	156.0
Moderate dancing	Dance halls	257.0	243.0	87.0	156.0
Walking at 1.5 m/s	Factory	286.0	285.0	107.0	178.0
Bowling (participant)	Bowling alley	428.5	414.0	166.0	248.0
Heavy work	Factory	428.5	414.0	166.0	248.0

Table (13) Expansion Tank minimum capacity

Boiler Capacity	Tank Volume (litter)
Up to 29	100
58	200
87	250
116	500
175	750

Figure (1)

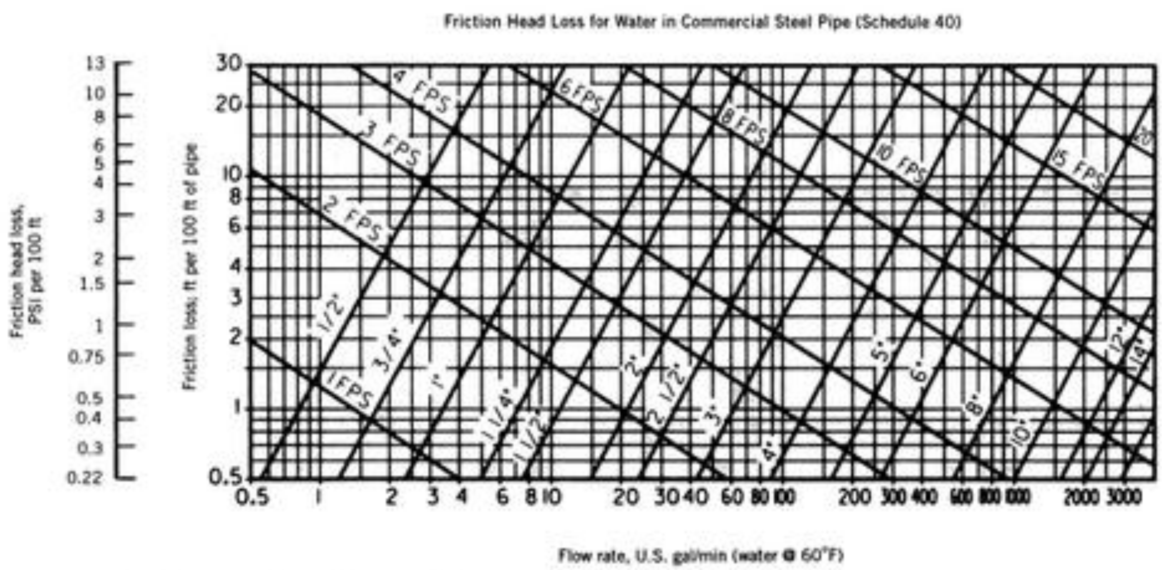
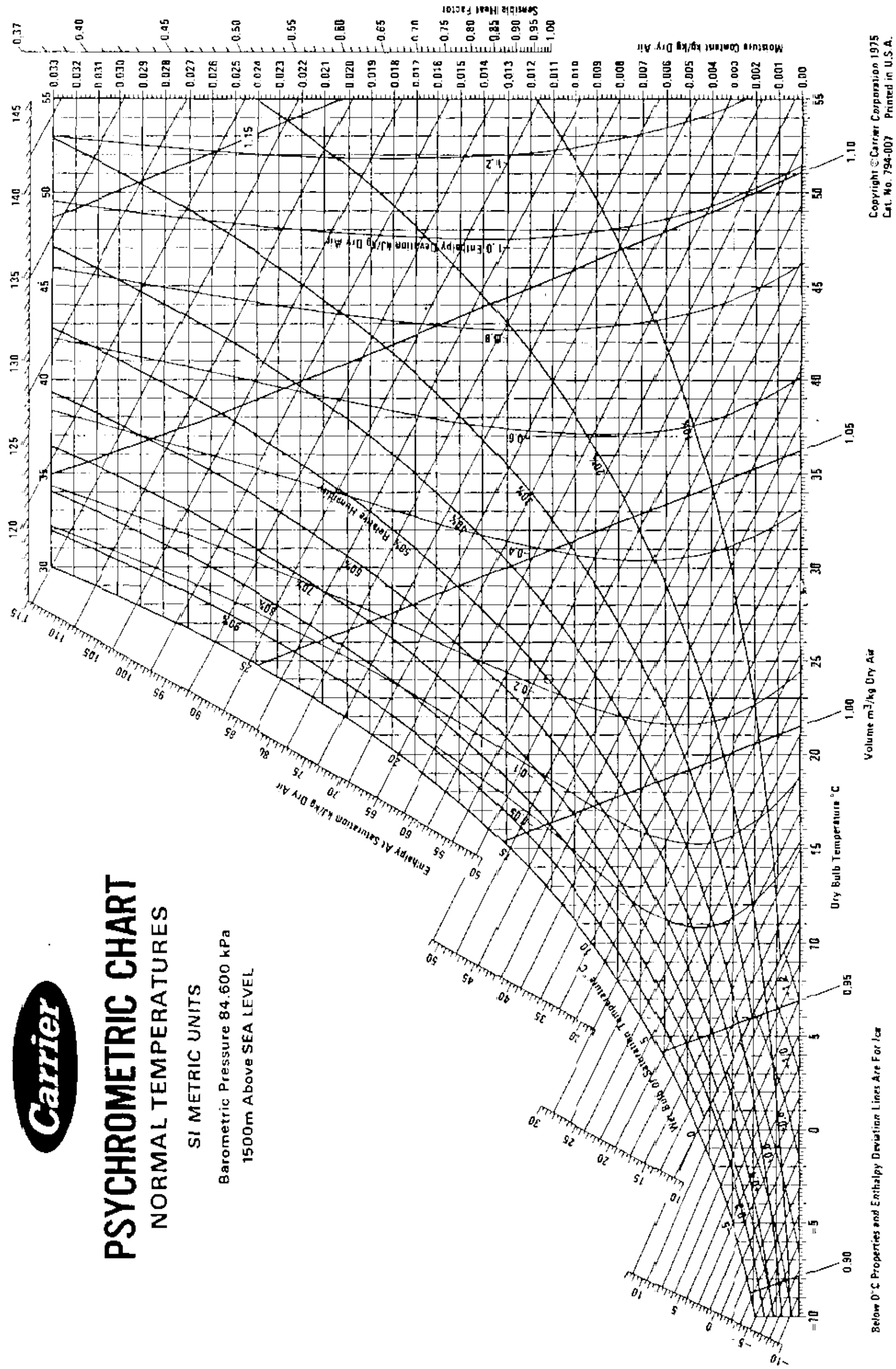


