Palestine Polytechnic University

College of Engineering

Design Of Mechanical System For The Public Services Center In Ramallah Municipality

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اهداء

الى من جرع الكأس فارغا ليسقني قطرة حب

الى من كلت انامله ليقدم لنا لحظة سعادة

الى من حصد الاشواك عن دربي ليمهد لي طريق العلم

الى القلب الكبير والدي العزيز

الى من ارضعتني الحب والحنان

الى رمز الحب وبلسم الشفاء

الى القلب الناصع بالبياض والدتي الحبيبة

الى القلوب الطاهرة الرقيقة والنفوس البريئة الى رياحين

حياتي إخوتي

الان تفتح الاشرعة وترفع المرساة لتنطلق السفينة في عرض بحر

واسع مظلم هو بحر الحياة وفي هذه الظلمة لا يضيء الا

قنديل الذكريات الى الذين احببتهم واحبوني اصدقائي.

شكر وتقدير

لا بد لنا ونحن نخطو خطواتنا الاخيرة في الحياة الجامعية من وقفة نعود الى اعوام قضيناها في رحاب الجامعة مع اساتذتنا الكرام الذين قدموا لنا الكثير باذلين بذلك جهود كبيرة في بناء جيل الغد لتبعث الامة من جديد....

وقبل ان نمضي نقدم اسمى ايات الشكر والامتنان والتقدير والمحبة الى الذين حملوا اقدس رسالة في الحياة ....

الى الذين مهدو لنا طريق العلم والمعرفة....

الى جميع اساتذتنا الافاضل...

ونخص بالذكر كل من الدكتور إسحاق سدر والمهندس كاظم إعسيلة والمهندس محمد عوض حيث كانو لنا خير عون واعطونا الزاد والوقود فكل الشكر والتقدير والاحترام لحضرتكم..

الى من زرعو التفائل في دربنا وقدمو لنا المساعدات والتسهيلات والافكار والمعلومات الزملاء الطلاب في الهندسة الميكانيكية

Abstract

يهدف هذا المشروع الى تصميم الخدمات الميكانيكية لمركز خدمات جمهور في مدينة رام الله . وتصميم هذا المشروع يشمل عمل حسابات وتجهيز رسومات واختيار المواد والمعدات لنظام تزويد المياه ونظام الصرف الصحي ونظام التكييف والتبريد وإطفاء الحريق .

This project aims to design the mechanical systems for Public Services Center In Ramallah Municipality. The design of this project include making the calculations, drawings, material selection for the water system, drainage system, air conditioning system and the firefighting system.

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Chapter 1

Introduction

Introduction:

In business, industry, schools, hospitals, hotels, theaters, restaurants and homes air conditioning is no longer auxiliary but an essential part of modern living. There are four atmospheric conditions. True air conditioning implies that all four of these atmospheric conditions for human comfort are being met.

The Air conditioning system includes much more than the control of the inside temperature of a given space. It includes the controlling and maintaining of the following four atmospheric conditions that affect the human comfort:

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

The main goal of plumbing design for building is to safely and reliably provide domestic water and water for fire fitting. And also to get rid of the wastes.

1.1. Project objectives

The main objectives for project are:

1. To calculate and design air conditioning, heating and plumbing systems.
2. To prepare the required drawings for each system.
3. To select the required equipments and parts.
4. Design a suitable firefighting system that covers the requirements of the building.

1.2 Time table:

Table 1-1: Time table for the first semester:

Task/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Collecting information	■	■	■												
General study about the project				■	■										
Study the human comfort						■	■	■							
Study about VRF system								■	■	■	■				
Calculating the cooling and heating load											■	■	■	■	
Project documentation													■	■	■

Table 1-2: Time table for the second semester:

Task/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Collecting information															
Fire fighting calculations															
HVAC system															
Division equipments															
Planning by AutoCAD															
Project documentation															

1.3. Project contents:

Chapter One: Introduction

Includes an overview, the project objectives and time table.

Chapter Two: Heating Load

Includes a sample calculation for one room in details, the other room's loads

Chapter Three: Cooling Load

Includes a sample calculation for one room in details, the other rooms loads and mechanical ventilation .

Chapter Four: VRF SYSTEM

Includes the calculation of VRF system to determine the total required amount of water and the drainage system.

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Chapter Five: Firefighting System

Includes general introduction about each system, and the pipe size calculations for one branch.

Chapter Six: Bill of Quantity

This chapter includes the total number of quantity for each system and its cost.

Chapter 2

Heating load calculations

2.1 Heating load:

The main purpose of air conditioning is to provide a comfortable atmosphere for people inside a closed space. The parameters that govern this comfort are four parameters namely air temperature, humidity, air velocity and air purity.

Therefore, cooling decrease the temperature of the surrounding air, heating increase the temperature of the surrounding air, humidifying increas the moisture content in the surrounding air, and dehumidifying decreases the moisture content in the surrounding air. Ventilation renews and clean the air inside the space.

Human body temperature is normally 37˚C . We are comfortable when the heat level in our body is transferring to the surrounding air at comfort rate. The rate of this heat transfer depends on the properties of surrounding air and other factors like the type of clothes the human put on .Therefore, to maintain the correct rate of heat transfer, the surrounding air must be conditioned (i.e. changing the properties of the air to suitable ones).

An air conditioner is an appliance or mechanism designed to extract heat from humanly occupied space air temperature using refrigeration cycle. When air conditioning is available it may be central air conditioning where all parts of the building including common areas are cooled or it may be provided only in the specific spaces. In general comfort occurs when body temperature is held within narrow ranges, skin moisture is low and physiological effort of regulation is minimized. Comfortable conditions result from a desirable combination of air temperature, humidity, air velocity, and air purity.

2.2 ASHRAE comfort chart:

The ASHRAE comfort chart of figure (1) indicate the acceptable zones of selecting the inside operative temperature and the inside relative humidity for winter heating summer cooling and year- round air conditioning application.

The inside operative temperature and the ordinate is the inside humidity ratio or the dew temperature. the acceptable operative temperature values and the inside humidity ratio are considered as standard comfort zones for summer operation , winter operation or year – round application , as indicated on figure (2.1) it can be observed that the minimum operating temperature for comfort winter is (21.2°C) (70 °F) dry-bulb temperature when the inside relative humidity is 50 % thus , the comfort zones figure (2.1) set the limits of both the operative in side temperature and the inside relative humidity of inside air for these zones .One can see from these zones that as the relative humidity increases the operative inside temperature must decrease to keep a desired comfortable environment.

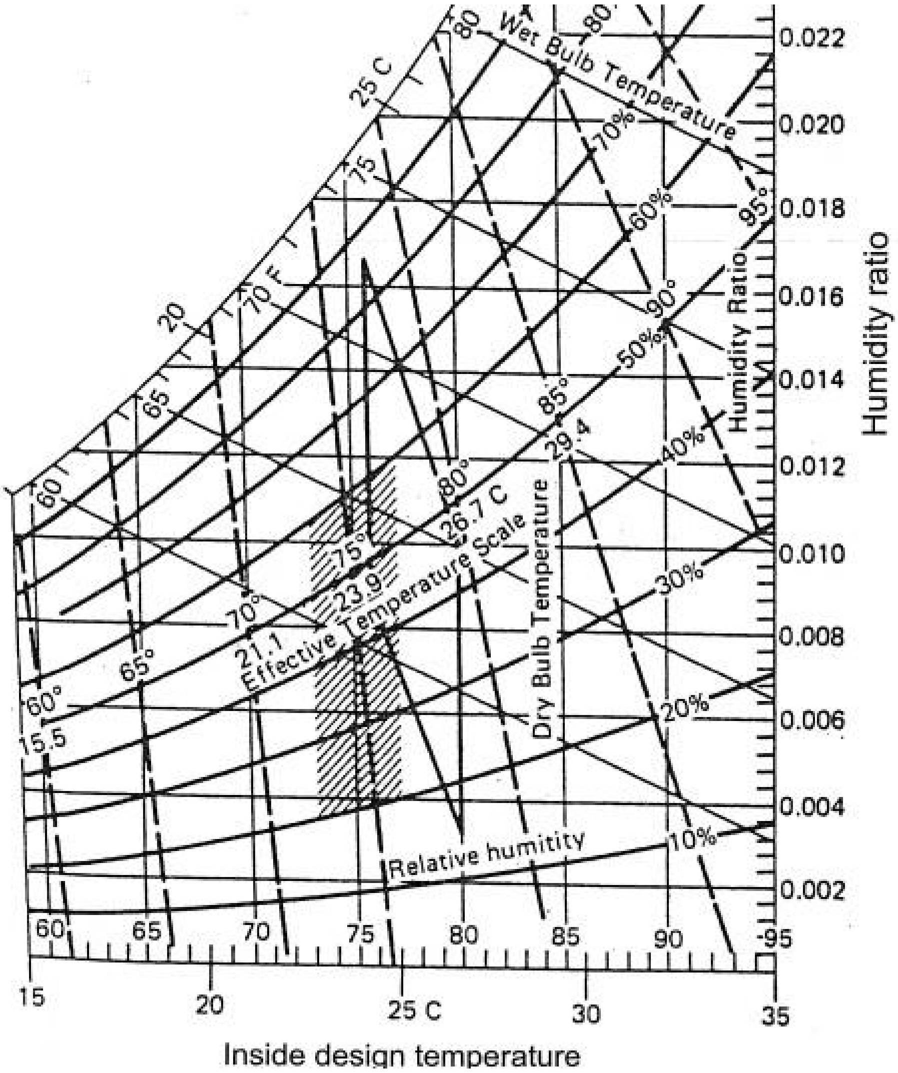


Figure 2.1**:** ASHRAE Comfort Chart

The inside design conditions refer to temperature, humidity, air speed and cleanliness of inside air that will induce comfort to occupants of the space at minimum energy consumption. There are several factors that control of selection of the inside design conditions and expenditure of energy to maintain those conditions; The outside design condition, The period of occupancy of the conditional space, The level of activity of the occupants in conditional space. And the type of building and its use.

Usually the range of temperature difference between inside and outside is 12°C. The relative humidity range from the conditioned space varies from 30% - 60%. A dry environment will be felt when the relative humidity falls below 30%, and sickness will be felt at relative humidity above 60%.

2.3 Calculation of the overall heat transfer coefficient:

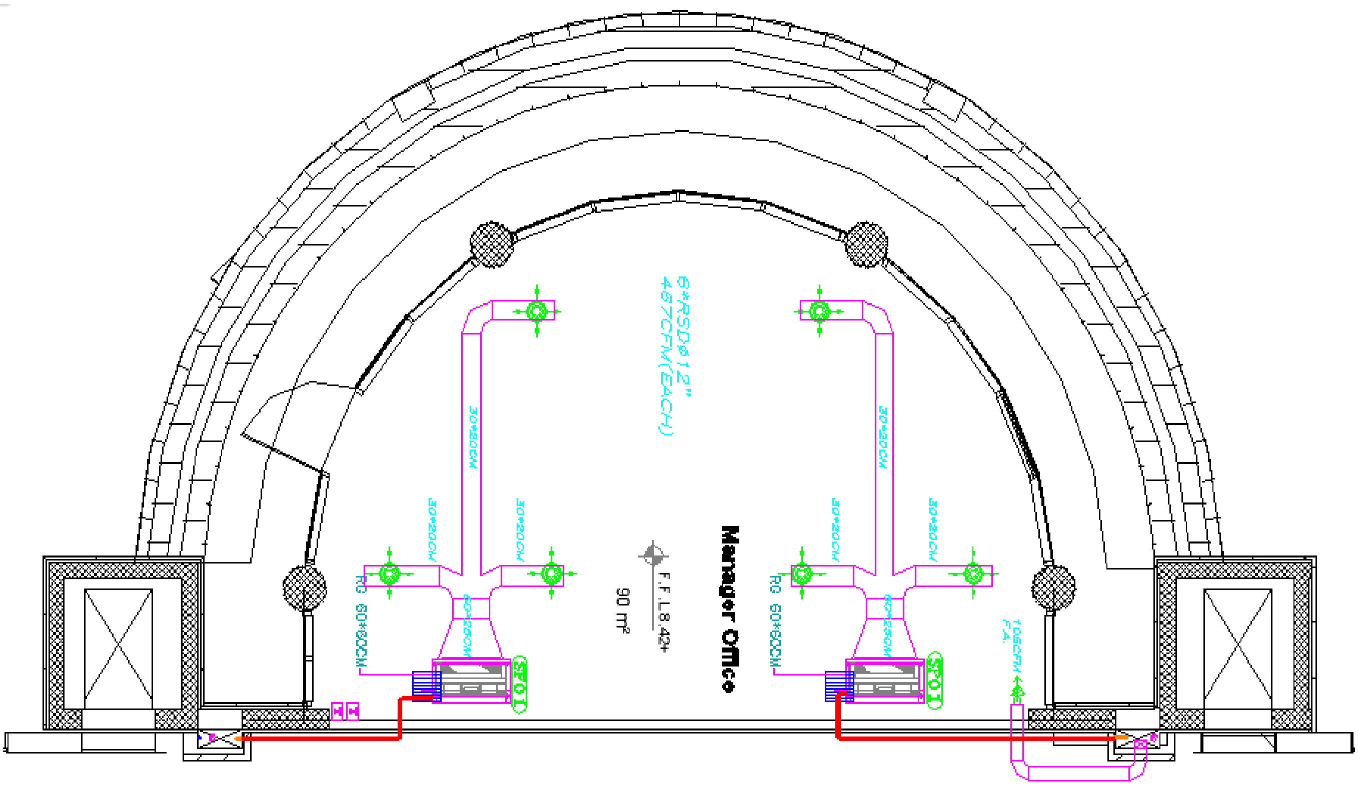


Figure 2.2: office sample

2.3.1 Overall heat transfer coefficient for external walls:

The constructions of the external walls are explained in details in the following figure:-

Table 2-1: External wall constructions:

Material	Thickness(m)	R-value (m². ℃ /W)
Outside air film	-------	0.06
Stone(1)	0.05	1.7
Concrete(2)	0.15	1.75
block(3)	0.07	0.9
randoban(4)	0.03	0.042
Plaster(5)	0.02	1.2
Inside air film	-------	0.12

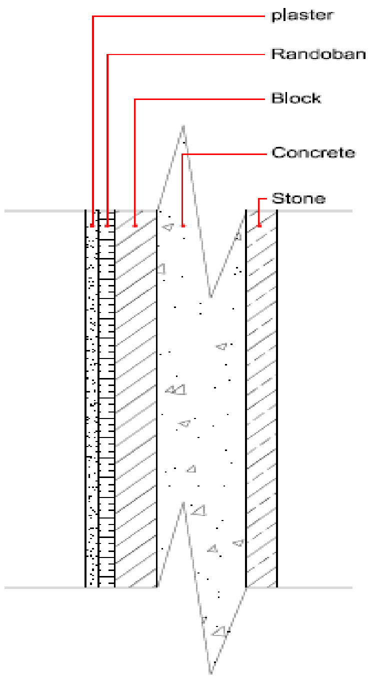


Figure 2.3: External wall

$$U_{walls,out} = \frac{1}{R_{th}} = \frac{1}{\frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \cdots + \frac{1}{h_o}} \quad (2.1)$$

$$U_{walls,out} = \frac{1}{R_{th}} = \frac{1}{0.12 + \frac{.05}{1.7} + \frac{0.15}{1.75} + \frac{0.07}{0.9} + \frac{0.03}{0.042} + \frac{0.02}{1.2} + 0.06}$$

$$U_{walls,out} = \frac{1}{R_{th}} = 0.9059 W/m^2. ℃$$

2.3.2 Overall heat transfer coefficient for internal walls:

The constructions of the internal walls are explained in details in the following figure:-

Table 2-2: Internal wall constructions:

Material	Thickness (m)	R-value (m². ℃ /W)
Inside air film	-------	0.12
Plaster	0.02	1.2
Brick	0.1	0.9
plaster	0.02	1.2
Inside air film	-------	0.12

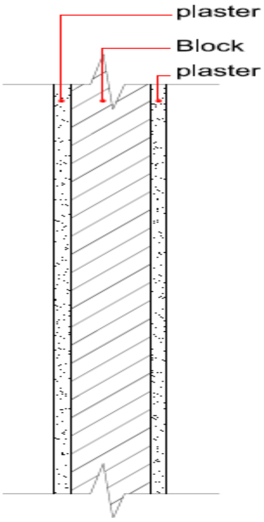


Figure 2.4: Internal wall

$$U_{walls,in} = \frac{1}{R_{th}} = \frac{1}{\frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \cdots + \frac{1}{h_i}}$$

$$U_{walls,in} = \frac{1}{R_{th}} = \frac{1}{0.12 + \frac{0.02}{1.2} + \frac{0.1}{0.9} + \frac{0.02}{1.2} + 0.12}$$

$$U_{walls,in} = 2.6 \ W/m^2. ℃$$

2.3.3 Overall heat transfer coefficient for ceiling:

The constructions of the ceiling are explained in details in the following figure:-

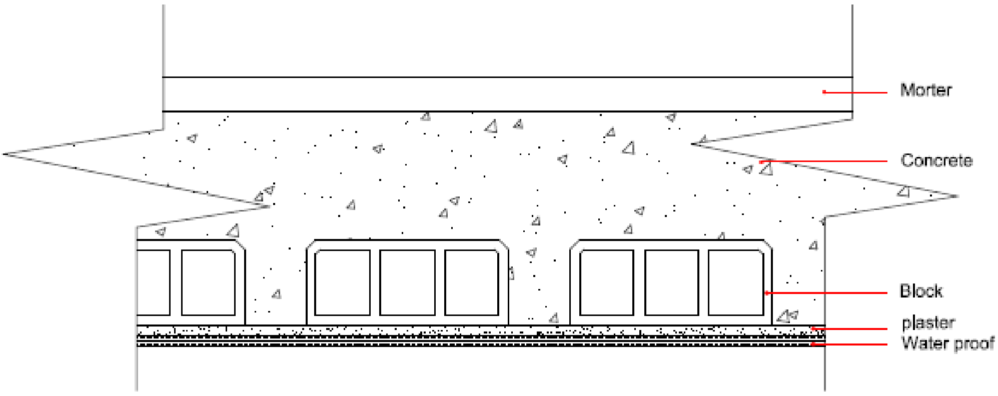


Figure 2.5: Ceiling construction

Table 2-3: Ceiling wall constructions:

Material	**Thickness (m)**	**R-value (m^2.°C /W)**
Outside air film	-------	0.04
Water proof	0.02	0.7
plaster	0.02	1.2
block	0.17	0.95
Concrete	0.25	1.75
mortar	0.07	1.2
Inside air film	-------	0.1

$\dot{Q}$ Ceiling = $(U1 * A1 + U2 * A2)\Delta T$

Where:

U1 : U Ceiling With brick.

U2 : U Ceiling Without brick.

A1 = 4/5 ∗ A Ceiling A2 = 1/5 ∗ A Ceiling

$\dot{Q}$ Ceiling = (1.016 ∗ 4 5 ∗ 54.7 + 1.194 ∗ 1 5 ∗ 54.7) ∗ 6

$\dot{Q}$ Ceiling = 345[W] = 0.345[kW]

2.3.4 Overall heat transfer coefficient for ceiling, doors and windows:

The doors are made from wood, and the windows are double glass Aluminum with a wind speed range from 0.5 to 5 m/s from (Appendix B) Table (B3) .

$U_{windows} = 3.2 \ W/m^2. ℃$

$U_{door} = 7 \ W/m^2. ℃$

2.4 Outdoor and indoor design conditions:

These conditions are include the dry temperature, relative humidity, and the average air speed. We obtain this value from The Palestinian Code.

Table 2-4: Outdoor design conditions:

Season	T_{out} (°C)	Φ_{out}%	v_{out} (m^3/kg dry air)	h_{out} (kJ/kg)
Heating	2	67	0.805	19

Table 2-5: Indoor design conditions:

Season	T_{in} (°C)	Φ_{in}%	h_{out} (kJ/kg)
Heating	24	50	48

2.4.1 Heat loss calculations:

The main resources of heat losses come from the walls, floor, ceiling, doors, and Windows. to calculate each one of them we use the following equation:

$$Q = A \times U \times (T_{in} - T_{out}) \tag{2.2}$$

Where:

Q: The heat transfer rate (W).

A: Area of the layer which heat flow through it (m^2).

ΔT: The difference between the inside and outside temperatures (°C).

