Palestine Polytechnic University

College of Engineering

Design of Mechanical Systems for a Hotel building in Hebron city

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بسم الله الرحمن الرحيم

{يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ}

صدق الله العظيم

إهداء

أهدي هذا العمل المتواضع إلى أبي الذي لم يبخل علي يوماً بشيء

وإلى أمي التي زودتني بالحنان والمحبة والدعاء

أقول لهم: أنتم وهبتموني الحياة والأمل والنشأة على شغف الاطلاع والمعرفة

إلى إخوتي وأسرتي جميعًا

إلى كل من علمني حرفًا أصبح سنا برقه يضيء الطريق أمامي

الى أمهات الشهداء والجرحى والأسرى

الى وطني الغالي فلسطين

الى كل من احبنا واحببناه

Abstract

The aim of the project is to design a complete mechanical system for a Hotel building which is located in Hebron city. This building consists of seven floors with an approximate area of 9100 m^2. These services are certainly designed to verify human comfort.

In this project, air conditioning system type (VRF) is used since it is efficient and economical. Also, gray water is recycled to be used in flushing tanks and irrigation in order to save water.

CHAPTER TWO

HEATING LOAD CALCULATIONS

2.1 Introduction

2.2 Human comfort

2.3 Calculation of overall heat transfercoefficient (U)

2.4 Outdoors and indoors design conditions

2.1 Introduction

The main objective of the air conditioning is to maintain the environment in enclosed spaces at conditions that induce the feeling of comfort to all occupants of the space. This feeling of comfort is influenced by a number of air related parameters which are the inside temperature, the humidity and the outside design condition.

2.2 Human comfort

Factors Affecting Human Comfort:

1. Dry Air: air that has a low relative humidity.

2. Moist Air: air that is a mixture of dry air and any amount of water vapor generally, air with a high relative humidity.

3. Humidity: is the amount of water vapor in the air.

4. Saturation: the degree or extent to which something is dissolved or absorbed compared with the maximum possible, usually expressed as a percentage. the pressure that would be exerted by one of the gases in a mixture Partial Pressure.

5.if it occupied the same volume on its own.

6. Dry Bulb Temperature: temperature that is usually thought of as air temperature.

7. Wet Bulb Temperature: is the temperature a parcel of air would have if it were cooled to saturation (100% relative humidity) by the evaporation of water into it.

8. Dew-Point Temperature: the temperature at which water vapor starts to condense out of the air (the temperature at which air becomes completely saturated). Above this temperature the moisture will stay in the air.

9. Relative Humidity: The ratio of the amount of water vapor in the air at a specific temperature.

2.3 Calculation of The overall heat transfer coefficient (U):

The overall heat transfer coefficient depends on the layers that the walls and roof consist of and the inside and outside convection heat transfer coefficients. So the overall heat transfer coefficient can be calculated by applying the following equation:

$$U = \frac{1}{\Sigma Rth} = \frac{1}{Rin + \Sigma\frac{\Delta x}{K} + Rout} \qquad (2.1)$$

Where:

Δx: the thickness of the wall.

R_{in}: inside film resistance.

R_{out}: Outside film resistance.

Calculation of overall heat transfer coefficient for walls,ceiling,floor, glass and door :

1- For external wall

Table 2.1:Construction of external walls

	Material	ΔX(m)	k(W/m.°C)	R(m^2. °C/W)
1	limestone	0.05	2.2	0.022
2	Concrete	0.15	1.75	0.085
3	polyurethane	0.03	0.04	0.750
4	Cement brick	0.07	0.9	0.07
5	Plaster	0.03	1.4	0.02

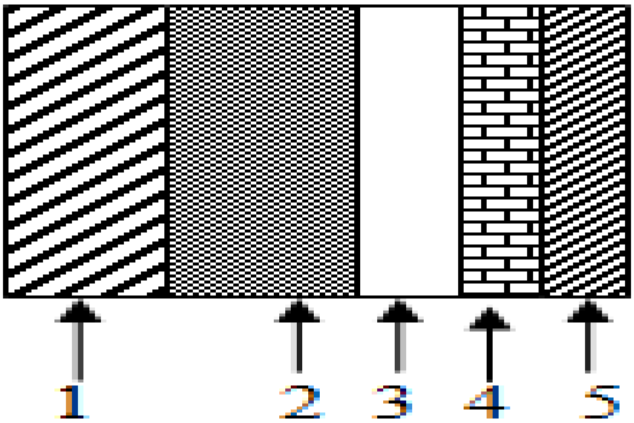


Figure 2.1: external wall construction

$R_{in}$and R_{out} for the external walls as 0.13 and 0.04$(m^2/W.°C)$, respectively from Table(A-27)

$$U_{out} = \frac{1}{Rin + \frac{\Delta x_{st.}}{k_{st.}} + \frac{\Delta x_{con.}}{k_{con.}} + \frac{\Delta x_{poly.}}{k_{poly.}} + \frac{\Delta x_{Brick}}{k_{Brick}} + \frac{\Delta x_{plaster}}{k_{plaster}} + Rout}$$

$$= \frac{1}{0.13 + \frac{0.05}{2.2} + \frac{0.15}{1.75} + \frac{0.03}{0.04} + \frac{0.07}{0.9} + \frac{0.02}{1.4} + 0.04}$$

$=0.83(W/m^2.°C)$.