Figure 9.5 Chart of friction head loss in Schedule 40 black iron or steel pipe, for water at 60°F, in feet of water and psi per 100 ft of equivalent pipe length. Pipe sizes are nominal. (Reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, Georgia, from the 1993 *ASHRAE Handbook—Fundamentals*.)

Figure (2)


Carrier
PSYCHROMETRIC CHART
NORMAL TEMPERATURES
SI METRIC UNITS
Barometric Pressure 84.600 kPa
1500m Above SEA LEVEL
Sensible Heat Factor
Moisture Content kg/kg Dry Air
Enthalpy Deviation kJ/kg Dry Air
Relative Humidity
Enthalpy At Saturation kJ/kg Dry Air
Wet Bulb or Saturation Temperature °C
Dry Bulb Temperature °C
Volume m3/kg Dry Air
Copyright © Carrier Corporation 1975
Cat. No. 794-007 Printed in U.S.A.
Below 0°C Properties and Enthalpy Deviation Lines Are For Ice

Cost estimation and Bill of quantities

Item number	Description	Unit	Quantity
1.1 1.1.1 A.	<u>Waste and drainage system</u>: <u>Vertical and Horizontal UPVC pipes</u> : Supply and install UPVC pipes and fittings include all needed connections and all type of fittings , according to the drawings Dia 4"	M.L	25 m
B.	Dia 2"	M.L	40 m
1.1.2 A.	Floor trap and Clean Out Threaded 15x15cm chrome plated cover UPVC red siphon and connect it with vertical pipes , including rings fittings and everything need to complete the job Floor trap size 2" Diameter	No.	12
B.	Floor drain size 4"/2" Diameter	No.	4
C.	Clean out`s 4"	No.	12
1.2	Supply install and test UPVC external Drainage Rain pipes and fittings include connections excavation covering with layer 20cm of sand around the pipe		
A.	Size 2 " Diameter	M.L	10 m
1.3 A.	Manholes Supply and install (Pre cast) concrete manholes of 15cm thickness walls and base , with heavy duty cast iron covers and frames . Size 60cm (inside diameter)	No.	13
2.1	<u>Demos tic hot and cold water system :</u> <u>Main water supply</u> Supply and install galvanized steel main water pipe(2") , with asphalt protection which will take from the main line of the city 4" with all necessary Fittings, elbow Tee union stop valves non return valve and whatever needed to complete the job	l.S	1
2.2	Supply and install galvanized pipes medium class for domestic cold water , hot water and the work include all fittings valves and what needed 1/2" Diameter	M.L	9

2.3	**Supply and install hot and cold water collectors and installing 16 mm plastic pipes with it`s 25 mm plastic conduits to be connected from the cupper collector**		
A.	**3/4"**	**Eye**	**12**
B.	**16 mm plastic pipes with it`s 24 mm plastic conduits**	**M.L**	**17**
2.4	**Supply and install galvanized Water tanks on the roof (1 m3 for each one)**	**No.**	**2**
2.6	**Supply and install solar plates**	**No.**	**2**
3.1	**Heating system :** **Under floor system :** **Supply and install pex pipe's with diameter 20(mm) For the first floor and, valves and whatever needed to complete the job**	**M.L**	**300**
3.2	**Supply and install the manifold and connect the pexs pipes With it , with all necessary Fittings, valves, presser gauges ,and whatever needed to complete the job**	**No.**	**1**
3.3	**Supply and install the boiler with capacity of 48kw with type of cast iron which is supply the hot water for the villa and for the heating systems**	**No.**	**1**
3.4	**Supply and install the pump which type is circulating pump (M12),and all valves and fittings and whatever needed to complete the job**	**No.**	**1**
A.	**VRV Air Conditioning system** **Supply and install outdoor units and connect them with indoor units include their junctions and all accessories**	**No.**	**2**
B.	**Supply and install indoor units with their accessories**	**No.**	**6**
C.	**Install joint refint which connect the copper pipes together and their branches and whatever needed to complete the job**	**No.**	**5**
D.	**Install copper pipes which connect the indoor and outdoor units**	**M.L**	**165**