U: The overall heat transfer coefficient (W/ m^2. °C)

2.4.2 Rate of heat transfer from the external walls:

From Table (2-4) and Figure (2.3) we know the construction of the external walls, then by using equation (2.2), we can determine the rate of heat transfer for the manager office from the Walls. Out as follow:

$$Q_{walls.out} = U_{walls.out} \times A_{walls.out} \times (T_{in} - T_{out})$$

$$Q_{walls.out} = 0.9059 \times 10.5 \times (24 - 2)$$

$$Q_{walls.out} = 0.209 \text{ kW}$$

2.4.3 Rate of heat transfer from the ceiling:

From Table (2 - 6) and (Figure 4) we know the construction of the ceiling, then by using equation (3.1), we can determine the rate of heat transfer for the manager office from the ceiling as Follow:

$$Q_{Roof} = U_{Roof} \times A_{Roof} \times (T_{in} - T_{out})$$

$$Q_{Roof} = 2.25 \times 90 \times (24 - 2)$$

$$Q_{Roof} = 4.455 \text{ kW}$$

2.4.4 Rate of heat transfer from the doors and windows:

By using the equation (3.1), we can determine the rate of heat transfer for the manager office from the doors and windows as follow:

Doors:

$$Q_{door} = U_{door} \times A_{door} \times (T_{in} - T_{out})$$

$$Q_{door} = 7 \times 2.64 \times (24 - 2)$$

$$Q_{door} = 0.407 \ kw$$

Windows:

$$Q_{windows} = U_{windows} \times A_{windows} \times (T_{in} - T_{out})$$

$$Q_{windows} = 3.2 \times 73.5 \times (24 - 2)$$

$$Q_{windows} = 5.175kw$$

2.4.5 Heat loss :

Infiltration is the leakage of the outside air through cracks or clearances around the windows and doors. The calculation method is as follows:

For windows:

$$Q_{infiltration} = m_{inf} \times (h_o - h_i) \quad (2.3)$$

$$m_f = \frac{V_f}{v_0} \quad (2.4)$$

V_f = crack length × Infiltration through windows (2.5)

Where V_f is obtained from(Appendix B) Table (B4) at 8 km/h as $2m^3/h$ per meter of crack. The crack length of the five double hung metal windows is:

$$L = (21 \times 2) + (3.5 + 2) = 49 \text{ m} .$$

$$V_f = 49 \times 2 = 98\frac{m^3}{h} = \frac{98}{3600} = 0.027222 \ \frac{m^3}{s} .$$

$$m_f = \frac{0.02722}{0.805} = 0.0338 \text{ kg/s}.$$

Also, from the psychometric chart, at the given outside conditions then the specific volume v_0 of outside air is:

$$v_0 = 0.805\ m^3/kg$$

Then total heat loss due to infiltration is:

$$Q_{infiltration} = 0.0338 \times 1\ \times (48 - 19) = 1\ kW$$

For Door:

$$Q_{infiltration} = m_f\ \times (h_o - h_i)$$

$$m_f = \frac{V_f}{v_0}$$

$$V_f = \text{crack length} \times \text{Infiltration through doors}$$

$$L = (2.2 \times 2) + (1.2 + 3) = 6.8\ m\ .$$

$$V_f = 6.8\ \times 5.4\ = 36.72 \frac{m^3}{h} = \frac{36.72}{3600} = 0.0102\ \frac{m^3}{s}\ .$$

Where V_f is obtained from table (Appendix B) Table (B2) at 8 km/h as 5.4 m^3/h per meter of crack. The crack length of the tow poorly fitted for is:

$$m_f = \frac{0.0102}{0.805} = 0.0127\ kg/s.$$

Also, from the psychometric chart, at the given outside conditions then the specific volume v_0 of outside air is:

$v_0 = 0.805\ m^3/kg$

Then total heat loss due to infiltration is:

$$Q_{infiltration} = 0.0126 \times 1\ \times (48 - 19) = 0.37\ kW$$

2.4.6 Heat loss due to ventilation:

$$Q_{ventilation} = m_{ventilation} \times (h_{out} - h_{in}) \quad (2.6)$$

$$m_v = \frac{V_v}{v_o} \quad (2.7)$$

V_v = minimum outside air requirements ventilation × No. of persons (2.8)

Minimum outside air requirements ventilation from Table (4-5) . Also, from the psychometric chart, at the given outside conditions then the specific volume

v_0 Of outside air is:

v_0 = 0.805 m^3/kg

$$m_v = \frac{10 \times 2}{0.805 \times (1000)} = 0.025 \text{ kg/s}$$

Then total heat loss due to ventilation is:

$$Q_{ventilation} = 0.025 \times 1000 \times (48 - 19)$$

$$Q_{ventilation} = 0.725 \text{ kW}$$

Finally, the total load for this manager office is the summation of all the heat Gain resources.

$$Q_{total} = 30 \text{ kw}$$

Table 2-6: Total heating load for each space building:

Name of space	Area (m^2)	Total heating load(kW)
2st basement floor plan		
hall	43	6.2
office	19.19	2.9
1st basement floor plan		
Restaurant	139.53	49
Distributed lounge	176.37	36
Grained floor plan		
reception hall	292	50
Public hall	200	41.1
1st floor plan		
Meeting hall	157.3	44
2st floor plan		
Manager office	90	30

Chapter 3

Cooling load calculations

3.1 Cooling load

3.1.1 Data analysis

$$(CLTD)_{corr} = (CLTD + LM)\,k + (25.5 - T_i) + (T_{o,m} - 29.4)\,f \quad (3.1)$$

Where:

- CLTD: Is called cooling load temperature difference for medium wall construction.

- LM: Latitude correction factor for horizontal and vertical surfaces.

- K: Colors adjustment factor such that k = 1.0 for dark colored roofs, and k=0.83 for permanently medium colored walls.

- DR: The daily temperature range which equal to the difference between the average maximum and Average minimum temperature for warmest month of the summer season.

- *f*: The factor f is attic or roof fan factor such that f =1 if there is no attic or roof fan, and the value of f = 0.75 if there is an attic or roof fan.

- $T_{o.m}$: The outdoor main temperature

$$T_{o.m} = T_{out} - \frac{DR}{2} \quad (3.2)$$

The following table (3-1) contains all assumptions needed for the next calculations:-

Table 3-1: Data for outside and inside temperature:

Outdoor temperature (T_o)	35 ˚C From the Palestinian code
Indoor temperature (T_i)	24˚C From Figure 1
Latitude(LM)	Apr/Aug @ latitude 32˚ North
Day of calculations	day of Apr/Aug
Color of surfaces	Permanent medium color wall

In the following table is the corrected CLTD for walls and roof and its tabulated as follow:

Table 3-2: $(CLTD)_{corr}$ for walls and roof :

Wall	CLTD From table (9-1)	LM From table (9-2)	K	F	$CLTD_{corr.}$
N	6	-1.1	0.83	1	11.167
NE	10	-0.5	0.83	1	14.985
E	14	0	0.83	1	18.72
SE	13	0	0.83	1	87.89
S	9	0.5	0.83	1	14.985
SW	9	0	0.83	1	14.57
W	8	0	0.83	1	13.74
NW	7	-0.5	0.83	1	12.495
Roof	19	0.5	1	1	26.6

Table 3-3: Parameters of $(CLTD)_{corr}$ for walls and roof :

Parameters	Properties
Roof	Without suspending ceiling type 2 @solar time 15h
Wall	Group B @solar time 16h
LM	Apr/Aug @Latitude 32c
K	Permanent medium color wall
F	The value of attic or roof fan factor
Type of glass	Double , thickness 6*14*6mm , with interior shading
CLF	Construction medium with inertia shading

3.2 Cooling load calculations:

We are did the calculations for office of manager in second floor which is an area of 90 m^2 and can accommodate 2 people. In the following subsections we determined the heat gain that comes from different resources. And these resources are the walls, sun, occupants, infiltration, ventilation, and windows.

3.2.1 Heat gain from walls, ceiling and the sun

In this step determined the heat gain from the direct contact with the sun, the sun is directly contact with the all walls and the ceiling for this room, the following table shows the total amount of heat gain from the sun using the cooling load temperature difference $(CLTD)_{corr}$.

Table 3-4: heat gain from the sun:

Surface	CLTD	LM	$CLTD_{corr}$	Area(m^2)	U ($W/m^2°C$)	Q (kW)
SE wall	13	0	17.89	3.5	0.9059	0.0567
SW wall	9	0	14.57	3.5	0.9059	0.04619
N wall	7	-0.5	12.495	3.5	0.9059	0.0396
ceiling	19	0.5	26.6	90	2.25	5.3865
					Q_{total}	5.529

3.2.2 Heat gain from the solar transmitted through windows:

In the selected office the all wall is exposed to the sun. heat gain due to solar transmission through glass window and glass door is estimated by using Table (9-7) to(9-11). The values of the variables are taken from the inserted tables in the appendix.

$$Q_g = A \times (SHG) \times (SC) \times (CLF) \quad (3.3)$$

Where:

- ❖ SHG : Solar heat gain factor
- ❖ SC : Shading coefficient
- ❖ CLF : Cooling load factor

Table 3-5: Heat gain from solar transmitted through the glass:

Surface	Area (m^2)	SHG From Table (9-7)	SC From Table (9-8)	CLF From Table (9-10)	Q(kW)
SE-glass	22.7	571	0.53	0.44	3.022
SW-glass	18	571	0.53	0.3	1.634
NW-glass	22.8	445	0.53	0.19	1.021
				Q_{total}	5.678

3.2.3 Sensible & latent heat gain from the occupants:

The heat gains from the occupants depend on the number of occupants inside the manager office.

$$Q_{oc} = Q_{oc,sens} + Q_{oc,latent} \quad (3.4)$$

$$Q_{oc,sens} = \# \text{ Of Occupants} \times \text{sensible heat} \quad (3.5)$$

CLF_{occ} cooling load factor due to occupants , for sensble heat gain , From (Appendix B) Table (B17) Sensible and Latent heat $from$ (Appendix B) Table (B1) .

$$Q_{oc,sens} = 2 \times \frac{71.5}{1000} \times 0.8 = 0.1144 \text{ kW}$$

$Q_{oc,sens}$= # Of Occupants × latent heat

$$Q_{oc,latent} = 2 * \frac{71.5}{1000} = 0.143 \text{ kW}$$

3.2.4 Heat gain from the lights:

There are twenty lights through this manager office, so:

$$Q_{lights} = N \times P \times CLF_{lights} \times \text{Diversity factor} \tag{3.6}$$

Where:

N: The number of lights.

P: The power for the lights.

CLF_{lights}: Cooling load factor for the lights, From Table (9 – 14).

CLF_{lights} = 0.84

Q_{lights} = 20 × 60 × 0.84× 0.5 = 0.504 kW

3.2.5 Heat loss due to infiltration:

Infiltration is the leakage of the outside air through cracks or clearances around the windows and doors. We use the crack. Age method to calculate it as follows:

For Windows:

$$Q_{infiltration} = m_f \times (h_o - h_i) \quad (3.7)$$

$$m_f = \frac{V_f}{v_0} \quad (3.8)$$

$$V_f = \text{crack length (L)} \times \text{Infiltration through windows} \quad (3.9)$$

Where V_f is obtained from (Appendix B) Table (B3) at 8 km/h as $2 m^3/h$ per meter of crack. The crack length of the five double hung metal windows is:

$$L = 21 \times 2 + (3.5 \times 2) = 49 \text{ m} .$$

Therefore;

$$V_f = 49 \times 2 = 98 \frac{m^3}{h} = \frac{98}{3600} = 0.02722 \frac{m^3}{s} .$$

Also, from the psychometric chart, at the given outside conditions then the specific

volume v_0 of outside air is:

$$v_0 = 0.905 \ m^3/kg$$

$$m_f = \frac{0.02722}{0.905} = 0.03 \text{ kg/s.}$$

Then total heat loss due to infiltration is:

$$Q_{infiltration} = 0.03 \times 1 \times (88 - 48) = 1.2 \text{ kW}$$

For Doors:

$$Q_{infiltration} = m_{inf} \times (h_o - h_i)$$

$$m_{inf} = \frac{V_f}{v_0}$$

V_f = crack length × Infiltration through doors.

Where V_f is obtained from Table (6-1) at 8 km/h as 5.4 m^3/h per meter of crack. Length of the five double hung metal windows is:

$$L = (1.2 \times 2) + (2.2 \times 2) = 6.8 \text{ m} .$$

Also, from the psychometric chart, at the given outside conditions then the specific volume v_0 of outside air is:

$$v_0 = 0.905 \text{ m}^3/\text{kg}$$

$$V_f = 6.8 \times 5.4 = 36.72 \frac{m^3}{h} = \frac{36.72}{3600} = 0.0102 \frac{m^3}{s} .$$

$$m_f = \frac{0.0102}{0.905} = 0.0112 \text{ kg/s}.$$

Then total heat loss due to infiltration is:

$$Q_{infiltration} = 0.0112 \times 1 \times (88 - 48) = 0.45 \text{ kW}$$

3.2.6 Heat gain due to ventilation:

$$Q_{ventilation} = m_v \times (h_o - h_i) \qquad (3.10)$$

$$m_v = \frac{V_v}{v_0} \qquad (3.11)$$

$$V_v = \text{minimum outside air requirements ventilation} \times \text{No. of persons} \qquad (3.12)$$

Minimum outside air requirements ventilation from Table (4-5).

V_v = 10 × 2=20= 0.02 m^3/s.

Also, from the psychometric chart, at the given outside conditions then the specific volume v_0 of outside air is:

v_0 = 0.905 m^3/kg

$m_v = \frac{0.02}{0.905} = 0.0221$ Kg/s.

Then total heat loss due to ventilation be:

$Q_{ventilation}$ = 0.0221 × 1000 × (88 - 48) = 0.884 kW.

❖ Finally, the total load for this office mangier is the summation of all the heat Gain resources.

$$Q_{total} = 32 \text{ kW}$$

Table 3-6: cooling load for each space building:

Name of space	Area (m²)	Total cooling load(kW)
2st basement floor plan		
Hall	43	8.8
Office	19.19	3.2
1st basement floor plan		
Restaurant	139.53	56
Distributed lounge	176.37	40.6
Grained floor plan		
reception hall	292	56
Public hall	200	45.2
1st floor plan		
Meeting hall	157.3	49
2st floor plan		
Manager office	90	32

3.3 Mechanical ventilation

3.3.1 Overview of ventilation:-

Ventilation is the process of supplying and removing air by natural or mechanical means to and from a building. The design of a building's ventilation system should meet the minimum requirements of the building (Ventilating Systems) regulations.

There are two ways for Ventilation:

- Natural ventilation: -
  Covers uncontrolled inward air leakage through cracks, windows, doorways and vents (infiltration) as well as air leaving a room (exfiltration) through the same routes. Natural ventilation is strongly affected by weather conditions and is often unreliable.

- Mechanical: -
  Forced ventilation is provided by air movers or fans in the wall, roof or air conditioning system of a building. It promotes the supply or exhaust airflow in a controllable manner.

The airflow rate into a room space, for general mechanical supply and extract systems, is usually expressed in:

- Air changes per hour.

An air change per hour (ACH) is the most frequently used basis for calculating the required airflow. Air changes per hour are the number of times in one hour an equivalent room volume of air will be introduced into, or extracted from the room space.

- Air flow rate per person.

Airflow rate per person are generally expressed as litters per person (L P), and are usually used where fresh air ventilation is required within occupied spaces.

- Airflow rate per unit floor area.

Airflow rates per unit floor area are similar in effect to air changes per hour except that the height of the room is not taken into consideration.

Mechanical ventilation system in this project is just for bathrooms and kitchens & by first method air changes per hour.

3.3.2Objectives of ventilation

Ventilation in a building serves to provide fresh and clean air, to maintain a thermally comfortable work environment, and to remove or dilute airborne contaminants in order to prevent their accumulation in the air. Air conditioning is a common type of ventilation system in modern office buildings. It draws in outside air and after filtration, heating or cooling and humidification circulates it throughout the building. A small portion of the return air is expelled to the outside environment to control the level of indoor air contaminants.

3.3.3 How ventilation systems work:-

A variety of mechanical ventilation systems are available to select, based on local climate and the home's heating and cooling system. In addition to one of the primary systems described below, "spot" ventilation fans should also be provided for kitchens and baths to remove the concentrated moisture and odors that can occur in these rooms.

3.3.4 Benefits ventilation

• Better Indoor Air Quality. Indoor air can be many times more polluted than outdoor air. Ventilation systems can significantly improve a home's air quality by removing allergens, pollutants, and moisture that can cause mold problems.

• More Control. When homes rely on air flow through walls, roofs, and windows for ventilation, there is no control over the source or amount of air that comes into the house. In fact, air leaking into the house may come from undesirable areas such as the garage. Mechanical ventilation systems provide proper fresh air flow along with appropriate locations.

• Improved Comfort. Mechanical ventilation systems allow a constant flow of outside air into the home and can also provide filtration, dehumidification, and conditioning of the incoming outside air.

Table 3.7:- Specifications of fans

Fans Schedule											
Fan Label	Type	System	Location	Flaw (CFM)	Head (IN)	Motor Data					
						RPM	kW	V	Ph.	HZ	QTY.
EXF#1	Centrifugal	Ventilation	1st Basement	560	0.3	1450	0.10	220	1	50	1
EXF#2	Centrifugal	Ventilation	1st Basement	140	0.25	1450	0.10	220	1	50	1
EXF#3	Centrifugal	Ventilation	1st Basement	2734	0.3	1450	0.30	220	1	50	1
EXF#4	Centrifugal	Ventilation	Ground	630	0.3	1450	0.10	220	1	50	1
EXF#5	Centrifugal	Ventilation	Ground	340	0.25	1450	0.10	220	1	50	1
EXF#6	Centrifugal	Ventilation	Top roof	2500	0.45	1450	0.40	220	1	50	1
EXF#7	Centrifugal	Ventilation	1st Basement	3000	0.3	1450	0.35	220	1	50	1
EXF#8	Centrifugal	Ventilation	Ground	300	-	1450	0.10	220	1	50	1
EXF#1	Axial wall	Fresh air	1st Basement	2874	0.3	1450	0.30	220	1	50	1
EXF#2	Axial wall	Fresh air	Top roof	210	0.3	1450	0.10	220	1	50	1
EXF#3	Axial wall	Fresh air	2nd Basement	690	0.3	1450	0.10	220	1	50	1
EXF#4	Axial wall	Fresh air	Ground	340	0.25	1450	0.10	220	1	50	1

CHAPTER 4

VRF SYSTEM

4.1 Introduction:

The primary function of all air-conditioning systems is to provide thermal comfort for building occupants. There are a wide range of air conditioning systems available, starting from the basic window-fitted units to the small split systems, to the medium scale package units, to the large chilled water systems, and currently to the variable refrigerant flow (VRF) systems.

Variable refrigerant flow (VRF) is an air-condition system configuration where there is outdoor condensing unit and multiple indoor units. The term variable refrigerant flow refers to the ability of the system to control the amount of refrigerant flowing to the multiple evaporators (indoor units), enabling the use of many evaporators of differing capacities and configurations connected to a single condensing unit. The arrangement provides an individualized comfort control, and simultaneous heating and cooling in different zones.

VRF systems operate on the direct expansion (DX) principle meaning that heat is transferred to or from the space directly by circulating refrigerant to evaporators located near or within the conditioned space. Refrigerant flow control is the key to many advantages as well as the major technical challenge of VRF systems.

4.2 VRF System types:-

4.2.1 Operating System:-

1- Cooling only systems.

2- Heat Pump systems.

3- Heat Recovery systems.

4.2.2 Number of pipes:

1) 2 Pipes Systems:

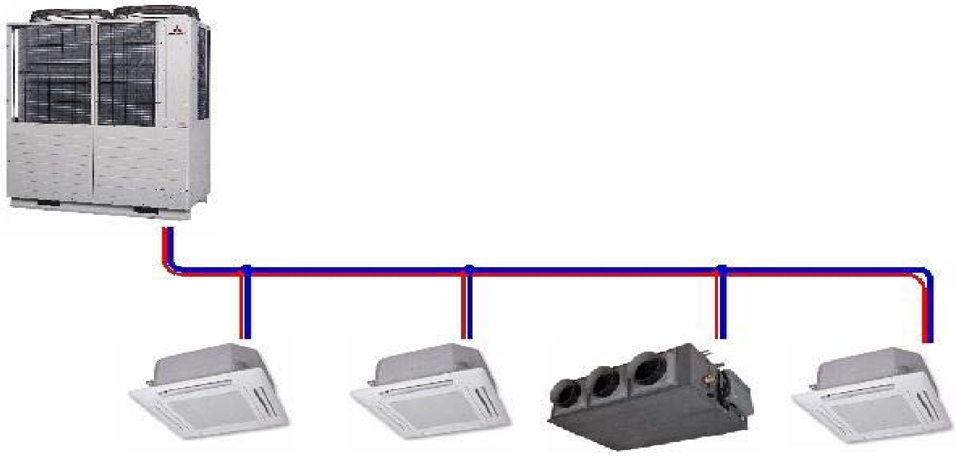


Figure 4.1: Two Pipes systems

2) 3 Pipes Systems:

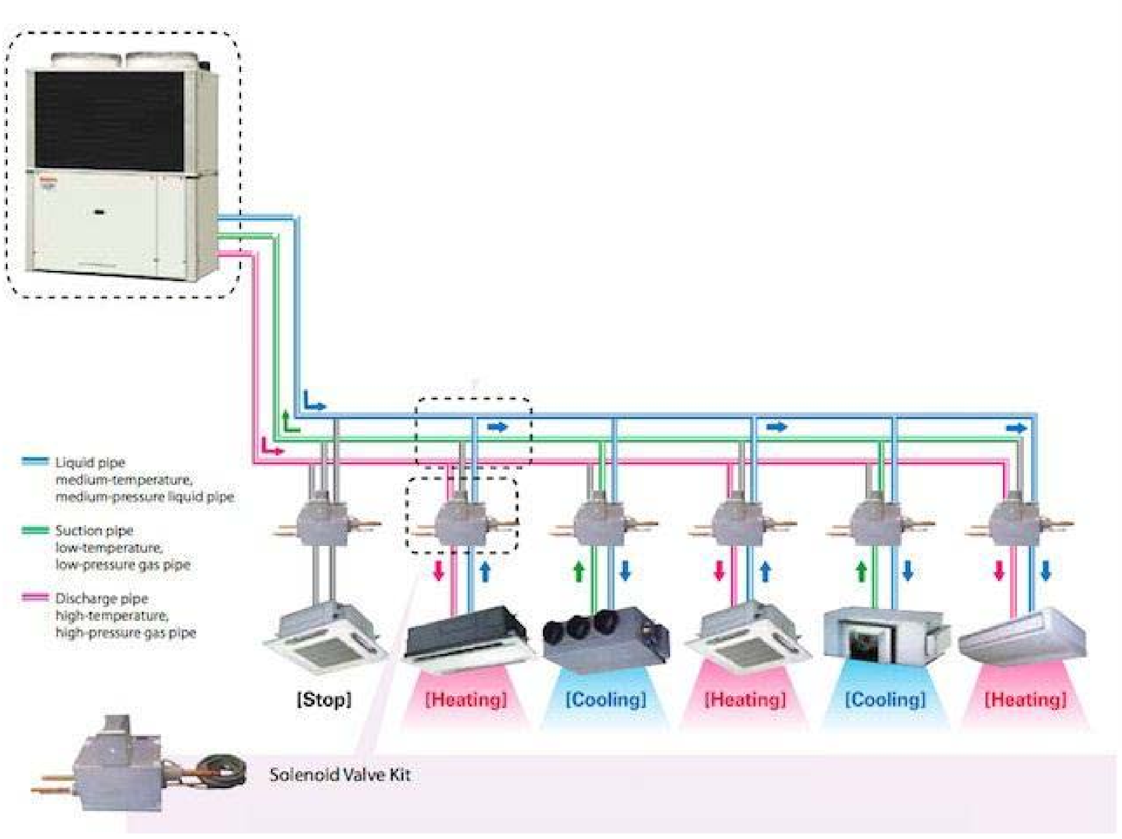


Figure 4.2: Three pipes systems

4.3 VRF Components:

1- Outdoor Units.

2- Indoor Units.

3- Piping Network.

4- Control.

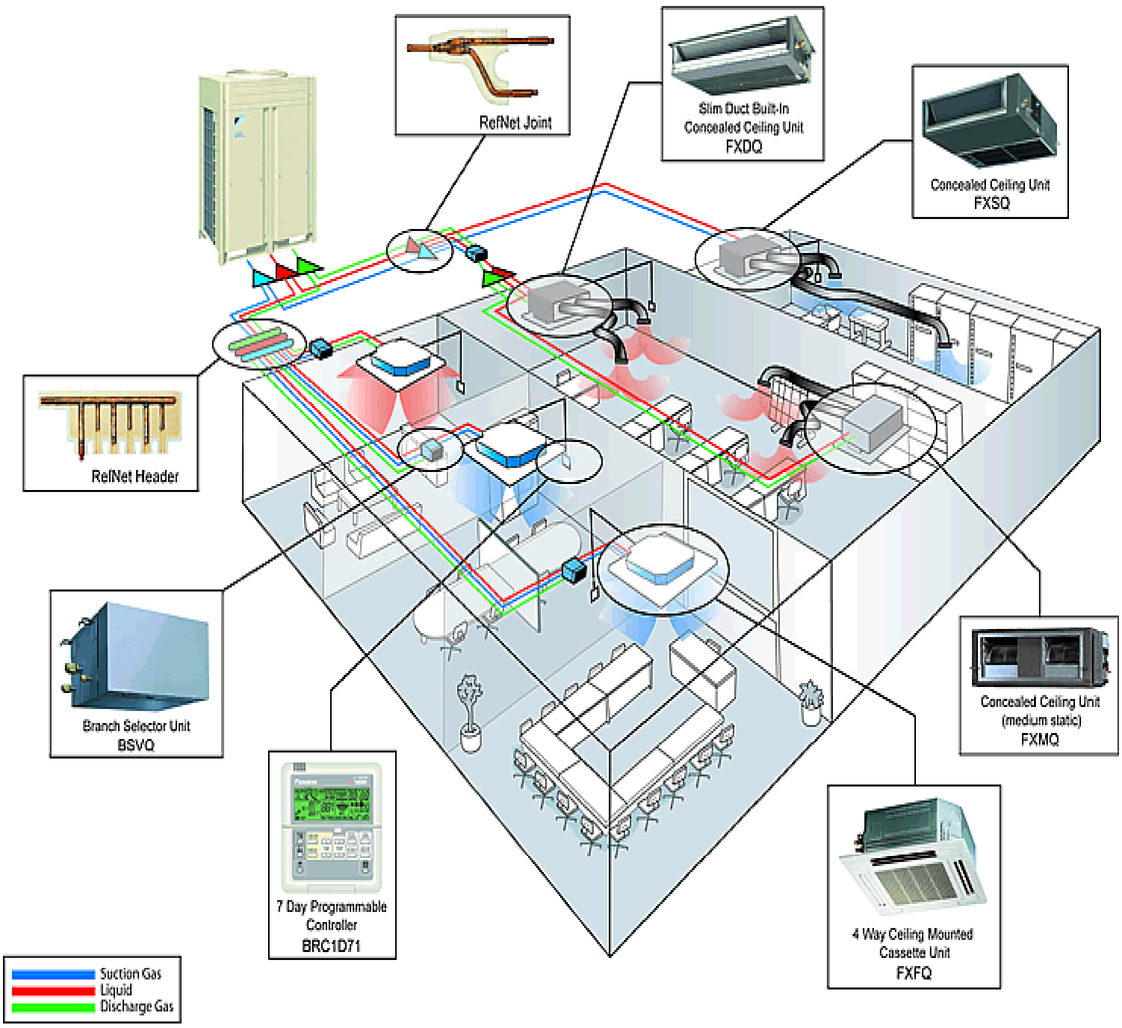


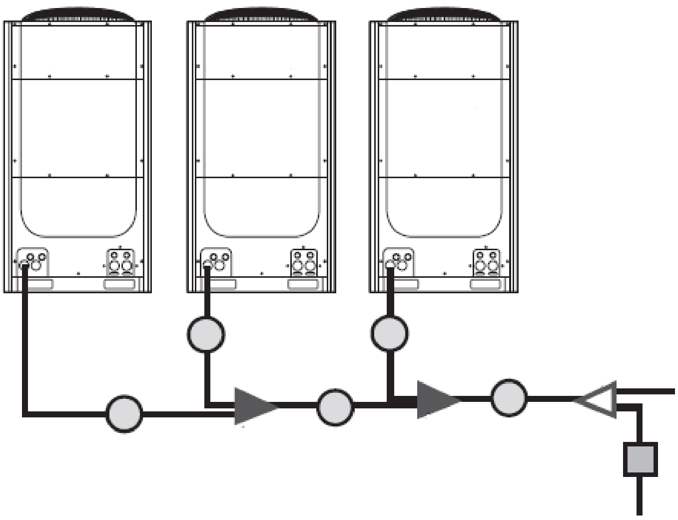
Figure 4.3: VRF system component

4.3.1 Outdoors units:-

The outdoor unit contains a heat pump, a heat pump is a machine that by reversing its refrigeration cycle can provide heating instead of cooling. Because a heat pump uses refrigerant it can upgrade the heat in air at even -10ºC to a usable heat source to heat buildings.

Individual Outdoor Unit Capacity 8 HP, 10 HP and up to 20 HP.

Outdoor Module Up to 80 HP



4.3.2 Indoor Units:-

The indoor units were developed to be highly efficient, compact, low noise, and to have user friendly operation. Care was also taken with the design to make that go well with the interior decoration and tube easy to install and maintain. Further, a variety of options are available to achieve an air conditioning environment that is more desirable from the user's perspective.

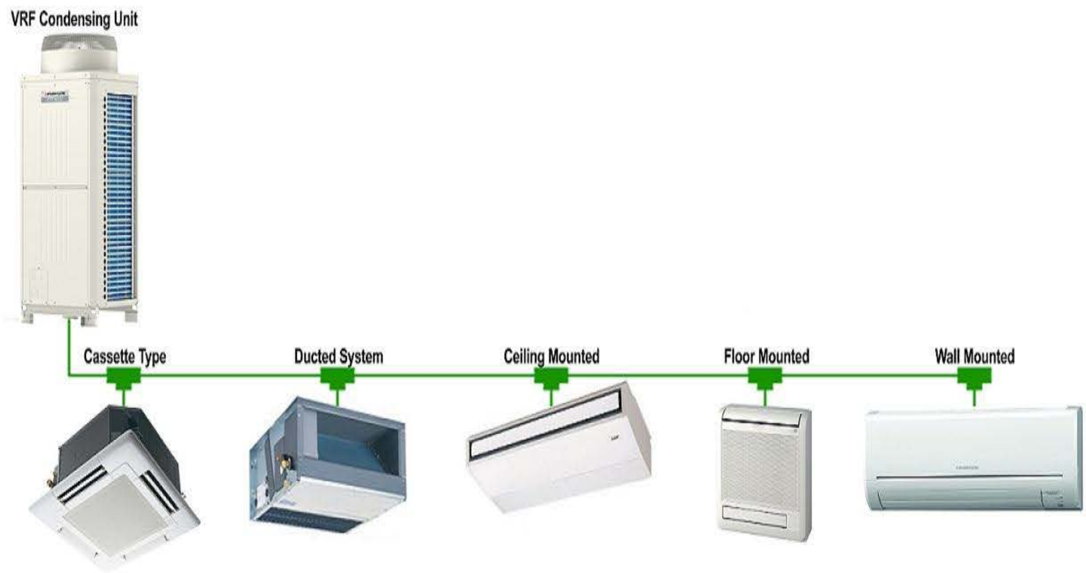


Figure 4.4: Different types for different applications

4.3.3 Piping Network:-

1-Copper Pipes:

Connect between all indoor units and all outdoor units in the same system It may be 2 pipes or 3 pipes according to the type of VRF System.

2-T-Joints:

Used to connect the pipes between the outdoor units

Figure 4.5:T-Joints

3-Separation Tubes (or Refnits Joints)

Used to distribute refrigerants on two branches and have different dimensions according to use.

Figure 4.6: Refnits Joints

4. Distribution headers

Used to distribute refrigerants to more than two branches so that the units are identical in convection.

Figure 4.7: Distribution headers

5. Insulation

Epoxy foam-ethylene propylene dinenomer and foam PE polyethylene foam.

Figure 4.8: Insulation

4.3.4 Control Systems:-

1- Individual control system.
Wired controller, Wireless controller and Timer controller .

2- Centralized control systems.
Used to control indoor units individually or as a group, and can connected 16 set of outdoor units and maximum 256 indoor units.

3- Integrated management system.
Built-in web server for PC-independent management and remote access control, weekly/ daily schedule control, power distribution function, emergency stop function with simple connection interface and data storage in non-volatile memory and plug-in memory.

4- Power distribution system.

5- External contact control system.

• Mainly used for accommodation facilities to control the internal units using the contact from the card holder.

• Guest room management is a smart way to save energy and money. When the key is in place, the air conditioner is activated. When the air conditioner switch is removed or turned off, you can avoid uninhabited room cooling and energy saving.

6- Building management system.
Mainly used to control the air conditioning system with an open protocol for easy interface to third-party known companies.

4.4 Design Process:-

There are two methods to design VRV according to Daikin company system:-

1) By Xpress program.

"Xpress" is selection software for VRV systems and it can helps your quick selection for quotation with easy operation.
This program is made from Daikin Company; the program can help you to choose a lot of very important thing about VRV system.

2) By Tables.

We used the tables to design the VRV system for the building.

4.4.1 Select preliminary Outdoor unit:-

Select preliminary Outdoor unit or module for each zone Consider design temperature conditions to select larger Outdoor with nominal capacity > actual load

17) 40HP Cooling

TC : Total Capacity, PI : Power Input

Combination, % (Capacity index)	Outdoor Temperature(°C)	Indoor Temperature (°C,WB)													
		14.0 °C		16.0 °C		18.0 °C		19.0 °C		20.0 °C		22.0 °C		24.0 °C	
		TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI	TC	PI
		kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW
130%	10 °C	88.96	14.64	105.24	18.51	119.81	21.75	126.37	22.69	132.44	23.14	143.14	23.04	152.12	23.42
	12 °C	88.96	15.01	105.24	18.97	119.81	22.29	126.37	23.26	132.44	23.72	143.14	23.62	152.12	24.00
	14 °C	88.96	15.26	105.24	19.29	119.81	22.67	126.37	23.65	132.44	24.12	143.14	24.02	152.12	24.41
	16 °C	88.96	15.65	105.24	19.78	119.81	23.24	126.37	24.25	132.44	24.73	143.14	24.62	152.12	25.02
	18 °C	88.96	16.26	105.24	20.56	119.81	24.16	126.37	25.20	132.44	25.70	143.14	25.59	152.12	26.01
	20 °C	88.96	17.07	105.24	21.58	119.81	25.36	126.37	26.46	132.44	26.98	143.14	26.87	152.12	27.31
	21 °C	88.96	17.54	105.24	22.17	119.81	26.05	126.37	27.18	132.44	27.72	143.14	27.60	152.12	28.05
	23 °C	88.96	18.57	105.24	23.47	119.81	27.58	126.37	28.78	132.44	29.35	143.14	29.22	152.12	29.70
	25 °C	88.96	19.69	105.24	24.89	119.81	29.25	126.37	30.51	132.44	31.12	143.14	30.98	152.12	31.49
	27 °C	88.96	20.85	105.24	26.35	119.81	30.97	126.37	32.31	132.44	32.95	143.14	32.81	152.12	33.35
	29 °C	88.96	22.00	105.24	27.80	119.81	32.68	126.37	34.09	132.44	34.76	143.14	34.62	152.12	35.18
	31 °C	88.61	22.98	104.82	29.04	119.33	34.13	126.37	35.75	131.91	36.31	142.57	36.16	151.52	36.75
	33 °C	86.88	23.44	102.78	29.63	117.00	34.82	126.37	37.20	129.34	37.04	139.79	36.88	148.56	37.49
	35 °C	85.40	23.75	101.03	30.02	115.01	35.28	126.37	38.34	127.14	37.53	137.41	37.37	146.04	37.98
	37 °C	84.15	23.86	99.55	30.16	113.33	35.45	119.54	36.98	125.28	37.71	135.40	37.55	143.90	38.16
	39 °C	83.06	23.74	98.26	30.00	111.86	35.26	117.99	36.79	123.65	37.51	133.65	37.36	142.03	37.97
	42 °C	81.48	23.00	96.39	29.07	109.73	34.16	115.74	35.64	121.30	36.35	131.10	36.19	139.33	36.78
	44 °C	80.25	22.06	94.94	27.89	108.07	32.78	113.99	34.19	119.47	34.87	129.12	34.72	137.23	35.29
	46 °C	78.66	20.72	93.06	26.18	105.94	30.77	111.74	32.10	117.11	32.74	126.57	32.60	134.51	33.13
120%	10 °C	86.93	14.50	102.83	18.32	117.07	21.53	123.48	22.46	129.41	22.91	139.87	22.81	148.65	23.18
	12 °C	86.93	14.86	102.83	18.78	117.07	22.07	123.48	23.03	129.41	23.48	139.87	23.38	148.65	23.77
	14 °C	86.93	15.11	102.83	19.10	117.07	22.45	123.48	23.42	129.41	23.88	139.87	23.78	148.65	24.17
	16 °C	86.93	15.49	102.83	19.58	117.07	23.01	123.48	24.01	129.41	24.48	139.87	24.38	148.65	24.77
	18 °C	86.93	16.10	102.83	20.35	117.07	23.92	123.48	24.95	129.41	25.45	139.87	25.34	148.65	25.75
	20 °C	86.93	16.91	102.83	21.37	117.07	25.11	123.48	26.20	129.41	26.72	139.87	26.60	148.65	27.04
	21 °C	86.93	17.37	102.83	21.95	117.07	25.80	123.48	26.91	129.41	27.45	139.87	27.33	148.65	27.77
	23 °C	86.93	18.39	102.83	23.24	117.07	27.31	123.48	28.49	129.41	29.06	139.87	28.93	148.65	29.40
	25 °C	86.93	19.49	102.83	24.64	117.07	28.96	123.48	30.21	129.41	30.81	139.87	30.68	148.65	31.18
	27 °C	86.93	20.65	102.83	26.09	117.07	30.67	123.48	31.99	129.41	32.63	139.87	32.49	148.65	33.02
	29 °C	86.93	21.78	102.83	27.53	117.07	32.35	123.48	33.75	129.41	34.42	139.87	34.27	148.65	34.83
	31 °C	86.93	22.84	102.83	28.87	117.07	33.93	123.48	35.40	129.41	36.10	139.87	35.94	148.65	36.53
	33 °C	86.66	23.69	102.52	29.94	116.71	35.19	123.48	36.83	129.01	37.44	139.44	37.28	148.19	37.89
	35 °C	85.19	24.00	100.78	30.34	114.72	35.66	123.48	37.96	126.82	37.93	137.07	37.77	145.67	38.39
	37 °C	83.94	24.12	99.30	30.49	113.05	35.83	119.24	37.38	124.97	38.12	135.06	37.96	143.54	38.57
	39 °C	82.85	23.99	98.01	30.33	111.58	35.64	117.69	37.18	123.34	37.92	133.31	37.76	141.68	38.37
	42 °C	81.27	23.25	96.15	29.38	109.45	34.53	115.45	36.02	121.00	36.74	130.77	36.58	138.98	37.18
	44 °C	80.05	22.30	94.70	28.19	107.80	33.13	113.71	34.56	119.17	35.24	128.80	35.09	136.88	35.67
	46 °C	78.46	20.94	92.82	26.46	105.67	31.10	111.46	32.45	116.81	33.09	126.25	32.95	134.18	33.49
110%	10 °C	83.61	13.96	98.91	17.65	112.60	20.74	118.77	21.64	124.47	22.06	134.53	21.97	142.97	22.33
	12 °C	83.61	14.31	98.91	18.09	112.60	21.26	118.77	22.18	124.47	22.62	134.53	22.52	142.97	22.89
	14 °C	83.61	14.55	98.91	18.39	112.60	21.62	118.77	22.55	124.47	23.00	134.53	22.90	142.97	23.27
	16 °C	83.61	14.92	98.91	18.86	112.60	22.16	118.77	23.12	124.47	23.58	134.53	23.48	142.97	23.86
	18 °C	83.61	15.51	98.91	19.60	112.60	23.04	118.77	24.03	124.47	24.51	134.53	24.40	142.97	24.80
	20 °C	83.61	16.28	98.91	20.58	112.60	24.18	118.77	25.23	124.47	25.73	134.53	25.62	142.97	26.04
	21 °C	83.61	16.73	98.91	21.14	112.60	24.84	118.77	25.92	124.47	26.43	134.53	26.32	142.97	26.75
	23 °C	83.61	17.71	98.91	22.38	112.60	26.30	118.77	27.44	124.47	27.98	134.53	27.86	142.97	28.32
	25 °C	83.61	18.78	98.91	23.73	112.60	27.89	118.77	29.10	124.47	29.67	134.53	29.54	142.97	30.03
	27 °C	83.61	19.88	98.91	25.13	112.60	29.53	118.77	30.81	124.47	31.42	134.53	31.29	142.97	31.80
	29 °C	83.61	20.98	98.91	26.51	112.60	31.16	118.77	32.51	124.47	33.15	134.53	33.01	142.97	33.55
	31 °C	83.61	22.00	98.91	27.80	112.60	32.67	118.77	34.09	124.47	34.76	134.53	34.62	142.97	35.18
	33 °C	83.61	22.89	98.91	28.93	112.60	34.00	118.77	35.47	124.47	36.17	134.53	36.02	142.97	36.60
	35 °C	82.35	23.24	97.43	29.37	110.91	34.51	118.77	36.56	122.61	36.72	132.51	36.56	140.83	37.16
	37 °C	81.15	23.35	96.00	29.51	109.29	34.68	115.27	36.18	120.81	36.90	130.57	36.74	138.77	37.34
	39 °C	80.10	23.23	94.75	29.36	107.87	34.50	113.78	35.99	119.24	36.70	128.88	36.55	136.97	37.14
	42 °C	78.57	22.50	92.95	28.44	105.82	33.42	111.61	34.87	116.97	35.56	126.43	35.41	134.36	35.99
	44 °C	77.39	21.59	91.55	27.29	104.22	32.07	109.93	33.45	115.21	34.12	124.52	33.97	132.33	34.53
	46 °C	75.86	20.27	89.74	25.62	102.16	30.11	107.75	31.41	112.93	32.03	122.06	31.90	129.72	32.42
100%	10 °C	78.84	12.98	93.28	16.41	106.18	19.29	112.00	20.12	117.38	20.52	126.87	20.43	134.83	20.77
	12 °C	78.84	13.31	93.28	16.82	106.18	19.77	112.00	20.63	117.38	21.04	126.87	20.95	134.83	21.29
	14 °C	78.84	13.54	93.28	17.11	106.18	20.11	112.00	20.98	117.38	21.39	126.87	21.30	134.83	21.65
	16 °C	78.84	13.88	93.28	17.54	106.18	20.61	112.00	21.50	117.38	21.93	126.87	21.84	134.83	22.19
	18 °C	78.84	14.42	93.28	18.23	106.18	21.42	112.00	22.35	117.38	22.79	126.87	22.70	134.83	23.07
	20 °C	78.84	15.14	93.28	19.14	106.18	22.49	112.00	23.47	117.38	23.93	126.87	23.83	134.83	24.22
	21 °C	78.84	15.56	93.28	19.66	106.18	23.11	112.00	24.11	117.38	24.58	126.87	24.48	134.83	24.88
	23 °C	78.84	16.47	93.28	20.82	106.18	24.46	112.00	25.52	117.38	26.03	126.87	25.92	134.83	26.34
	25 °C	78.84	17.46	93.28	22.07	106.18	25.94	112.00	27.06	117.38	27.60	126.87	27.48	134.83	27.93
	27 °C	78.84	18.49	93.28	23.37	106.18	27.47	112.00	28.66	117.38	29.22	126.87	29.10	134.83	29.57
	29 °C	78.84	19.51	93.28	24.66	106.18	28.98	112.00	30.23	117.38	30.83	126.87	30.70	134.83	31.20
	31 °C	78.84	20.46	93.28	25.86	106.18	30.39	112.00	31.71	117.38	32.33	126.87	32.19	134.83	32.72
	33 °C	78.84	21.29	93.28	26.90	106.18	31.62	112.00	32.99	117.38	33.64	126.87	33.50	134.83	34.04
	35 °C	78.84	21.94	93.28	27.73	106.18	32.59	112.00	34.00	117.38	34.67	126.87	34.53	134.83	35.09
	37 °C	77.69	22.05	91.91	27.86	104.63	32.75	110.36	34.16	115.66	34.84	125.01	34.69	132.85	35.26
	39 °C	76.68	21.93	90.72	27.72	103.27	32.58	108.93	33.99	114.16	34.66	123.39	34.51	131.13	35.07
	42 °C	75.22	21.25	88.99	26.85	101.31	31.56	106.85	32.93	111.99	33.58	121.04	33.43	128.63	33.98
	44 °C	74.09	20.38	87.65	25.76	99.78	30.28	105.24	31.59	110.30	32.21	119.21	32.08	126.69	32.60
	46 °C	72.62	19.14	85.91	24.19	97.80	28.43	103.16	29.66	108.12	30.24	116.85	30.12	124.19	30.61

17) 40HP *Heating*

TC : Total Capacity, PI : Power Input

Combination, % (Capacity index)	Outdoor Temperature(°C)		Indoor Temperature (°C,DB)									
			16.0 °C		18.0 °C		20.0 °C		22.0 °C		24.0 °C	
			TC	PI	TC	PI	TC	PI	TC	PI	TC	PI
	DB	WB	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW
130%	-20	-21	110.26	40.47	111.60	39.10	105.29	37.24	100.02	36.12	96.02	35.40
	-17	-18	118.88	39.96	114.31	38.61	107.84	36.77	102.45	35.67	98.35	34.96
	-15	-16	123.19	41.20	118.46	39.81	111.75	37.91	106.16	36.78	101.92	36.04
	-12	-13	131.41	42.99	126.36	41.54	119.21	39.56	113.25	38.37	108.72	37.60
	-10	-11	141.02	43.91	135.60	42.42	127.92	40.40	121.52	39.19	116.66	38.41
	-7	-8	145.11	44.60	139.53	43.09	131.63	41.04	125.05	39.81	120.05	39.01
	-5	-6	149.50	44.51	143.75	43.00	135.61	40.95	128.83	39.73	123.68	38.93
	-3	-4	153.00	43.94	147.11	42.46	138.78	40.43	131.85	39.22	126.57	38.44
	0	-1	156.57	42.25	150.55	40.82	142.02	38.88	134.92	37.71	129.53	36.96
	3	2.2	158.62	39.75	152.52	38.40	143.89	36.57	136.69	35.48	131.22	34.77
	5	4.1	159.67	37.81	153.53	36.53	144.84	34.79	137.60	33.75	132.09	33.07
	7	6	161.03	35.83	154.83	34.62	152.16	33.67	138.77	31.98	133.22	31.34
	9	7.9	163.30	34.02	157.02	32.87	148.13	31.31	140.72	30.37	135.10	29.76
	11	9.8	167.23	32.61	160.80	31.50	151.70	30.00	144.11	29.10	138.35	28.52
	13	12	167.74	30.76	161.28	29.72	152.16	28.30	144.55	27.45	138.77	26.91
	15	14	167.74	29.28	161.28	28.29	152.16	26.94	144.55	26.14	138.77	25.61
120%	-20	-21	115.93	40.98	111.47	39.59	105.16	37.71	99.91	36.58	95.91	35.84
	-17	-18	118.74	40.47	114.17	39.10	107.71	37.24	102.33	36.12	98.23	35.40
	-15	-16	123.05	41.72	118.32	40.31	111.62	38.39	106.04	37.24	101.80	36.49
	-12	-13	131.26	43.53	126.21	42.06	119.07	40.05	113.11	38.85	108.59	38.08
	-10	-11	140.86	44.46	135.44	42.96	127.77	40.91	121.38	39.68	116.53	38.89
	-7	-8	144.94	45.16	139.37	43.63	131.48	41.55	124.90	40.31	119.91	39.50
	-5	-6	149.33	45.07	143.58	43.54	135.46	41.47	128.68	40.22	123.54	39.42
	-3	-4	152.82	44.49	146.94	42.99	138.62	40.94	131.69	39.71	126.42	38.92
	0	-1	156.39	42.78	150.37	41.33	141.86	39.37	134.77	38.19	129.38	37.42
	3	2.2	158.43	40.24	152.34	38.88	143.72	37.03	136.53	35.92	131.07	35.20
	5	4.1	159.49	38.28	153.35	36.99	144.67	35.23	137.44	34.17	131.94	33.49
	7	6	160.84	36.28	154.65	35.06	148.88	33.40	138.60	32.39	133.06	31.74
	9	7.9	163.11	34.45	156.84	33.28	148.88	31.26	140.56	30.75	134.94	30.13
	11	9.8	164.12	32.44	157.81	31.34	148.88	29.85	141.43	28.95	135.78	28.37
	13	12	164.12	30.51	157.81	29.48	148.88	28.07	141.43	27.23	135.78	26.69
	15	14	164.12	29.04	157.81	28.06	148.88	26.72	141.43	25.92	135.78	25.40
110%	-20	-21	110.43	38.77	106.18	37.45	100.17	35.67	95.16	34.60	91.36	33.91
	-17	-18	113.10	39.05	108.75	37.73	102.60	35.93	97.47	34.85	93.57	34.15
	-15	-16	117.21	40.26	112.70	38.89	106.32	37.04	101.00	35.93	96.96	35.21
	-12	-13	125.03	42.00	120.22	40.58	113.42	38.65	107.74	37.49	103.43	36.74
	-10	-11	134.17	42.90	129.01	41.45	121.71	39.47	115.62	38.29	111.00	37.52
	-7	-8	138.06	43.57	132.75	42.10	125.23	40.10	118.97	38.89	114.21	38.12
	-5	-6	142.24	43.48	136.77	42.01	129.02	40.01	122.57	38.81	117.67	38.04
	-3	-4	145.56	42.93	139.96	41.48	132.04	39.50	125.44	38.32	120.42	37.55
	0	-1	148.96	41.28	143.23	39.88	135.12	37.99	128.37	36.85	123.23	36.11
	3	2.2	150.91	38.83	145.11	37.52	136.89	35.73	130.05	34.66	124.85	33.97
	5	4.1	151.91	36.94	146.07	35.69	137.80	33.99	130.91	32.97	125.68	32.31
	7	6	153.20	35.01	147.31	33.83	138.97	32.22	132.02	31.25	126.74	30.62
	9	7.9	153.20	32.78	147.31	31.67	138.97	30.16	132.02	29.26	126.74	28.67
	11	9.8	153.20	30.67	147.31	29.64	138.97	28.23	132.02	27.38	126.74	26.83
	13	12	153.20	28.85	147.31	27.87	138.97	26.55	132.02	25.75	126.74	25.24
	15	14	153.20	27.46	147.31	26.54	138.97	25.27	132.02	24.51	126.74	24.02
100%	-20	-21	101.62	36.85	97.71	35.60	92.18	33.91	87.57	32.89	84.07	32.23
	-17	-18	104.08	36.39	100.08	35.16	94.42	33.48	89.70	32.48	86.11	31.83
	-15	-16	107.86	37.52	103.71	36.25	97.84	34.52	92.95	33.49	89.23	32.82
	-12	-13	115.06	39.14	110.63	37.82	104.37	36.02	99.15	34.94	95.19	34.24
	-10	-11	123.47	39.98	118.72	38.63	112.00	36.79	106.40	35.69	102.14	34.97
	-7	-8	127.05	40.61	122.16	39.24	115.25	37.37	109.49	36.25	105.11	35.52
	-5	-6	130.89	40.53	125.86	39.16	118.74	37.29	112.80	36.17	108.29	35.45
	-3	-4	133.95	40.01	128.80	38.66	121.51	36.82	115.44	35.71	110.82	35.00
	0	-1	137.08	38.47	131.81	37.17	124.35	35.40	118.13	34.34	113.41	33.65
	3	2.2	138.88	36.19	133.54	34.97	125.98	33.30	119.68	32.30	114.89	31.66
	5	4.1	138.90	34.20	133.56	33.05	126.00	31.47	119.70	30.53	114.91	29.92
	7	6	138.90	32.15	133.56	31.06	126.00	29.00	119.70	28.69	114.91	28.12
	9	7.9	138.90	30.10	133.56	29.08	126.00	27.69	119.70	26.86	114.91	26.33
	11	9.8	138.90	28.16	133.56	27.21	126.00	25.92	119.70	25.14	114.91	24.64
	13	12	138.90	26.49	133.56	25.59	126.00	24.37	119.70	23.64	114.91	23.17
	15	14	138.90	25.22	133.56	24.36	126.00	23.20	119.70	22.51	114.91	22.06

4.4.2Select preliminary indoor unit for each zone:-

Consider design temperature conditions to select larger Indoor types than actual load

1) Cooling

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

Model	Outdoor temperature (°C, DB)	Indoor temperature (°C, WB)													
		20 (°C, DB)		23 (°C, DB)		26 (°C, DB)		27 (°C, DB)		28(°C, DB)		30 (°C, DB)		32 (°C, DB)	
		14 (°C, WB)		16 (°C, WB)		18 (°C, WB)		19 (°C, WB)		20 (°C, WB)		22 (°C, WB)		24 (°C, WB)	
		TC	SHC	TC	SHC	TC	SHC	TC	SHC	TC	SHC	TC	SHC	TC	SHC
112	10	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.5	8.3	13.6	8.4
	12	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.5	8.3	13.6	8.4
	14	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.5	8.3	13.5	8.3
	16	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.5	8.3	13.5	8.3
	18	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	20	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	21	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	23	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	25	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	27	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	29	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	31	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	33	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	35	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.4	8.2	13.4	8.3
	37	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.7	8.6	12.3	8.2	13.2	8.2
	39	8.5	7.0	9.3	7.5	10.7	8.3	11.2	8.5	11.6	8.5	12.1	8.0	13.0	8.0
	42	8.5	7.0	9.3	7.5	10.7	8.3	10.9	8.3	11.3	8.3	11.6	7.7	12.6	7.8
	44	8.5	7.0	9.3	7.5	10.7	8.3	10.9	8.3	11.3	8.3	11.6	7.7	12.4	7.7
128	10	9.7	8.0	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.3	9.8	15.4	9.8
	12	9.7	8.0	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.3	9.8	15.3	9.7
	14	9.7	8.0	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.3	9.8	15.3	9.7
	16	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.2	9.6
	18	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	20	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	21	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	23	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	25	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	27	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	29	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	31	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	33	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	35	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.3	10.0	14.2	9.7	15.1	9.6
	37	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.2	9.9	14.0	9.6	14.9	9.4
	39	9.7	8.2	10.4	8.3	12.0	8.9	12.8	10.0	13.1	9.8	13.8	9.4	14.5	9.2
	42	9.7	8.2	10.4	8.3	12.0	8.9	12.4	9.7	12.7	9.5	13.2	9.0	13.7	8.7
	44	9.7	8.2	10.4	8.3	12.0	8.9	12.4	9.7	12.7	9.5	13.2	9.0	13.7	8.7
140	10	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.7	11.3	15.7	11.0	16.8	10.9
	12	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.6	10.9	16.7	10.9
	14	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.6	10.9	16.7	10.9
	16	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.6	10.9	16.6	10.8
	18	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.6	10.8
	20	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.5	10.7
	21	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.5	10.7
	23	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.5	10.7
	25	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.5	10.7
	27	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.5	10.7
	29	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.5	10.7
	31	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.5	10.7
	33	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.5	10.7
	35	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.5	10.9	16.5	10.7
	37	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.6	11.2	15.4	10.8	16.3	10.6
	39	10.5	9.1	11.6	9.9	13.3	10.9	14.0	11.2	14.5	11.2	15.1	10.6	15.9	10.3
	42	10.5	9.1	11.6	9.9	13.3	10.9	13.6	10.9	14.1	10.9	14.4	10.1	15.0	9.8
	44	10.5	9.1	11.6	9.9	13.3	10.9	13.6	10.9	14.1	10.9	14.4	10.1	15.0	9.8

2) Heating

TC:Total Capacity(kW)

Model	Outdoor temperature (°C, DB)		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
112	-20	-21	7.2	6.9	6.6	6.5	6.5
	-17	-18	8.0	7.6	7.4	7.3	7.3
	-15	-16	8.4	8.1	7.9	7.7	7.5
	-12	-13	8.8	8.6	8.4	8.2	8.1
	-10	-11	9.2	9.0	8.9	8.8	8.7
	-7	-8	9.7	9.6	9.4	9.2	9.0
	-5	-6	10.2	10.1	9.9	9.6	9.3
	-3	-4	10.7	10.6	10.5	10.1	9.7
	0	-1	11.3	11.1	11.1	10.5	10.0
	3	2.2	11.8	11.6	11.5	11.0	10.6
	5	4.1	12.3	12.2	12.0	11.3	10.6
	7	6	12.9	12.7	12.5	11.5	10.6
	9	7.9	13.3	12.9	12.5	11.5	10.6
	11	9.8	13.7	13.1	12.5	11.5	10.6
	13	12	14.0	13.3	12.5	11.5	10.6
	15	14	14.4	13.5	12.5	11.5	10.6
128	-20	-21	7.9	7.7	7.3	7.2	7.2
	-17	-18	8.8	8.5	8.1	8.0	8.0
	-15	-16	9.2	9.0	8.7	8.5	8.2
	-12	-13	9.7	9.5	9.3	9.1	8.9
	-10	-11	10.1	10.0	9.9	9.7	9.6
	-7	-8	10.7	10.6	10.4	10.2	10.0
	-5	-6	11.3	11.1	11.0	10.7	10.3
	-3	-4	11.9	11.7	11.5	11.1	10.7
	0	-1	12.4	12.3	12.1	11.6	11.0
	3	2.2	13.0	12.9	12.7	12.2	11.7
	5	4.1	13.6	13.4	13.2	12.4	11.7
	7	6	14.2	14.0	13.8	12.7	11.7
	9	7.9	14.6	14.2	13.8	12.7	11.7
	11	9.8	15.1	14.4	13.8	12.7	11.7
	13	12	15.5	14.7	13.8	12.7	11.7
	15	14	15.9	14.9	13.8	12.7	11.7
140	-20	-21	9.2	8.9	8.5	8.4	8.4
	-17	-18	10.2	9.8	9.4	9.3	9.3
	-15	-16	10.7	10.4	10.1	9.8	9.5
	-12	-13	11.2	11.0	10.8	10.6	10.3
	-10	-11	11.7	11.6	11.4	11.3	11.1
	-7	-8	12.4	12.2	12.1	11.8	11.5
	-5	-6	13.1	12.9	12.7	12.3	12.0
	-3	-4	13.8	13.6	13.4	12.9	12.4
	0	-1	14.4	14.2	14.0	13.4	12.8
	3	2.2	15.1	14.9	14.7	14.1	13.5
	5	4.1	15.8	15.6	15.3	14.4	13.5
	7	6	16.5	16.2	16.0	14.8	13.5
	9	7.9	17.0	16.5	16.0	14.8	13.5
	11	9.8	17.5	16.7	16.0	14.8	13.5
	13	12	18.0	17.0	16.0	14.8	13.5
	15	14	18.5	17.2	16.0	14.8	13.5

4.5 Sizing the pipe network using the nominal capacity of the units.

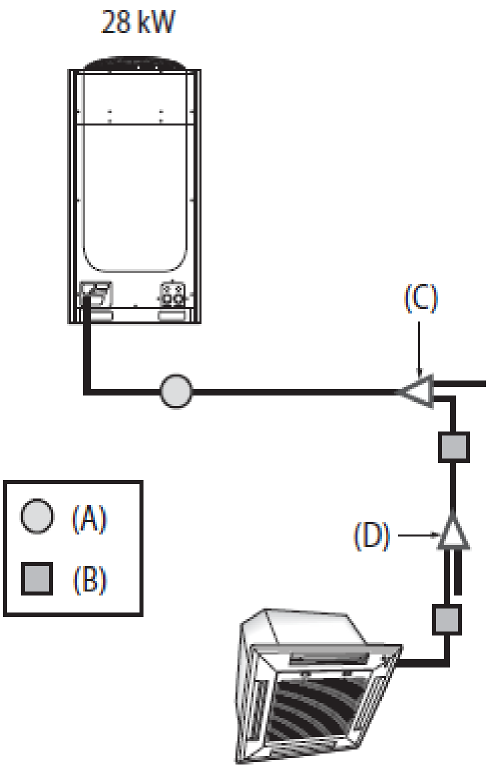


Table 4.1: longest pipe allowed

<table>
<tr><td colspan="3"></td><td>Permitted value</td></tr>
<tr><td rowspan="4">Piping length</td><td colspan="2">Total piping length (Actual)</td><td>1000m</td></tr>
<tr><td rowspan="2">Longest piping (L)</td><td>Actual length</td><td>175m</td></tr>
<tr><td>Equivalent length</td><td>200m</td></tr>
<tr><td colspan="2">Piping (The farthest IDU from the first indoor unit branch) equivalent length</td><td>40m/90m</td></tr>
<tr><td rowspan="3">Level difference</td><td rowspan="2">Level difference between IDU-ODU</td><td>Outdoor unit up</td><td>70m</td></tr>
<tr><td>Outdoor unit down</td><td>110m</td></tr>
<tr><td colspan="2">Level difference between IDU-ODU</td><td>30m</td></tr>
</table>

Table 4.2 size the pipe connected to the outdoor unit

Outdoor unit capacity(kW)	Main pipe length within 90 m		Size up (Main pipe length within 90 m)	
	Liquid pipe(mm) ϴ	Gas pipe (mm) ϴ	Liquid pipe(mm) ϴ	Gas pipe (mm) ϴ
22.4kW	9.52	19.05	12.70	22.22
28.0kW		22.22		25.40
33.6kW	12.70	28.58	15.88	28.58
40.0kW				
45.0kW				31.75

Table 4.3 size the pipe between branch joints

Indoor unit capacity(kW)	Branch pipe length within 45 m		Branch pipe length within 45-90 m	
	Liquid pipe(mm) ϴ	Gas pipe (mm) ϴ	Liquid pipe(mm) ϴ	Gas pipe (mm) ϴ
15.0kW and below	9.52	15.88	12.70	19.05
Over15.0kW-22.4kWand below		19.05		22.22
Over22.4kW-28.1kWand below		22.22		25.48
Over28.1kW-40.0kWand below	12.70	28.58	15.88	28.58
Over40.0 kW-45.0kWand below				31.75
Over45.0kW-70.3kWand below	15.88		19.05	

CHAPTER 5

PLUMBING SYSTEM

5.1 Introduction

The most basic human is reliable table supply of potable water and getting rid of human waste product’s, so the goal of modern plumbing design for building is to safely and reliable, provide domestic water, cold water and remove sanitary waste.

In this chapter the designs of the water supply and sanitary drainage system will be discuss as following:

5.2 Water supply system

5.2.1 Calculations of hot and cold water supply systems

To determine the pipe size for cold and hot water supply system the water supply fixture unit (WSFU) for each fixture unit must be determined and total fixture unit on each piping run out be calculated, the minimum floor pressure required at the critical fixture unit must be determined.

Example: calculation of water supply unit (WSFU) in the Bathroom in restaurant.

As follow:

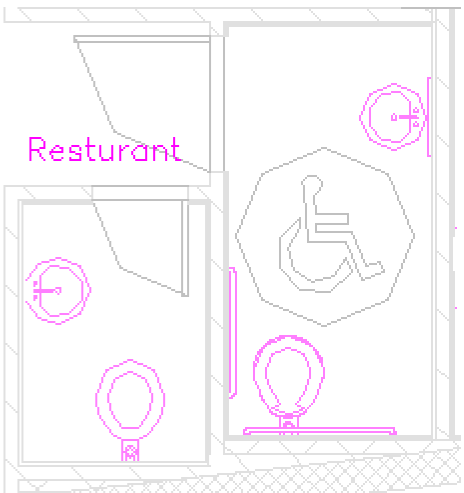


Figure 5.1: sample bathroom

1- Lavatory: is a fixture unit needs cold and hot water supplies as the demand of the lavatory for general use is 2WSFU (for both cold and hot water), while if cold or hot water only was needed then this value should be multiplied by (3/4), so the demand of the lavatory will be as follow:

a. 1WSFU for both hot and cold water demand.
b. (3/4)*2 WSFU for hot or cold water only.

2- Water closet: is a fixture unit needs cold supplies as shown (Appendix B) Table (B20) the

demand of the water closet for private use is 5 WSFU

Based on the above information the following table can performed:

Table 5.1: The WSFU for Building

Fixture unit	No. Of Units	WSFU	Total no. Of WSFU for cold water	Total no. Of WSFU for hot water	Total no. of WSFU for hot & cold water
The (WSFU) for the restaurant					
Lavatory (general)	2	2	3	3	4
Water closet flush tank (general)	2	5	10	--------	10
The (WSFU) for the kitchen					
Lavatory (General)	1	2	1.5	1.5	2
Kitchen sink (General)	2	4	6	6	8
The (WSFU)for the first basement(A)					
Lavatory (General)	4	2	6	6	8
Water closet flush tank (General)	4	5	20	--------	20
The (WSFU)for the first basement(B)					
Lavatory	3	2	4.5	4.5	6

(General)					
Urinal Flushometer (General)	3	5	15	--------	15
Water closet flush tank(General)	3	5	15	--------	15
The (WSFU)for the ground floor(A).					
Lavatory (General)	3	2	4.5	4.5	6
Urinal Flushometer (General)	3	5	15	--------	15
Water closet flush tank(General)	2	5	10	--------	10
The (WSFU)for the ground floor(B).					
Lavatory (General)	4	2	6	6	8
Water closet flush tank (General)	5	5	25	--------	25
			$\sum = 141.5$ WSFU	$\sum = 31.5$ WSFU	$\sum$ 154 WSFU

Table 5.7: The WSFU and gpm all floors

No. Of Floor	Total no. Of WSFU For cold water	Total no. Of WSFU for hot water	Total no. Of WSFU for hot & cold water	Total no. Of gpm for cold water	Total no. Of gpm for hot water	Total no. Of gpm for hot & cold water
Restaurant+ kitchen	20.5	10.5	26	14	8	17.5
basement(A+B)	60.5	10.5	64	33	8	34.5
ground floor(A+B).	60.5	10.5	64	33	8	34.5
------	------	--------	--------	∑=80 gpm	∑=24 gpm	∑=86.5 Gpm

5.3 Pipe size calculations:

By using the down feed distribution system in which the water is supplied to the building from water tank in basement floor to roof tank to feed the building.

Before we calculations should now some information's:

- By using appendix B the minimum flow pressure can be determined for the fixture unit lavatory by 8 psi.
- The pressure pump equal 37 psi from water well to roof tank .
- by equation The friction loss through the water meter equal 5psi .
- The total equivalent length from the roof tank to critically fixture unit is 65 meter &equal 213 feet.
- The static pressure equal 20.75meter equal 68 feet & equal 30 psi.

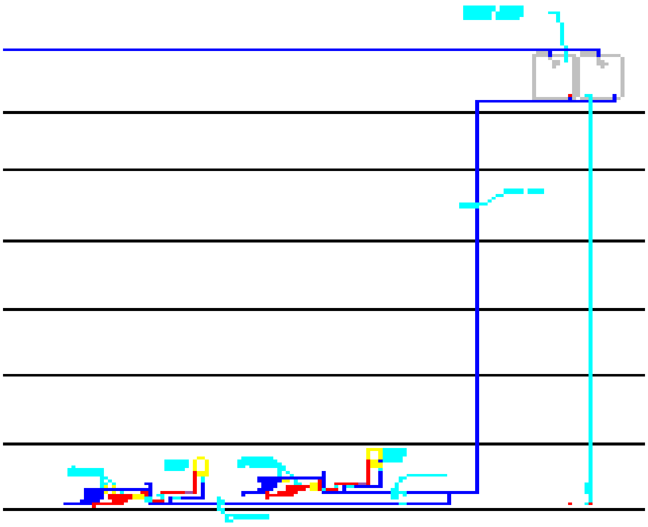


Figure 5.2: static head

$$\text{Static pressure} = \text{Friction head loss} + \text{minimum flow pressure} \quad (5.1)$$

$$\text{Static pressure} = 20.75 \times \frac{0.433}{0.305} = 30\text{psi}$$

$30 = \text{Friction head loss} + 8$

Then: Friction head loss $= 22$ psi

$$\text{Equivalent length} = \frac{65 \times 1.5}{0.305} = 320\text{ft.}$$

$$Uniform\,design\;friction\,loss = \frac{Available\,headloss}{Equivalent\,length} \qquad (5.2)$$

$$Uniform\ design\ \ friction\ loss = \frac{22 \times 100}{320} = 6.9\,psi/100ft$$

Table 1:Properties of cold and hot water riser

No. of Riser	Total WSFU	Total gpm	Diameter (inch)	Velocity (fps)
First riser	26	18	1.25	4
Second	128	69	2	4
∑	154WSFU	87gpm		

5.4 selections

5.4.1 selection for coldwater pump

In order to choose the details of the required water pump we have to determine two main conditions, the amount of total flow rate of demand water and the total head:-

1. Flow rate determination

According to the previews calculation and equation estimation, the total flow rate for the(1.2) risers is 87gpm, so by converting 87gpm equal to 16 $m^{\wedge 3}$/h.

2. Head estimation

According to the previews calculation and equation estimation the head is 37 psi & equal 2.5Bar, Adding 1 bar for fittings losses the value is almost 3.5bar

5.4.2 Pump selection

Using (dp-select) software and with filling data into brackets as follow:-

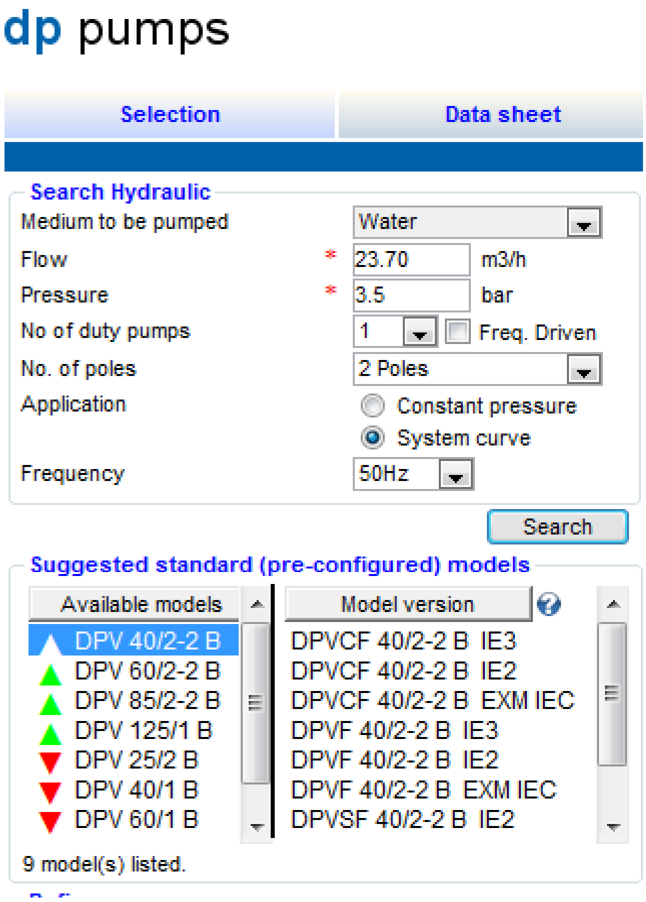


Figure 5.3: Pump data

The pump model selected “DPV 40/2-2B”.

The characteristic curves of this pump as follow:

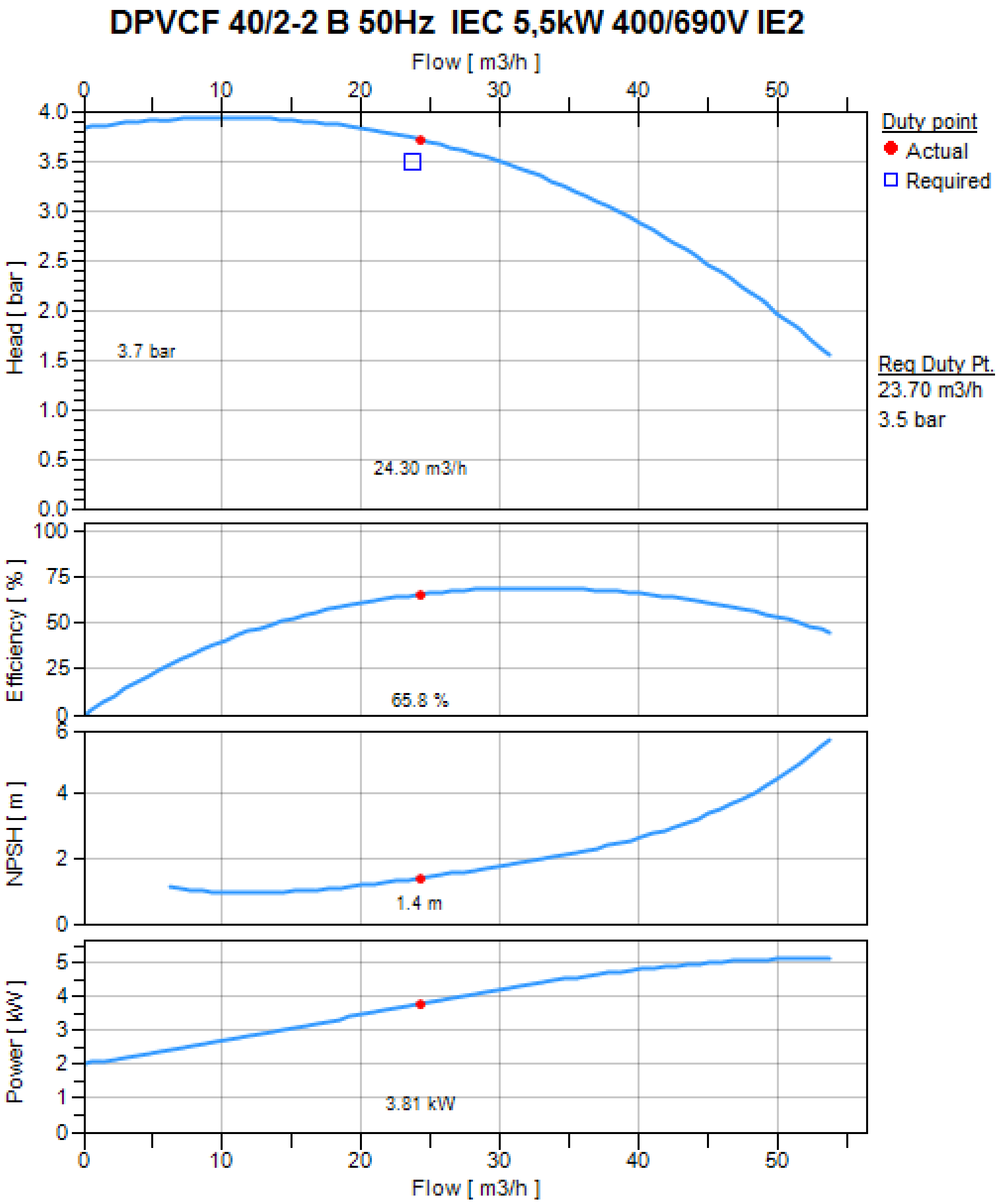


Figure 5.4: Pump characteristic curves

5.4.3selection for tank

5.4.3.1selection for main water tank

To calculate the size of the water tank which is to be in accordance with the degree of risk depending on the type of threat that we own.

Table:5-9: Degree of risk

Hazard	Time
Light Hazard	min *03 : 03*
Ordinary Hazard	min *023 : 03*
Extra Hazard	min *023*

.It is time that the network must work until the arrival of firefighters and civil defence

If we assume that the need of hydraulic calculations to 87gpm and an average degree of seriousness of Ordinary Hazard, we find that the size of the reservoir as follows

V = 87gpm X 60 min X (3.785 / 1000)

Tank volume equal to = 20 m^3

5.4.4selection for boiler

Where electric power is more economically available than fossil fuels, or where fossil fuel combustion and the handling of combustion by-products are unacceptable, electric boilers offer a viable alternative.

Designed for heating applications Electric boilers are able to withstand virtually any return water temperature. With combustion by-products and High temperature differentials eliminated, condensation and thermal shock do not limit return water Temperatures.

Because of the design characteristics, the electric boiler is well suited for applications utilizing indoor/outdoor, Reset controls, radiant floor heating, snow melt systems, and ground source heat pump systems.

For potable water applications, the IWH can be used with the optional epoxy lining or with the optional Stainless steel trim.

According to the previews calculation and equation estimation, the total flow rate for the(1.) risers is 98gpm, so by

$$Q = Cp \times m \times \Delta T \qquad (5.3)$$

kW = gph (gallons per hour) x delta T (as expressed in ˚F) divided by 410

Where:

Q: boiler capacity. [kW]

m: mass flow rate from data sheet [g/h]

ΔT:-hot water temperature [˚F]

kW= g/h x delta T/410

kW = (8*60) x 20/410

kW =9600/410

kW = 23.4

5.5 Sanitary Drainage System

The main objective of drainage system is to carry the waste water from the fixture unit to manhole and from the manhole to the septic tank or to the municipal sewage system.

The provision of drainage systems:

- Sanitary drainage

5.5.1 Drainage system components

The main components of drainage system are:

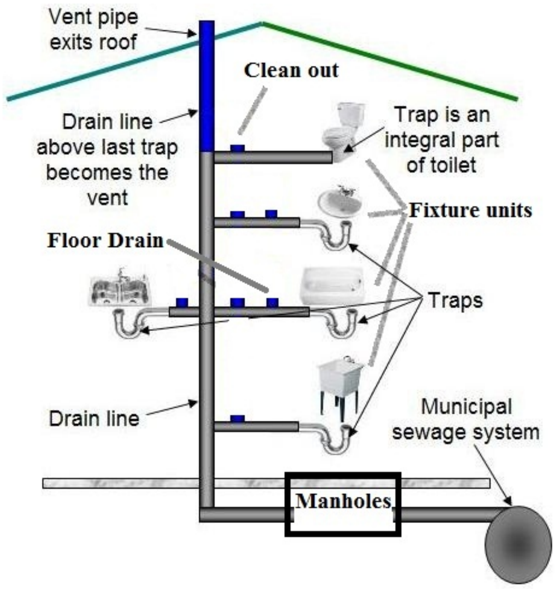


Figure 5.5: Drainage system components

- Fixture units
- Trap
- Clean out
- Drainage pipe
- Stack and vent pipes
- Manholes
- Septic tank or municipal sewage system
- Accessories

This project deals with two types of wastewater which is gray and black water, the separation of waste water will rationalize consumption of water and reuse it in irrigation and in flushing water closet.

5.5.2 sanitary drainage Design procedure and pipe sizing

Pipe size is calculated by using a concept of fixture units (DFU) instead of using gpm of drainage water. This unit takes into account not only the fixtures water use but also its frequency of use, which is the DFU has a built–in diversity factor. This enables us, exactly as for water supply to add DFU of various fixtures to obtain the maximum expected drainage flow. Drainage pipes sized for a particular number of drainage fixture units, according to Tables (10.1), (10.2) (10.4). 10.5). These tables are built into the fill factors, which are:

- 50% fill in branches (horizontal pipes)
- (25-33)% fills in stack (vertical pipes)
- 50% fill in building and swear drains

The recommended velocity for drainage piping:

- For branches the recommended velocity is 2 ft/s
- For building pipes the recommended velocity is 3 ft/s
- For greasy flow the recommended velocity is 4 ft/s

Velocity of water flow through drainage piping depends on:

- Pipe diameter
- Slope

Minimum slope requirements for horizontal drainage piping:

- For pipes of diameter ≤ 3" the minimum slope is 1/4”/ft (2%)
- For pipes of diameter ≥ 4" the minimum slope is 1/8”/ft (4%)

Design procedure:

1. Calculation of the number of DFU for each branch by using Table (10.2)
2. Calculation of the number of DFU for each stack
3. Choosing the branch pipe diameter by using Table (10.4)
4. Choosing the stack pipe diameter by using Table (10.4)
5. Comparing the stack pipe diameter with branch diameter
6. Choosing the building drain pipe diameter by using Table (10.5)

To achieve the recommended velocities which are 3 fps in building drain, it will be chosen the slope and flow velocity in building drain by using Table A(10.1).

The following figure and tables shows the sizing of stacks:

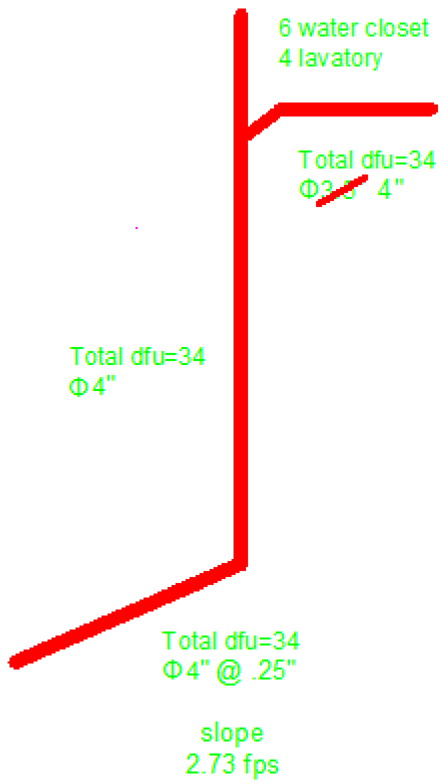


Figure 5.6: sample of stacks

Table 5.10: Sizing sample of stack1

Stack 1	Total dfu value	Diameter (inch)
From ground floor (branch)	34	3.5 (4)
From ground floor to first basement floor (stack)	34	4
From first basement floor to building drain (stack)	34	4

Table5.11:Sizing of water stacks and building drain

#of stack	Total Dfu	Diameter (in)	Diameter of building drain	Slope %	Velocity ft/s
Stack 1	34	4	3(4)	1/4	2.25
Stack 2	33	4	3(4)	1/4	2.25
Stack 3	39	4	3(4)	1/4	2.25
Stack 4	28	4	3(4)	1/4	2.25
Stack 5	7	2.5(4)	2(4)	1/4	1.99
Stack 6	7	2.5(4)	2(4)	1/4	1.99

5.5.3 Manhole design

The main purpose of the manholes is to carry the water from stacks to various drainage points. This project contains three types of manhole, which is:

- Sanitary manhole for black water
- Sanitary manhole for gray water

The design of the manholes depend on the ground and its nature around the building, and so as the first manhole height should not be less than 50 cm, and the depth of the other manholes will depend on the distance between the manholes and the slope of the pipe that connecting them.

According to the table below, it will be estimated the diameter of the manhole according to their depth. [١١]

Table 2: Diameter of manhole according to their depth

Depth (cm)	Diameter (cm)
70-80	60
80-140	80
140-250	100
250-∞	125

5.5.3.1 Manhole calculation

The depth of the first manhole is 50 cm, the calculation of the second manhole done according to the first manhole and so on. Using these equations does the calculations:

- Depth ($x_{manholes}$) = Depth ($_{manholes}x-1$) + (Slope × Distance) + 5 + Level Difference) in cm
- Top level: Manholes face level on the ground
- Invert level = outlet level of manholes +5 (m)
- Outlet level = top level- depth manholes (m)

The figure below shows the details of the manholes:

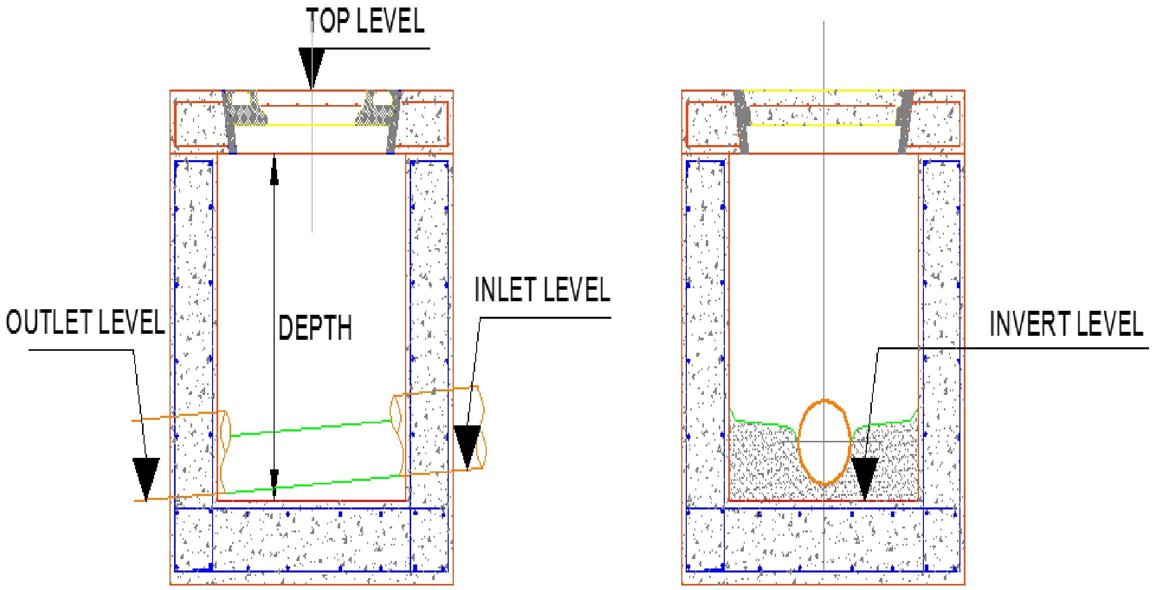


Figure 5.7 Manholes details

The result calculation of the gray water and black water manholes is listed in the tables below:

Table 3:Black water manholes

Manhole No.	Top level (m)	Invert level (m)	Outlet level (m)	Depth (cm)	Dia. Size (cm)	Cover Type
M01	+0.0	-390	-385	390	150	Concrete
M02	-3.50	-4.10	-4.05	60	60	Concrete
M03	-3.50	-4.27	-4.22	82	60	Concrete
M04	-3.40	-4.61	-4.56	121	80	Concrete
M05	-3.40	-4.77	-4.72	137	80	Concrete
M06	-3.50	-5.09	-5.04	159	80	Concrete
M07	-3.55	-5.31	-5.26	176	80	Concrete
M08	-4.21	-5.48	-5.43	127	80	Concrete
M09	-4.52	-5.70	-5.65	117	80	Concrete
M10	-4.84	-5.90	-5.85	106	80	Concrete
M11	-4.11	-5.47	-5.42	136	80	Concrete
M12	-5.32	-5.92	-5.87	60	60	Concrete
M13	-5.32	-6.18	-6.1	86	60	Concrete

5.6 Storm drainage

The design of the rain collection piping, whether exterior gutters, and leaders, or interior conductors and drain depends upon three factors:

- The amount of rain fall in a specified period of time
- The size of the area being drained
- The degree of pipe fill, that is whether a pipe or gutter runs 50%, 33% or 100% fill

The general rule for the distribution of floor drains (FD):

Every 100 m^2 from roof area needs one 4” FD.

The roof area of this building is 1620 m^2, and therefore needs Sixteenth 4” FD.

To see all drainage systems go to drawings from (M08).

5.7FIRE FIGHTING SYSTEM

5.7.1 Introduction

A firefighting system is probably the most important of the building services, as its aim is to protect human life and property, strictly in that order. Firefighting systems and equipment vary depending on the age, size, use and type of building construction.

5.7.2 Types of firefighting system

- Fire extinguishers.
- Fire hose reels.
- Fire hydrant systems.
- Automatic sprinkler systems.

5.7.2.1 Fire extinguishers

Fire extinguishers are provided for a 'first attack' firefighting measure generally undertaken by the occupants of the building before the fire service arrives. It is important that occupants are familiar with which extinguisher type to use on which fire.

Most fires start as a small fire and may be extinguished if the correct type and amount of extinguishing agent is applied whilst the fire is small and controllable.

The principle fire extinguisher types currently available include:

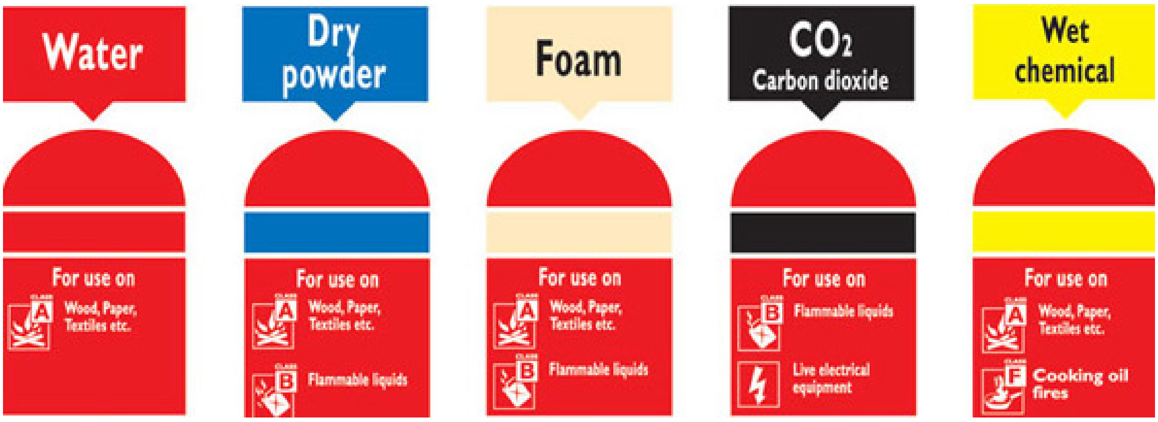


Figure 5.8: Fire extinguishers

5.7.2.2 Fire hose reel

Fire hose reel systems consist of pumps, pipes, water supply and hose reels located strategically in a building, ensuring proper coverage of water to combat a fire.

The system is manually operated and activated by opening a valve enabling the water to flow into the hose that is typically 30 meters away. The usual working pressure of a firehouse can vary between 8 and 20 (116 and 290 psi).

Fire hose reels are provided for use by occupants as a first attack firefighting measure but may, in some instances, also be used by firefighters. When stowing a fire hose reel, it is important to first attach the nozzle end to the hose reel valve, then close the hose reel valve, then open the nozzle to relieve any pressure in the wound hose, then close the nozzle.

Figure 5.9: Fire hose reel

5.7.2.3 Fire hydrate system

Fire hydrant systems are installed in buildings to help fire fighters quickly attack the fire. Essentially, a hydrant system is a water reticulation system used to transport water in order to limit the amount of hose that fire fighters have to lay; thus speeding up the firefighting process.

Fire hydrants are for the sole use of trained fire fighters (which includes factory firefighting teams). Because of the high pressures available serious injury can occur if untrained persons attempt to operate the equipment connected to such installations. Fire hydrant systems sometimes include ancillary parts essential to their effective operation such as pumps, tanks and fire service booster connections. These systems must be maintained and regularly tested if they are to be effective when needed.

Figure 5.10: Fire hydrate system

5.7.2.4 Automatic sprinkler system

Time is essential in the control of fire. Automatic sprinkler systems are one of the most reliable methods available for controlling fires. Today's automatic fire sprinkler systems offer state of the art protection of life and property from the effects of fire. Sprinkler heads are now available which are twenty times more sensitive to fire than they were ten years ago.

A sprinkler head is really an automatic (open once only) tap. The sprinkler head is connected to a pressurized water system. When the fire heats up the sprinkler head, it opens at a preset temperature, thus allowing pressurized water to be sprayed both down onto the fire and also up to cool the hot smoky layer and the building structure above the fire. This spray also wets combustible material in the vicinity of the fire, making it difficult to ignite, thereby slowing down or preventing fire spread and growth.

When a sprinkler head operates, the water pressure in the system drops, activating an alarm, which often automatically calls the fire brigade via a telephone connection.

5.8 Select the most effective type

After the identification of the fire systems now the best performance for the building is hose reel & extinguisher.

The number of hose reels to be used in hotel is30fire hose reel for all floors most fire hose is designed to be stored flat to minimize the storage space required.

5.9 Pipe size calculation:

The fire hose reel system is to be used, so the pipe size for this system will be calculated as follows:

The minimum flow rate for single cabinet = 30 (l/min).

Then:

$$\text{The total flow rate} = \text{min. flow rate} \times \text{No. of cabinet}$$

Table 5.14: Pipe schedule - standpipes and supply piping

Total Accumulated Flow		Total Distance of Piping from Farthest Outlet		
L/min	gpm	<15.2 m (<50 ft)	15.2–30.5 m (50–100 ft)	>30.5 m (>100 ft)
379	100	2	2½	3
382–1893	101–500	4	4	6
1896–2839	501–750	5	5	6
2843–4731	751–1250	6	6	6
4735	1251 and over	8	8	8

Note: For SI units, 3.785 L/min = 1 gpm; 0.3048 m = 1 ft.

Then the table 42 is to be used to calculate the pipe size by follow the next procedure. First, the total flow rate is determined which is 450 l/min for our calculation sample. Then the total distance of piping from farthest outlet is to be chosen. Finally, the intersection between the two values in table42 will give the size of pipe supply, which is equal to 3".

Then to determine the outlet pipe size from pipe supply to hose connection For this building. The selection diameter is (2.5 in.) hose stations to supply water for use primarily by the building occupants or by the fire department during initial response.

5.10 Firefighting pumps

Continuous water and pumping station supply should always be available and ready to fight fire, the following three pumps should be connected to a suction header (from water tank), and discharge header (to firefighting network).

Pumping should be included: -

1. Electrical fire fighting pump.
2. Jockey Pump: Work to make up the system pressure in case of leakage or during the first seconds of fire.

5.11 Pump selection:-

Using (d p-select) software and with filling data into brackets as follow:

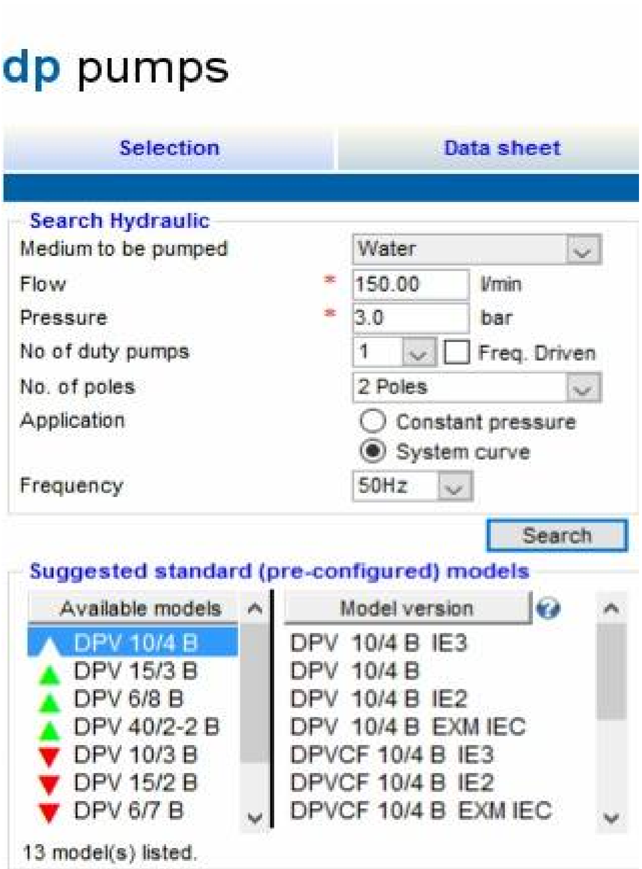


Figure 5.11: Pump data

The pump model selected “DPV 10/4B”

The characteristic curves of this pump as follow:

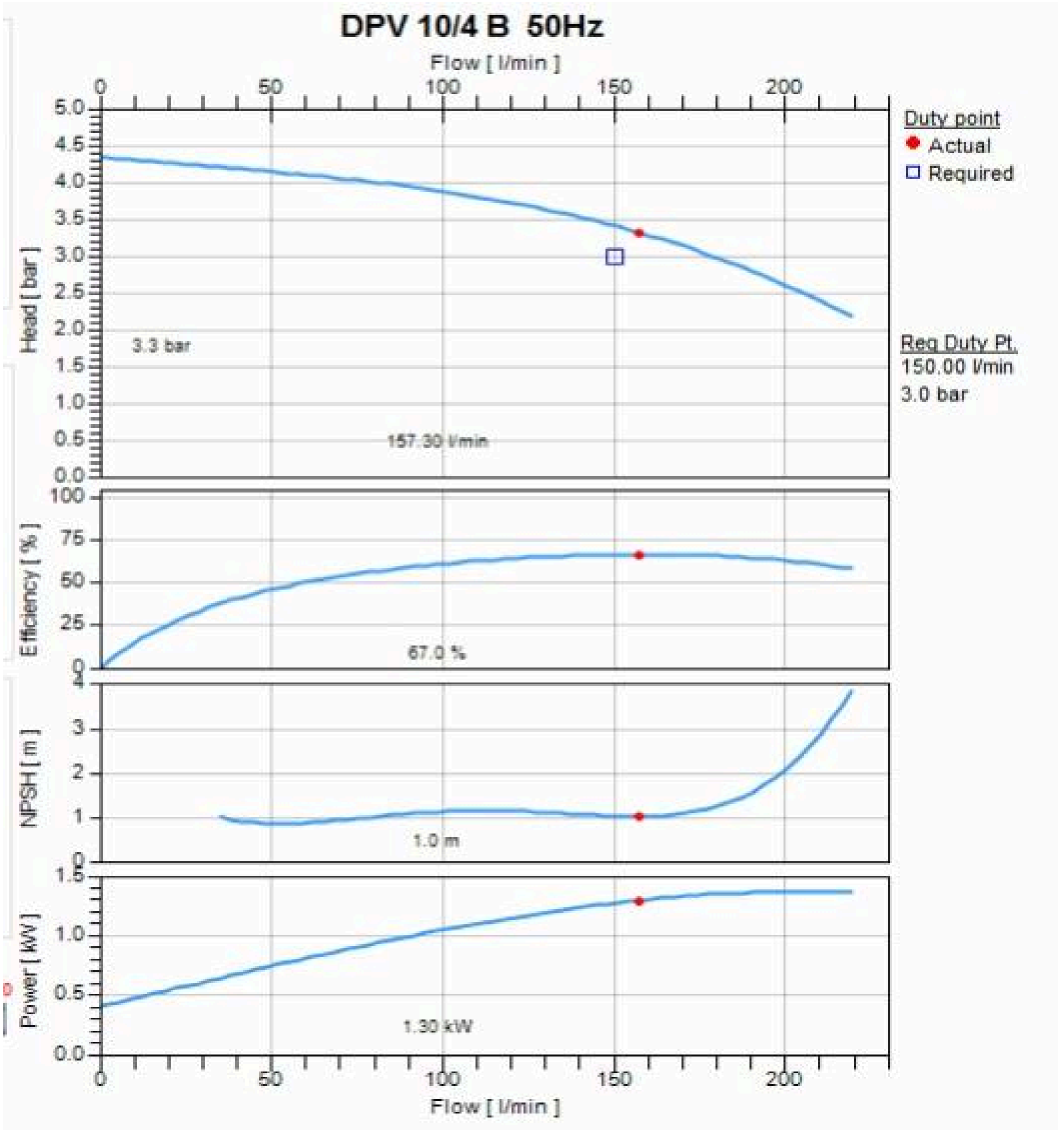


Figure 5.12: Pump characteristic curves

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Appendix A

Quantities Table

Item	Description	Unit	Qt.	Rate $	Total $
	PLUMBING, SANITARY AND MECH. WORKS Preamble All Meshwork items mentioned hereinafter for all project facilities and units shall include supply, delivery installation adjustment, testing, commissioning, and all required materials, equipment and workmanship to execute the items of construction in accordance with the drawings, specifications and supervising engineer's instructions, complete in place and ready for handing over. Measurements and payments shall be described in the relevant documents. Radiator section, sanitary fixture and water distribution cabinet. Prices must include supply & install cross linked polyethylene pexgol pipes PEX 16mm, 25mm pipes with protection sleeve . Working drawings for all mechanical works that should be submitted by the contractor should be approved by the supervisor engineer before starting works. The contractor shall submit shop drawings, coordinate drawings and as-built drawings.				
1	**Internal Drainage System Supply and install of SN4 UPVC Vent and drainage pipes to floor drains or down to manholes with all required fittings 'Y", "T" etc. The price includes digging and plastering hangers and supports also incasing with concrete cover**				

	for underground pipes and roof vent caps, including connections as shown in drawings, specifications and approval of supervisor engineer.				
1.1	**size 2 inch diameter**	**m**	**60**	**1**	**60**
1.2	**size 4 inch diameter**	**m**	**200**	**3**	**600**
1.3	**size 6 inch diameter**	**m**	**500**	**6**	**3000**
1.4	**Ditto but HDPE 2"**	**m**	**50**	**2**	**100**
1.5	**Ditto but HDPE 4"**	**m**	**75**	**6**	**450**
1.6	**Ditto but HDPE6"**	**m**	**100**	**10**	**1000**
2	**Rain Water pipes** **Supply and install SN4 UPVC rain water pipes down to the rain manholes with wired mesh above ground level, with all required fittings and vent caps, all as shown in drawings, specifications, and approval of supervisor engineer includes all pipes and fittings from roof inlet till ground outlet, all necessary digging and plastering work.**				
2.1	**size 4 inch diameter**	**m**	**150**	**3**	**600**
3	**Water well(underground)**				
3.1	**Supply and install all needed for the water well. The price includes flanged water supply, flanged water outlet, flanged overflow and vent, Floats and all needed to complete the job.**	**ls**	**1**		
4	**Water tank**				
4.1	**Supply and install all needed for the water tank 2000L. The price includes flanged water supply, flanged water outlet, flanged overflow and vent, valves, floats and all needed to complete the job.**	**ls**	**10**	**150**	**1500**
5	**Floor Drains**				
5.1	**Supply and install 4" floor trap UPVC include stainless steel one closed cover & one grating cover**	**no**	**10**	**15**	**150**

	type (15*15 cm) completed with connections including 2" UPVC pipes) to 4" UPVC drain pipes as located in drawings, specifications and approval of supervisor engineer.				
5.2	Ditto but suspended HDPE	no	2	10	20
5.3	Ditto but floor drain size 4"/2" Dia30 x 30 cm	no	7	5	35
5.4	Supply and install gully drain with medium duty cast iron grating cover complete with frame and anchor for boiler room of the following size:30 x 30 cm	no	2	50	100
6	Water Grills				
6.1	Supply and install, and commissioning of stainless steel grills , and of 15-30cm and width 25-40cm. located in cafeteria and Ablution .Price includes UPVC pipes connected it to the manhole or riser, painting, and smooth sloped concrete bedding in drawing the length is as shown in drawing .All as shown in drawings and specifications.	mr	3	50	150
7	Clean Out				
7.1	Supply and install Floor Clean Out 4" UPVC including stainless steel(sealed type) cover (15*15 cm) complete with connection to drain pipes as located in drawings , specifications and approval of supervisor engineer.	no	15	10	150
7.2	Ditto but suspended HDPE	no	5	20	100
8	Roof Drains Supply and install 4" UPVC (Type Reid) rain water roof drain including connections all as shown in drawings, specifications and approval of supervisor engineer.				

8.1	**Rain water drain size 4" with cover of 20*20 cm.(4" outlet) SANITARY FIXTURES Supply and install where shown on drawings the following sanitary fixtures with the required fittings and accessories complete as described. The price includes the supply and installation of all fittings e.g. elbow, T, valve, union, etc.**	**no**	**8**	**8**	**64**
9	**Wash Basin &Lavatories**				
9.1	**Supply and install of virtuosi china wall hung type wash basin, size 550*400 mm complete with chrome plated lever tap, chrome plated 13mm angle valves. The price includes 2" PVC pipes from wash basin to floor drain, with plastic plated P-trap connected to floor drain, stainless steel soap dispenser, stainless steel paper dispenser, mirror size 700*500mm with stainless steel frame, The price shall also include supply of 10 units handle and mechanism spare parts as shown in drawings, specifications and approval of supervisor engineer.**	**no**	**12**	**100**	**1200**
9.2	**Ditto, but wash basin for Handicapped, with all accessories needed as per engineer's approval.**	**no**	**3**	**150**	**450**
10	**Water closet**				
10.1	**Supply and install of virtuous china close couple water closets, Floor mounted ,p trap .complete with6-Lt.capacity cistern, valves , fittings, solid seat and cover ,toilet stainless steel roll paper holder, chrome plated 13 mm stop angle valve, chrome plated 13mm hose and all accessories for complete**	**no**	**13**	**100**	**1300**

	installation, Price includes supply of 4 units flushing tank mechanism spare parts. All is according to drawings, specifications and approval of supervisor engineer.				
10.2	**Ditto, but floor mounted WC for Handicapped, including grab bar, etc. As per engineer's approval.**	**no**	**3**	**150**	**450**
11	**Urinal** **Supply and install and commission white virtuous china wall mounted urinal bowel complete with the following accessories:- pair bowl supports 40 mm diameter, plastic plated outlet grating, 2" PVC connection to floor drain, 40 mm diameter plastic plated p-trap with extension tube to wall and wall flange, 20 mm diameter chrome plated flush valve with regulator and spreader, Price includes supply of 6 units spare parts flushing valve. all is according to drawings, specifications and engineer approval.**	**no**	**9**	**100**	**900**
12	**Sink**				
12.1	**Supply and install vitreous china single bowel of size 60X50cm, complete with chrome plated Tap , chrome plated 13mm stop valve, supports, 2" PVC waste outlet connected to floor drain, P- trap, chrome plated 13mm hose and all required parts for water supply line , as shown in drawings , specifications and approval of supervisor engineer.**	**no**	**8**	**50**	400
12.2	**Ditto but double bowl 80cm*50cm**	**no**	**2**	**60**	**120**
13	**Water Tap**				
13.1	**Supply and install water tap and all required parts for water supply line, as shown in drawings, specifications and approval of**	**no**	**15**	**5**	**75**

	supervisor engineer.				
14	Shower Head				
14.1	Supply and install all necessary fittings and accessories for 80cm*80cm shower. The price includes shower mixer that includes shower arm and shower head. The price includes shower floor trap to be connected to the main trap. The price also includes PEX pipes between the shower and the collector, elbows and all other fittings needed to comply with the drawings and specifications.	no	1	300	300
15	External Drainage System				
15.1	Supply and install of SN8 UPVC drainage pipes and fittings, including connections, excavation, covering with a layer of 20 cm sand around the pipe and back filling and cutting asphalt for connection to the existing sewage manhole as shown in drawings and specifications and approval of supervisor engineer.6"diam.	m	280	5	1400
16	Sewer , Rain and water Manholes Supply and install and commission of reinforced precast concrete Manholes of 15cm thickness for walls and 20 cm thickness readymade base with all necessary excavation, back filling as specified to the required depth complete with iron steps, with medium duty C.I (25 Ton cover and frame, benching and plastering. Price includes supply of portable water turbidity meter as testing equipment.				
16.1	Manhole of 60 cm internal diam.	no	6	20	120

16.2	**Ditto but Manhole of 80 cm internal diameter.**	**no**	**2**	**25**	**50**
16.3	**Ditto but Manhole of 100 cm internal diameter.**	**no**	**5**	**40**	**200**
16.4	**Ditto but Manhole of 120 cm internal diameter. (25 ton cover)**	**no**	**1**	**100**	**100**
17	**WATER SUPPLY**				
17.1	**Main water connection** **Supply and install galvanized steel main W.P. 3"(schedule 40 type) of wall thickness 3.65 mm wrapping from outside with layer of PE high density polyethylene insulated protection factory covered laid underground cement inside with asphalt protection with all necessary fittings e.g. elbow, union, stop valves, no return valve, auto. Air vent and all are approved quality. The price shall include constructing, supplying and installing of pressure reducing station, as per details shown in drawings. The price shall also include piping connections with all needed fittings and accessories, 3" water meter,3/4" water meter for cafeteria ,excavation, back filling, disposal of remained exacted soil. All is according to drawings, specifications, and approval of supervisor engineer.**	**job**	**1**		

18	**Main fire connection** **Supply and install galvanized steel main F.P. (schedule 40 type) of wall thickness 3.65 mm wrapping from outside with layer of PE high density polyethylene insulated protection factory covered laid underground cement inside with asphalt protection with all necessary fittings e.g. elbow, T, union, stop valves, no return valve , auto. Air vent and all are approved quality. The price shall also include piping connections with all needed fittings and accessories, excavation, back filling, disposal of remained exacted soil. All is according to drawings, specifications, and approval of supervisor engineer.**				
18.1	**size 3" G.S.P**	**m.r**	**50**	**10**	**500**
19	**Galvanized Steel Fire Fighting Pipes** **Supply and install of galvanized steel SCH40 (Seamless type) for firefighting system from pressure reducing station up to fire cabinets distributed in floors, with all YT necessary fittings like valves, elbow ,T, vent, of approved quality. The price includes supports, hangers as shown on drawing, in addition to asphalt insulation of underground pipes, all according to specifications and approval of supervisor engineer, and as follows:**				
19.1	**Size2.5" diameter**	**m.r**	**90**	**10**	**900**
19.2	**size 3" diameter**	**m.r**	**180**	**15**	**2700**
20	**Feed and Domestic Galvanized Steel Water Pipes**				
20.1	**size 3/4" G.S.P**	**m.r**	**250**	**3**	**750**

20.2	size 1" G.S.P	m.r	130	5	650
20.3	size 1 1/4" G.S.P	m.r	170	7	1190
20.4	size 1 1/2" G.S.P	m.r	60	10	600
20.5	size 2" G.S.P	m.r	90	12	1080
20.6	size 2" G.S.P insulated)	m.r	80	15	1200
20.7	size 3" G.S.P	m.r	20	15	300
20.8	size 4" G.S.P	m.r	10	20	200
21	**Domestic and flush Water Collectors** Supply and install copper collectors for domestic cold water and Flush systems, of approved quality, with all necessary fittings, nipples, nuts, unions, quick shut off valves, branch valves, thermometer gauge, brass fittings adapter, automatic vents...Etc. of approved quality. Rate includes hardwood architecture frame with ceramic tiles inside and Formica on sandwich wood cover with double doors for collectors. The price should also supplying and installing 16mm PEX plastic pipes with its 25mm plastic conduits with 5cm thick concrete layer to fixture units outlets, copper elbows recessed in walls and all civil works needed, all according to plans and engineer’s instructions:				
21.1	3/4" Domestic Cold Water Collector	no	12	8	96
21.2	1" Domestic Cold Water Collector	no	10	10	100
21.3	1 1/4" Domestic Cold Water Collector	no	6	15	90
22	Electric Water Heater				
22.1	Supply and install hot water storage cylinder of 60 Liters capacity (1.5kW electric power), of approved quality. The price includes galvanized pipes to collectors, all accessories needed to	no	4	100	400

	complete the job, fixing the cylinder on ceiling, with all related necessary fittings, i.e. air vent, valves, pressure relief valve, check valve,.... all according to drawings and engineer's instructions				
23	**Fire Cabinets**				
23.1	**Supply and install 120*80*30 cm steel fire hose reel cabinet, of thickness 2mm red color paint, 25mm diam., 30m length, mounted on swinging reel, an angle isolation valve inside the cabinet, a jet nozzle, and 25m long textile hose, an angle globe valve of size 2" with 2.5 hose adapter ,1" ball valve hose roll each 15 m length with 2" jet nozzle inside cabinet. Each cabinet should be supplied with two 2kg Co2 fire extinguisher, and approved sticker (FIRE CABINET in Arabic and English) from outside. As shown in drawings.**	**no**	**5**	**200**	**1000**
24	**Fire Extinguisher**				
24.1	**Supply and install 4 kg Capacity Co2 gas manual fire extinguishers, The price includes all accessories and fittings needed for installation and fixing wall.**	**no**	**17**	**20**	**340**
25	**Electrical water cooler**				
25.1	**Supply and install electrical water cooler of capacity 40 L/h with drinking chrome plated fountain of approved quality with hermetic type compressor complete with all required fixing connection, water supply and 2"PVC drainage pipe to the nearest floor trap. as shown in drawings, specifications and approval of supervisor engineer.**	**no**	**2**	**80**	**160**
26	**Submersible Pump For Elevator Pit**				

26.1	**Supply and install submersible pump for sump pit complete with all needed accessories and valves like gate valves, check valves, controls and electrical board and electrical connections wherever shown on drawings and to the approval of the Engineer, Submersible pump`s specification: 2m3/hr. at 5 m head .**	**no**	**1**	**500**	**500**
27	**Duct**				
27.1	**Supply and install galvanized metal sheet duct, with thickness according to ASHREA Standards. The price includes all joints, sealant compound, and all necessary accessories, galvanized hangers, hooks, penetration in walls as per drawings , all according to plans and engineer's instructions**	**N2**	**500**	**10**	**5000**
28	**Exhaust Air Fans** **Supply and install ducted exhaust air fan of low noise sound level. The price includes vibration isolators, flexible connection between the fan and duct, in addition to installing galvanized steel duct from the outdoor grille till the fan outlet and all accessories needed for installation. The price shall also include control and electrical connections, according to drawings & engineer's instructions:**				
28.1	**560CFM air flow, 0.2" wg static pressure**	**no**	**2**	**50**	**100**
28.2	**140CFM air flow**	**no**	**1**	**150**	**150**
28.3	**2734CFM air flow, 0.2" wg static pressure**	**no**	**1**	**500**	**500**
28.4	**630CFM air flow, 0.2" wg static pressure**	**no**	**1**	**300**	**300**
28.5	**340CFM air flow, 0.2" wg static**	**no**	**1**	**200**	**200**

	pressure				
28.6	2500cfm air flow, 0.2” wg static pressure	no	1	150	150
28.7	3000cfm air flow0.2” wg static pressure	no	1	200	200
28.8	300cfm centrifugal fan on roof for Cafeteria	no	1	250	250
28.9	2874cfm air flow	no	1	400	400
28.10	210cfm air flow, 0.2” wg static pressure	no	1	100	100
29	Exhaust Air Grilles (EAG) Supply and install white anodized Aluminum, ventilation air grilles of two opposed blades with registers, including openings in gypsum boards or false ceiling. The price includes galvanized box, and connections to grilles through flexible duct connection, complete as per specifications				
29.1	6"*6"	no	27	20	440
29.2	9"*9"	no	4	40	160
29.3	14"*8"	no	2	50	100
30	Split Units Supply, install, and commission high wall mounted air conditioning DX split unit, with low temperature kit and automatic restart. The price includes all accessories and fittings needed for installation and commissioning, insulated copper pipes, connection of drain pipe, galvanized steel base for the outdoor units vibration isolators, hangers and supports, high performance washable filters. In addition to control &electrical connections. Rate shall also include openings in wall (for pipes) through sleeves of good quality, and refilling works all according				

	to engineer's instructions and as follows:				
30.1	**2.9 kW Cooling Capacity**	**no**	**1**	**400**	**400**
30.2	**8.8 kW Cooling Capacity**	**no**	**1**	**800**	**800**
30.3	**14 kW Cooling Capacity**	**no**	**4**	**1000**	**4000**
30.4	**24.5 kW Cooling Capacity**	**no**	**2**	**2000**	**4000**
30.5	**16 kW Cooling Capacity**	**no**	**2**	**1500**	**3000**
	VRF Units				
31	**Supply, install, test and commission heat pump VRF (variable refrigerant volume)system. Refrigerant R410A Complete with the outdoor and indoor units system, thermostat, drain pipes pn16 from the indoor unit to the riser, Flexible connection from the indoor unit to the main duct, return box behind the VRF indoor units and all the needed necessary parts according to the drawings and specifications. As for the following: The Agent or authorized dealer should be representing the manufacturer for not less than Five years, and should have not less than 5 years' experience in selling, installing and maintaining VRF systems in Palestine. And the VRF System has been in satisfactory use in similar projects in Palestine of the same size or larger. Guarantee: Air conditioning units shall include a three (3) years warranty on compressor and one (1) year on all parts and labor after acceptance by the Engineer. ·Condensing Unit: Factory**				

	assembled and tested air cooled. Comprising full inverter compressor / compressors, condenser coil, condenser fan and motor, refrigerant receiver, charging valve and controls, assembled in a common casing. Unit to be tested at factory and supplied complete with refrigerant and dehydrated compressor oil. Condensing Unit and indoor units shall be equipped with a serial communication that provide a non-Stop operation for any numbers of indoor units when indoor unit needs maintenance (Electrical power cutoff) , condensing unit and related indoor units can keep operating , also if only one indoor unit needed to be running for long period alone and Electrical power cutoff from the remaining indoor units the system should keep running without any risk on the compressors from damage(a written guarantee will be requested from the agent or authorized dealer for the safety of the compressors). The price includes the control panel on roof with cables from outdoor units to the main panel on roof including panels for each system. Centralized controller in control room in ground floor.				
31.1	**Indoor units**				
31.1.1	**SP-B01(10.12kw)**	**no**	**6**	**1500**	**9000**
31.1.2	**SP-B02(11.02kw)**	**no**	**6**	**2000**	**12000**
31.2	**outdoor units**				
31.2.1	**40.5TR**	**no**	**1**	**10000**	**10000**
31.2.2	**36.3TR**	**no**	**1**	**8000**	**8000**

32	**Air grills**				
32.1	**Supply and install white anodized Aluminum, air grilles of two opposed blades with registers, including openings in gypsum boards or false ceiling. The price includes galvanized box, and connections to grilles through flexible duct connection, complete as per specifications**				
32.1.1	**12"*12"SD**	**no**	**43**	**10**	**430**
32.1.2	**Linear two slots**	**mr**	**16**	**10**	**160**
32.2	**Ditto but return grills without register**				
32.2.1	**60"*60"RG**	**no**	**15**	**10**	**150**
32.2.2	**24"*24" RG**	**no**	**4**	**20**	**800**
32.2.3	**Linear two slots**	**mr**	**4**	**15**	**600**
33	**Supply and install and test Kitchen hood of stainless steel 1.25mm size (115cm *90cm*50cm) including stainless steel filters also price includes 12 inch round duct to roof level with all accessories needed to complete the job. Price includes fume hood controller as testing equipment.**	**no**	**1**	**500**	**500**

APPENDIX (B)

HUMAN COMFORT

TABLE B1 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

(a) Adjusted heat dissipation is based on the percentage of men, women and children for the application.

TABLE B2 Minimum outside air requirements for mechanical ventilation[4].

Application	Maximum Occupancy Per 100 m^2	Ventilation Air Requirements	
		L/s/Person	L/s/m^2
Offices:			
Office space	7	10.0	2.5-10.0
Reception areas	60	8.0	3.5-7.5
Telecomm. Centers	60	10.0	—
Conference rooms	50	10.0	—
Public spaces:			
Corridors	—	—	0.25
Public restrooms	100	25.0	—
Locker and dressing rooms	50	7.5-17.5	5-2.5
Smoking lounge	70	30.0	—
Elevators:	—	7.5	5.00
Laundries:			
Commercial laundry	10	13.0	—
Commercial dry cleaner	30	15.0	—
Coin-operated laundries	20	8.0	—
Coin operated dry cleaner	20	8.0	—
Food and beverage services:			
Dining rooms	70	10.0	—
Cafeteria	100	10.0	—
Bars	100	15.0	—
Kitchens	20	8.0	—
Garages, service stations:			
Enclosed parking garage	—	5L/s/car	7.50
Auto repair rooms	—	—	7.50
Factories:	—	—	0.80
Retail stores:			
Basement and street stores	30	2.5-12.5	1.50
Upper floors	20	2.5-12.5	1.00
Storage rooms	15	2.5-12.5	0.75
Dressing rooms	—	3.5-12.5	1.00
Malls	20	2.5-5.0	1.00
Warehouses	5	2.5-5.0	0.25
Smoking lounge	70	30.0	—
Specialty shops:			
Barbers	25	8.0	—
Beauty saloons	25	13.0	—
Reducing saloons	20	8.0	—
Florist	8	8.0	—
Supermarkets	8	8.0	—
Hardware, drugs, fabrics	8	8.0	—
Pet shops	—	—	5.00
Furniture stores	—	—	1.50
Sports:			
Spectator areas	70-150	3.5-17.5	—

[4] Adapted from "*ASHRAE Handbook of Fundamentals,*" 1993.

Application	Maximum Occupancy Per 100 m^2	Ventilation Air Requirements	
		L/s/Person	L/s/m^2
Bath, toilets[3]	—	10.0	—
Hotels and motels:			
Bedrooms	—	—	7.5-15 L/s/room
Living rooms	—	—	5-10 L/s/room
Bathes	—	—	15-25 L/s/room
Lobbies	30	2.5-7.5	—
Conference rooms	50	3.5-17.5	—
Assembly rooms	120	3.5-17.5	—
Dormitory sleeping areas	20	8.0	—
Gambling casinos	120	15.0	—

(1) or 0.35 air change/hour (2) or 50 L/s intermittent or openable window.
(3) or 25 L/s intermittent or openable window.

TABLE B3 Overall Heat Transfer Coefficient for Windows, W/m²·°C

Material Type and Frames	Single Glass, Wind Speed, m/s			Double Glass, 6mm air gap, Wind Speed, m/s		
	< 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 B Overall heat transfer coefficients for wood and metal doors, W/m²·°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 B 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 B Values of the factor S_1 of Eq. (6–7).

№	Topography of Location	Value of S_1
1	Protected locations by hills or buildings (wind speed = 0.5 m/s)	0.9
2	Unprotected locations such as sea shores, hill tops, etc.	1.1
3	Locations other than that listed in item (1) or (2) of this table.	1.0

[2] Tables 6–2 through 6–4 are abridged from BS 6375. Values of infiltration air coefficients for doors are taken to be equal to that of windows of the same type.

Class (1) Locations having very high and close obstacles such as capital cities, down town of large cities, etc.

Class (2) Locations having numerous and close obstacles such as small cities, suburbs of large cities, etc.

Class (3) Locations having obstacles whose height less than 10 m such as airports, villages, etc.

Class (4) Locations with obstacles whose height is less than 1.5 m such as desert areas, plains without trees, etc.

Catagory A Structures and buildings whose maximum horizontal or vertical dimension is more than 50 m.

Catagory B Structures and buildings whose maximum dimension (horizontal or vertical) is less than 50 m.

Catagory C Individual structures.

TABLE B 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 B 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
40	December	−3.3	−4.4	−5.5	−7.2	−5.5	−3.8	0.0	3.8	5.5	−11.6
	Jan./Nov.	−2.7	−3.8	−5.5	−6.6	−5.0	−3.3	0.5	4.4	6.1	−10.5
	Feb./Oct.	−2.7	−3.8	−4.4	−5.0	−3.3	−1.6	1.6	4.4	6.6	−7.7
	Mar/Sept.	−2.2	−2.7	−2.7	−3.3	−1.6	0.5	2.2	3.8	5.5	−4.4
	Apr./Aug.	−1.1	−1.6	−1.6	−1.1	0.0	0.0	1.1	1.6	2.2	1.6
	May/July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
	June	0.5	0.5	0.5	0.5	0.0	0.5	0.0	0.0	−0.5	1.1
48	December	−3.3	−4.4	−6.1	−7.7	−7.2	−5.5	−1.6	1.1	3.3	−13.8
	Jan./Nov.	−3.3	−4.4	−6.1	−7.2	−6.1	−4.4	−0.5	2.7	4.4	−13.3
	Feb./Oct.	−2.7	−3.8	−5.5	−6.1	−4.4	−2.7	0.5	4.4	6.1	−10.0
	Mar/Sept.	−2.2	−3.3	−3.3	−3.8	−2.2	−0.5	2.2	4.4	6.1	−6.1
	Apr./Aug.	−1.6	−1.6	−1.6	−1.6	−0.5	0.0	2.2	3.3	3.8	−2.7
	May/July	0.0	−0.5	0.0	0.0	0.5	0.5	1.6	1.6	2.2	0.0
	June	0.5	0.5	1.1	0.5	1.1	0.5	1.1	1.1	1.6	1.1

TABLE B9 Approximate CLTD values for sunlit roofs, °C.

Solar Time	Roof Construction		
	Light	Medium	Heavy
10:00	5	—	—
11:00	12	—	—
12:00	19	3	0
13:00	25	8	2
14:00	29	14	5
15:00	31	19	8
16:00	31	23	10
17:00	29	25	12
18:00	24	26	14
19:00	19	25	15
20:00	11	22	16

TABLE B10 Approximate CLTD values for light, medium, and heavy weight construction walls, °C.

Solar Time	Wall construction											
	Light				Medium				Heavy			
	N	E	S	W	N	E	S	W	N	E	S	W
8:00	—	16	—	—	—	—	—	—	—	—	—	—
9:00	—	20	—	—	—	6	—	—	—	—	—	—
10:00	—	21	2	—	—	11	—	—	—	—	—	—
11:00	—	18	7	—	—	14	—	—	—	3	—	—
12:00	—	12	12	—	—	15	—	—	—	5	—	—
13:00	2	9	15	5	—	14	5	—	—	7	—	—
14:00	3	7	16	13	—	12	9	1	—	8	—	—
15:00	3	7	14	21	1	10	11	6	—	8	1	—
16:00	4	6	11	27	2	9	12	12	—	8	3	—
17:00	4	5	7	30	2	8	11	17	—	8	5	3
18:00	5	3	4	27	3	7	9	22	—	8	6	7
19:00	2	1	1	17	3	5	7	23	—	7	6	10
20:00	—	—	—	6	3	3	5	20	1	7	6	12

TABLE B11 Solar heat gain factor (SHG) for sunlit glass, W/m², for a latitude angle of 32 °N.

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
N	76	85	101	114	120	139	126	117	104	88	76	69
NNE/NNW	76	85	117	252	350	385	350	249	110	88	76	69
NE/NW	91	205	338	461	536	555	527	445	325	199	91	69
ENE/WNW	331	470	577	631	656	656	643	615	546	451	325	265
E/W	552	647	716	716	694	675	678	691	678	615	546	511
ESE/WSW	722	764	748	691	628	596	612	663	716	738	710	688
SE/SW	786	782	716	590	489	439	473	571	688	754	773	776
SSE/SSW	789	732	615	445	213	262	303	429	596	710	776	795
S	776	697	555	363	233	189	227	350	540	678	767	795
Horizontal	555	685	795	855	874	871	861	836	770	672	552	498

TABLE B12 Shading coefficient (SC) for glass windows with interior shading.

Type of Glass	Nominal Thickness, mm	Type of Interior Shading: Venetian Blinds: Medium	Venetian Blinds: Light	Roller Shade: Opaque: Dark	Roller Shade: Opaque: White	Roller Shade: Translucent: Light
Single Glass						
Clear, regular	2.5-6.0	—	—	—	—	—
Clear, plate	6.0-12.0	—	—	—	—	—
Clear Pattern	3.0-12.0	0.64	0.55	0.59	0.25	0.39
Heat Absorbing	3	—	—	—	—	—
Pattern or Tinted(gray sheet)	5.0-5.5	—	—	—	—	—
Heat Absorbing, plate	5.0-6.0	0.57	0.53	0.45	0.30	0.36
Pattern or Tinted, gray sheet	3.0-5.5	—	—	—	—	—
Heat Absorbing Plate or Pattern Heat Absorbing	10	0.54	0.52	0.40	0.82	0.32
Heat Absorbing or Pattern	—	0.42	0.40	0.36	0.28	0.31
Reflective Coated Glass	—	0.30	0.25	0.23	—	—
	—	0.40	0.33	0.29	—	—
	—	0.50	0.42	0.38	—	—
	—	0.60	0.50	0.44	—	—
Double Glass						
Regular	3	0.57	0.51	0.60	0.25	—
Plate	6	0.57	0.51	0.60	0.25	—
Reflective	6	0.20-0.40	—	—	—	—
Insulating Glass						
Clear	2.5-6.0	0.57	0.51	0.60	0.25	0.37
Heat Absorbing	5.0-6.0	0.39	0.36	0.40	0.22	0.30
Reflective Coated	—	0.20	0.19	0.18	—	—
	—	0.30	0.27	0.26	—	—
	—	0.40	0.34	0.33	—	—

Note: Shading coefficient SC, for other shading types and shading devices that are not included in Table 9–9 are as follows:

Dark venetian blinds	0.72
Canva awning	0.25
Roof overhang	0.25
Outside shading screen	0.30
Wood sash	0.85

TABLE B12 Cooling Load factors (CLF) for glass windows with interior shading, North latitude.

Fenestration Facing	Solar Time, *h*																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
N	0.08	0.07	0.06	0.06	0.07	0.73	0.66	0.65	0.73	0.80	0.86	0.89	0.89	0.86	0.82	0.75	0.78
NNE	0.03	0.03	0.02	0.02	0.03	0.64	0.77	0.62	0.42	0.37	0.37	0.37	0.36	0.35	0.32	0.28	0.23
NE	0.03	0.02	0.02	0.02	0.02	0.56	0.76	0.74	0.58	0.37	0.29	0.27	0.26	0.24	0.22	0.20	0.16
ENE	0.03	0.02	0.02	0.02	0.02	0.52	0.76	0.80	0.71	0.52	0.31	0.26	0.24	0.22	0.20	0.18	0.15
E	0.03	0.02	0.02	0.02	0.02	0.47	0.72	0.80	0.76	0.62	0.41	0.27	0.24	0.22	0.20	0.17	0.14
ESE	0.03	0.03	0.02	0.02	0.02	0.41	0.67	0.79	0.80	0.72	0.54	0.34	0.27	0.24	0.21	0.19	0.15
SE	0.03	0.03	0.02	0.02	0.02	0.30	0.57	0.74	0.81	0.79	0.68	0.49	0.33	0.28	0.25	0.22	0.18
SSE	0.04	0.03	0.03	0.03	0.02	0.12	0.31	0.54	0.72	0.81	0.81	0.71	0.54	0.38	0.32	0.27	0.22
S	0.04	0.04	0.03	0.03	0.03	0.09	0.16	0.23	0.38	0.58	0.75	0.83	0.80	0.68	0.50	0.35	0.27
SSW	0.05	0.04	0.04	0.03	0.03	0.09	0.14	0.18	0.22	0.27	0.43	0.63	0.78	0.84	0.80	0.66	0.46
SW	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38	0.59	0.75	0.83	0.81	0.69
WSW	0.05	0.05	0.04	0.04	0.03	0.07	0.10	0.12	0.14	0.16	0.17	0.23	0.44	0.64	0.78	0.84	0.78
W	0.05	0.05	0.04	0.04	0.03	0.06	0.09	0.11	0.13	0.15	0.16	0.17	0.31	0.53	0.72	0.82	0.81
WNW	0.05	0.05	0.04	0.03	0.03	0.07	0.10	0.12	0.14	0.16	0.17	0.18	0.22	0.43	0.65	0.80	0.84
NW	0.05	0.04	0.04	0.03	0.03	0.07	0.11	0.14	0.17	0.19	0.20	0.21	0.22	0.30	0.52	0.73	0.82
NNW	0.05	0.05	0.04	0.03	0.03	0.11	0.17	0.22	0.26	0.30	0.32	0.33	0.34	0.34	0.39	0.61	0.82
HORIZ.	0.06	0.05	0.04	0.04	0.03	0.12	0.27	0.44	0.59	0.72	0.81	0.85	0.85	0.81	0.71	0.58	0.42

***Note*:** Values of the cooling load factors (CLF) of Tables 9–10 and 9–11 for the hours 18:00 to 24:00 may be obtained from McQuiston and Parker, 1994, "*Heating, Ventilating, and Air Conditioning*", 4th ed., Wiley.

TABLE B13 Cooling load temperature differences (CLTD) for convection heat gain for glass windows.

Solar Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
CLTD °C	1	0	−1	−1	−1	−1	−1	0	1	2	4	5	7	7	8	8	7	7	6	4	3	2	2	1

TABLE B1 Heat gain rate from miscellaneous appliances, W.(2)

Appliances	Without Hood			With Hood
	Sensible	Latent	Total	All Sensible
Hair dryers (Blower type)	675	120	795	—
Hair dryers (Helmet type)	550	100	650	—
Coffee brewer (electrical)	225	65	290	95
Coffee brewer (gas)	490	210	700	415
Water heater	1,130	335	1,465	—
Coffee urn (electrical)	1,075	350	1,425	440
Coffee urn (gas)	1,460	625	2,085	415
Deep fat fryer (electrical)	820	1,930	2,750	730
Deep fat fryer (gas)	2,080	2,080	4,160	830
Toaster	1,055	705	1,760	440
Domestic gas oven	2,430	1200	3,630	—
Roasting oven	500	320	820	—
Food warmer (gas)	1,550	400	1,950	400
Egg boiler	335	220	555	—
Frying griddle	13,600	7,200	20,800	4,150
Hotplate	1,550	1,060	2,610	780
Neon sign, per meter length	56	—	56	—
Sterilizer	190	350	540	—
Laboratory burner	470	120	590	—
Small copy machine	1,760	—	1,760	—
Large copy machine	3,515	—	3,515	—
Motors:				
400–2,000 W	1,100	—	1,100	—
2,000–15,000 W	2,430	—	2,430	—

TABLE B1 Cooling load factor $(CLF)_{Lt}$, for lights.[3]

Number of hours after lights are turned On	Fixture X[c] hours of operation		Fixture Y[c] hours of operation	
	10	16	10	16
0	0.08	0.19	0.01	0.05
1	0.62	0.72	0.76	0.79
2	0.66	0.75	0.81	0.83
3	0.69	0.77	0.84	0.87
4	0.73	0.80	0.88	0.89
5	0.75	0.82	0.90	0.91
6	0.78	0.84	0.92	0.93
7	0.80	0.85	0.93	0.94
8	0.82	0.87	0.95	0.95
9	0.84	0.88	0.96	0.96
10	0.85	0.89	0.97	0.97
11	0.32	0.90	0.22	0.98
12	0.29	0.91	0.18	0.98
13	0.26	0.92	0.14	0.98
14	0.23	0.93	0.12	0.99
15	0.21	0.94	0.09	0.99
16	0.19	0.94	0.08	0.99
17	0.17	0.40	0.06	0.24
18	0.15	0.36	0.05	0.20

TABLE B1 Diversity factor for selected applications.[4]

Application	Diversity Factor	
	Lights	People
Peripheral aras of offices with glazing area of 20%-50%	0.70-0.85	0.7-0.8
Core areas of offices and peripheral areas with less than 20% glazing	0.90-1.00	0.7-0.8
Apartments and hotel bedrooms	0.30-0.50	0.4-0.6
Public rooms in hotels	0.90-1.00	0.4-0.6
Department stores and supermarkets	0.90-1.00	0.8-1.0

TABLE B1 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 B1 Circular equivalent diameters of rectangular ducts for equal pressure drop and flow rate[3].

Lgth. Adj.	Length of One Side of Rectangular Duct , mm																			
	100	125	150	175	200	225	250	275	300	350	400	450	500	550	600	650	700	750	800	900
100	109																			
150	133	150	164																	
200	152	172	189	204	219															
250	169	190	210	228	244	259	273													
300	183	207	229	248	266	283	299	314	328											
400	207	235	260	283	305	325	343	361	378	409	437									
500	227	258	287	313	337	360	381	401	420	455	488	518	547							
600	245	279	310	339	365	390	414	436	457	496	533	567	598	628	656					
700	261	298	331	362	391	418	443	467	490	533	573	610	644	677	708	737	765			
800	275	314	350	383	414	442	470	496	520	567	609	649	687	722	755	787	818	847	875	
900	289	330	367	402	435	465	494	522	548	597	643	686	726	763	799	833	866	897	927	984
1000	301	344	384	420	454	486	517	546	574	626	674	719	762	802	840	876	911	944	976	1037
1200	324	370	413	453	490	525	558	590	620	677	731	780	827	872	914	954	993	1030	1066	1133
1400	344	394	439	482	522	559	595	629	662	724	781	835	886	934	980	1024	1066	1107	1146	1220
1600	362	415	463	508	551	591	629	665	700	766	827	885	939	991	1041	1088	1133	1177	1219	1298
1800	379	434	485	533	577	619	660	698	735	804	869	930	988	1043	1096	1146	1195	1241	1286	1371
2000	395	453	506	555	602	646	688	728	767	840	908	973	1034	1092	1147	1200	1252	1301	1348	1438
2200	410	470	525	577	625	671	715	757	797	874	945	1013	1076	1137	1195	1251	1305	1356	1406	1501
2400	424	486	543	597	647	695	740	784	826	905	980	1050	1116	1180	1241	1299	1355	1409	1461	1561
2600	437	501	560	616	668	717	764	810	853	935	1012	1085	1154	1220	1283	1344	1402	1459	1513	1617
2800	450	516	577	634	688	738	787	834	879	964	1043	1119	1190	1259	1324	1387	1447	1506	1562	1670

Lgth. Adj.[b]	Length of One Side of Rectangular Duct (a), mm																			
	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900
1000	1093																			
1100	1146	1202																		
1200	1196	1256	1312																	
1300	1244	1306	1365	1421																
1400	1289	1354	1416	1475	1530															
1500	1332	1400	1464	1526	1584	1640														
1600	1373	1444	1511	1574	1635	1693	1749													
1700	1413	1486	1555	1621	1684	1745	1803	1858												
1800	1451	1527	1598	1667	1732	1794	1854	1912	1968											
1900	1488	1566	1640	1710	1778	1842	1904	1964	2021	2077										
2000	1523	1604	1680	1753	1822	1889	1952	2014	2073	2131	2186									
2100	1558	1640	1719	1793	1865	1933	1999	2063	2124	2183	2240	2296								
2200	1591	1676	1756	1833	1906	1977	2044	2110	2173	2233	2292	2350	2405							
2300	1623	1710	1793	1871	1947	2019	2088	2155	2220	2283	2343	2402	2459	2514						
2400	1655	1744	1828	1909	1986	2060	2131	2200	2266	2330	2393	2453	2511	2568	2624					
2500	1685	1776	1862	1945	2024	2100	2173	2243	2311	2377	2441	2502	2562	2621	2678	2733				
2600	1715	1808	1896	1980	2061	2139	2213	2285	2355	2422	2487	2551	2612	2672	2730	2787	2842			
2700	1744	1839	1929	2015	2097	2177	2253	2327	2398	2466	2533	2598	2661	2722	2782	2840	2896	2952		
2800	1772	1869	1961	2048	2133	2214	2292	2367	2439	2510	2578	2644	2708	2771	2832	2891	2949	3006	3061	
2900	1800	1898	1992	2081	2167	2250	2329	2406	2480	2552	2621	2689	2755	2819	2881	2941	3001	3058	3115	3170

Table based on $D_e = 1.30(ab)^{0.625}/(a + b)^{0.25}$.

[b] Length of adjacent side of rectangular duct , mm.

Table B1 Water Supply Fixture Units and Fixture Branch Sizes

Fixture[a]	*Use*	*Type of Supply Control*	*Fixture Units*[b]	*Min. Size of Fixture Branch*[d] *in.*
Bathroom group[c]	Private	Flushometer	8	—
Bathroom group[c]	Private	Flush tank for closet	6	—
Bathtub	Private	Faucet	2	1/2
Bathtub	General	Faucet	4	1/2
Clothes washer	Private	Faucet	2	1/2
Clothes washer	General	Faucet	4	1/2
Combination fixture	Private	Faucet	3	1/2
Dishwasher[f]	Private	Automatic	1	1/2
Drinking fountain	Offices, etc.	Faucet 3/8 in.	0.25	1/2
Kitchen sink	Private	Faucet	2	1/2
Kitchen sink	General	Faucet	4	1/2
Laundry trays (1–3)	Private	Faucet	3	1/2
Lavatory	Private	Faucet	1	3/8
Lavatory	General	Faucet	2	1/2
Separate shower	Private	Mixing valve	2	1/2
Service sink	General	Faucet	3	1/2
Shower head	Private	Mixing valve	2	1/2
Shower head	General	Mixing valve	4	1/2
Urinal	General	Flushometer	5	3/4[e]
Urinal	General	Flush tank	3	1/2
Water closet	Private	Flushometer	6	1
Water closet	Private	Flushometer/tank	3	1/2
Water closet	Private	Flush tank	3	1/2
Water closet	General	Flushometer	10	1
Water closet	General	Flushometer/tank	5	1/2
Water closet	General	Flush tank	5	1/2

Water supply outlets not listed above shall be computed at their maximum demand, but in no case less than the following values:

Table B19 Table for Estimating Demand

Supply Systems Predominantly for Flush Tanks		*Supply Systems Predominantly for Flushometers*	
*Load, WSFU**	*Demand, gpm*	*Load, WSFU**	*Demand, gpm*
6	5	—	—
10	8	10	27
15	11	15	31
20	14	20	35
25	17	25	38
30	20	30	41
40	25	40	47
50	29	50	51
60	33	60	55
80	39	80	62
100	44	100	68
120	49	120	74
140	53	140	78
160	57	160	83
180	61	180	87
200	65	200	91
225	70	225	95
250	75	250	100
300	85	300	110
400	105	400	125
500	125	500	140
750	170	750	175
1000	210	1000	218
1250	240	1250	240
1500	270	1500	270
1750	300	1750	300
2000	325	2000	325
2500	380	2500	380
3000	435	3000	435
4000	525	4000	525
5000	600	5000	600
6000	650	6000	650
7000	700	7000	700
8000	730	8000	730
9000	760	9000	760
10,000	790	10,000	790

Table B20 Minimum Pressure Required by Typical Plumbing Fixtures

Fixture Type	*Minimum Pressure, psi*
Sink and tub faucets	8
Shower	8
Water closet—tank flush	8
Flush valve—urinal	15
Flush valve—siphon jet bowl	
floor-mounted	15
wall-mounted	20
Flush valve—blowout bowl	
floor-mounted	20
wall-mounted	25
arden hose	
[illegible]-in. sill cock	15
[illegible]-in. sill cock	30
inking fountain	15

Source. *EPA Manual of Individual Water Supply System*, 75 and manufacturers' data.

Table B21 **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

[a]Computed from the Manning Formula for ½-full pipe, $n = 0.015$.

[b]Half full means filled to a depth equal to one-half the inside diameter.

Note: For ¼ full, multiply discharge by 0.274 and multiply velocity by 0.701. For ⅓ full, multiply discharge by 0.44 and multiply velocity by 0.80. For ¾ full, multiply discharge by 1.82 and multiply velocity by 1.13. For full, multiply discharge by 2.00 and multiply velocity by 1.00. For smoother pipe, multiply discharge and velocity by 0.015 and divide by n value of smoother pipe.

Table B21 Drainage Fixture Unit Values for Various Plumbing Fixtures

Type of Fixture or Group of Fixtures	*Drainage Fixture Unit Value, dfu*
Automatic clothes washer (2-in. standpipe and trap required, direct connection)	3
Bathtub group consisting of a water closet; lavatory and bathtub or shower stall:	6
Bathtub (with or without overhead shower)[a]	2
Bidet	1
Clinic sink	6
Clothes washer	2
Combination sink-and-tray with food waste grinder	4
Combination sink-and-tray with one 1-in. trap	2
Combination sink-and-tray with separate 1-in. trap	3
Dental unit or cuspidor	1
Dental lavatory	1
Drinking fountain	1/2
Dishwasher, domestic	2
Floor drains with 2-in. waste	3
Kitchen sink, domestic, with one 1-in. trap	2
Kitchen sink, domestic, with food waste grinder	2
Kitchen sink, domestic, with food waste grinder and dishwasher 1-in. trap	3
Kitchen sink, domestic, with dishwasher 1-in trap	3
Lavatory with 1-in. waste	1
Laundry tray (1 or 2 compartments)	2
Shower stall, domestic	2
Showers (group) per head	2
Sinks	
surgeon's	3
flushing rim (with valve)	6
service (trap standard)	3
service (P trap)	2
pot, scullery, etc.	4
Urinal, syphon jet blowout	6
Urinal, wall lip	4
Wash sink (circular or multiple) each set of faucets	2
Water closet, private	4
Water closet, general use	6
Fixtures not already listed	
trap size 1¼ in. or less	1
trap size 1½ in.	2
trap size 2 in.	3
trap size 2½ in.	4
trap size 3 in.	5
trap size 4 in.	6

[a] A shower head over a bathtub does not increase the fixture unit value.

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Table B22 Horizontal Fixture Branches and Stacks

Diameter of Pipe, in.	Any Horizontal Fixture Branch,[a] dfu	One Stack of Three Branch Intervals or Less, dfu	Stacks with More Than Three Branch Intervals: Total for Stack, dfu	Stacks with More Than Three Branch Intervals: Total at One Branch Interval, dfu
	Maximum Number of Fixture Units That May Be Connected to			
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			

[a]Does not include branches of the building drain.
[b]Not more than two water closets or bathroom groups within each branch interval nor more than six water closets or bathroom groups on the stack.

Note: Stacks shall be sized according to the total accumulated connected load at each story or branch interval and may be reduced in size as this load decreases to a minimum diameter of half of the largest size required.

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Table B23 Building Drains and Sewers[a]

Diameter of Pipe, in.	1/16 in.	1/8 in.	1/4 in.	1/2 in.
	Maximum Number of Fixture Units That May Be Connected to Any Portion of the Building Drain or the Building Sewer — Slope per Foot			
2			21	26
2½			24	31
3			42[b]	50[b]
4		180	216	250
5		390	480	575
6		700	840	1000
8	1400	1600	1920	2300
10	2500	2900	3500	4200
12	2900	4600	5600	6700
15	7000	8300	10,000	12,000

[a]On site sewers that serve more than one building may be sized according to the current standards and specifications of the Administrative Authority for public sewers.
[b]Not over two water closets or two bathroom groups, except that in single family dwellings, not over three water closets or three bathroom groups may be installed.

Source. Reprinted with permission from The National Standard Plumbing Code, published by The National Association of Plumbing Heating Cooling Contractors.

Figure (1)

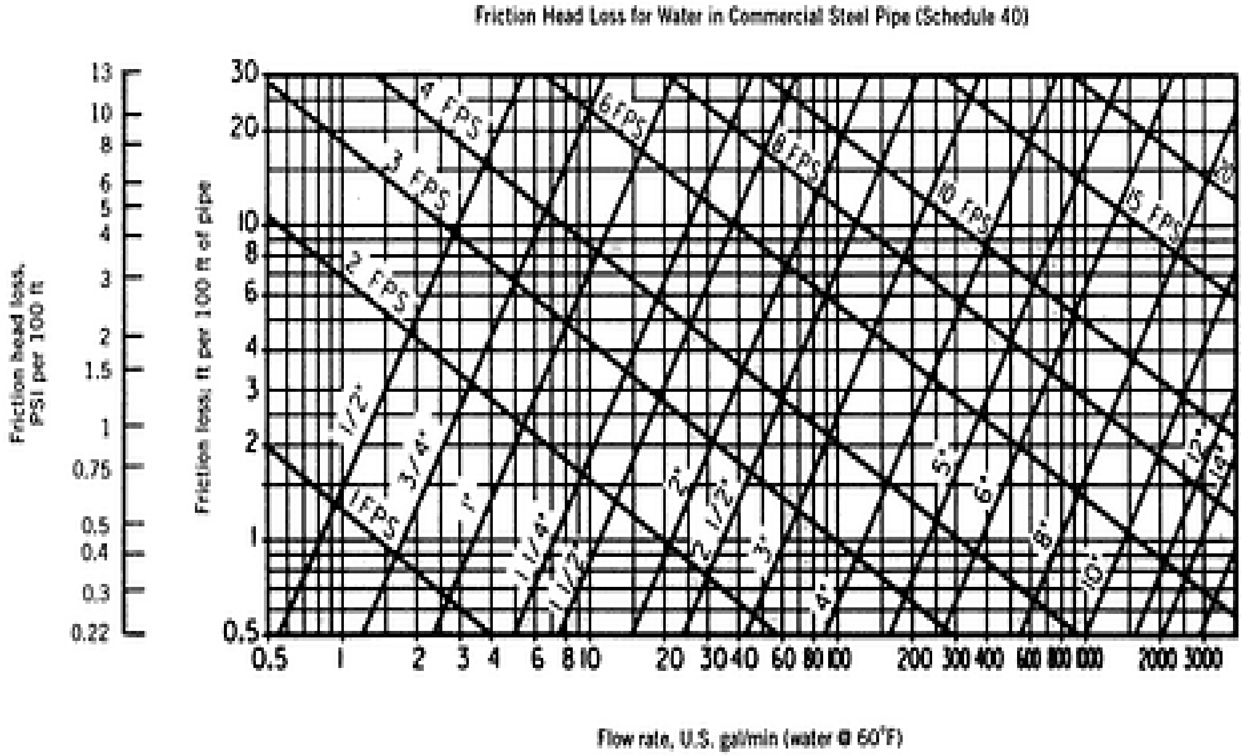

Figure 9.5 Chart of friction head loss in Schedule 40 black iron or steel pipe, for water at 60°F, in feet of water and psi per 100 ft of equivalent pipe length. Pipe sizes are nominal. (Reprinted by permission of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta,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

dp pumps

Technical specifications sheet

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[illegible]

Quotation details

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Search criteria

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dp pumps

Hydraulic performance sheet

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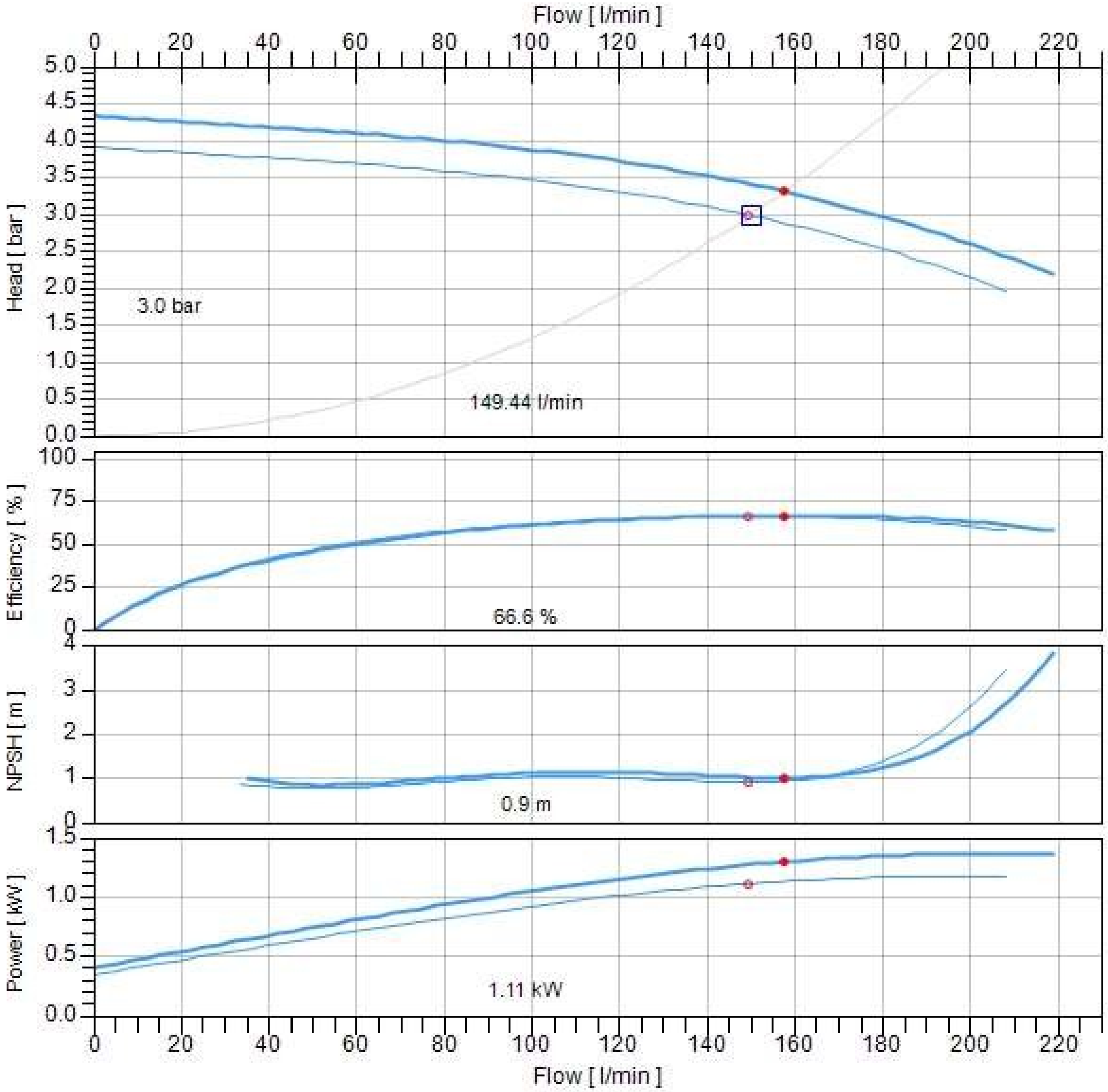

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dp pumps

Dimensions sheet

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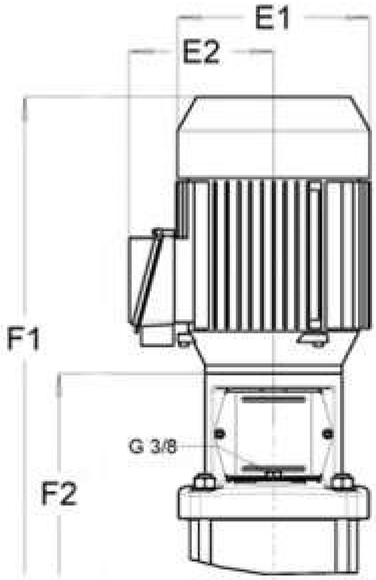

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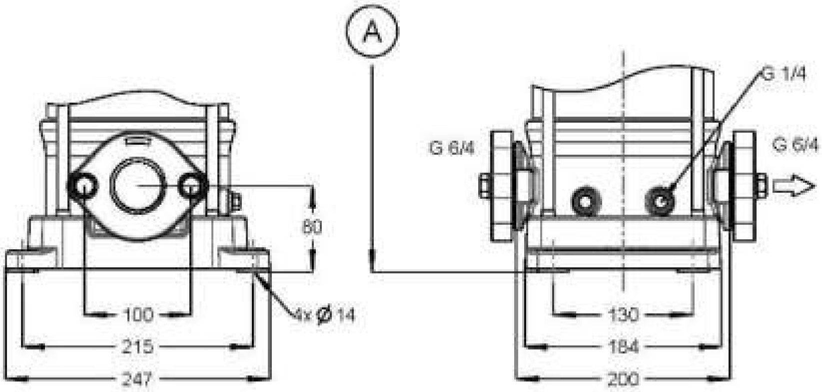

dp pumps

Motor specifications

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□□□□r□□□□ Motor DMC 1,5kW 230/400V 2P IE2 90S IP55 No Pos. 800

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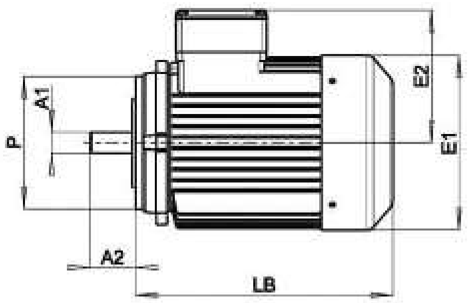
□□□ □□□□ □□□□	□□□ □□□□d

Dimensions

□□□ □□□r □□□□□□1	2□□□
□□□□□□ □□□□□□2	□0□□
□□□ □□□r □ □□□r □1	1□□□□
□□r□ □□□□□□□ □□□□□□□2	1□1□□
□□□ □□□r □□□□□ □	1□0□□
□□□ □□□r □□□□□□□□□□□□□B	2□1□□
□r□□ □ □□□	90□
M□□r □□□□r□□□□□ □□□	□M □1□
M□□r □□□	□□□ □003□□ □□r□ □□ 11□



Bearings / lubrication

□r□□□□ □□□□□	
B□□r□□ □□□□□□ □□□	□□□□d
□□□d □□□r□□ □□□□	□30□□2□□□3
B□□r□□ □r□□□	□□□□□□ □□□□d □20□□□1□0

Details

M□□r □□□□□	□M□
□ □□□□□	1□2□□
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M□□r □□□□□	□□□□002
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