2- For internal wall

Table 2.2:Construction of internal walls

	Material	ΔX(m)	k(W/m.°C)	R(m^2. °**C**/W)
1	Plaster	0.02	1.4	0.014
2	Brick	0.1	1	0.1
3	Plaster	0.02	1.4	0.014

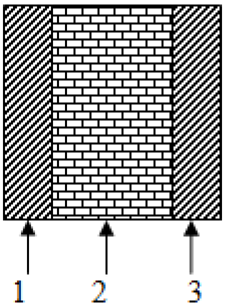


Figure 2.2: internal wall construction

$$\text{Uin} = \frac{1}{\text{Rin} + \frac{\Delta x_{\text{Brick}}}{k_{\text{Brick}}} + 2 * (\frac{\Delta x_{\text{plaster}}}{k_{\text{plaster}}}) + \text{Rin}}$$

$$= \frac{1}{0.13 + \frac{0.1}{1} + 2 * (\frac{0.02}{1.4}) + 0.13}$$

$=2.57(W/m^2.°C)$.

3- For celling

Table 2.3:Construction of celling

Material	ΔX(m)	k(W/m.°C)	$R(m^2.°C/W)$
Asphalt	0.02	0.81	0.024
Concrete	0.05	1.75	0.028
Polystyrene	0.03	0.04	0.750
Reinforced concrete	0.05	1.75	0.028
Hollow Brick	0.2	0.95	0.21
Plaster	0.02	1.2	0.016

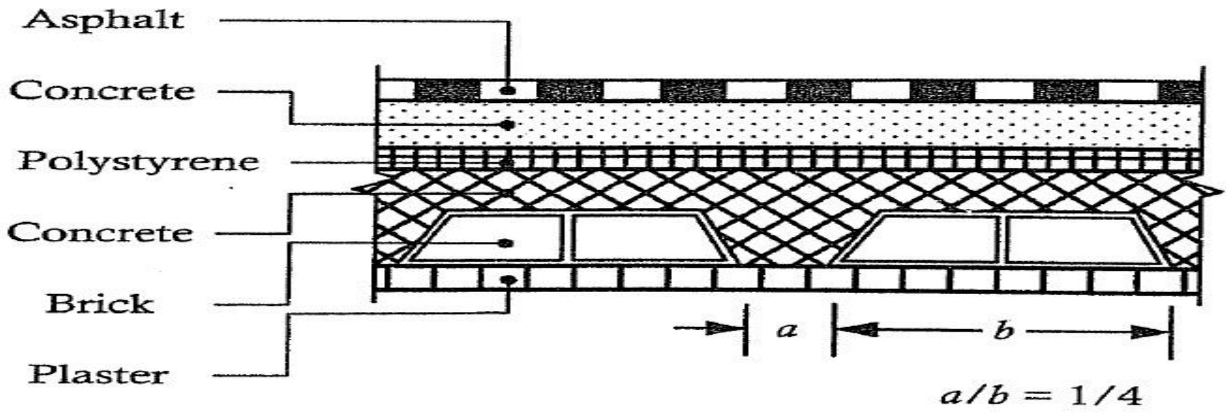


Figure 2.3: Ceiling construction

For ceiling:

Because of its construction, the ceiling is divided into two overall heat transfer coefficient one with brick and the other without.

R_{in} and R_{out} for the ceiling are 0.1 and 0.04(m^2/W. °C), respectively from Table (A-27)

$$U_1 = \frac{1}{\text{Rin}+\frac{\Delta x_{asph.}}{k_{asph.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{poly.}}{k_{poly.}}+\frac{\Delta x_{conc.}}{k_{conc.}}+\frac{\Delta x_{Brick}}{k_{Brick}}+\frac{\Delta x_{Plaster}}{k_{Plaster}}+\text{Rout}}$$

$$=\frac{1}{0.1+\frac{0.02}{0.810}+\frac{0.05}{1.75}+\frac{0.03}{0.04}+\frac{0..05}{1.75}+\frac{0.2}{0.95}+\frac{0.02}{1.2}+0.04}$$

$= 0.836$ (W/m^2. °C).

Similarly, $U_2 = 1.014$(W/m^2. °C)

4- For floor

Table 2.4:Construction of floor

Material	ΔX(m)	k(W/m.°C)	R(m^2. °**C**/W)
Reinforced concrete	0.15	1.75	0.085
Ceramic Tiles	0.02	1.2	0.016
Aggregates	0.1	1.05	0.095
Morter	0.02	0.16	0.125
Sand layer	0.1	0.7	0.142

R_{in} = 0.15(m^2/W. °C), from Tables (A-27)

$$U1 = \frac{1}{\text{Rin} + \frac{\Delta x_{ceramic}}{k_{ceramic}} + \frac{\Delta x_{mortar}}{k_{mortar}} + \frac{\Delta x_{aggregates}}{k_{aggregates}} + \frac{\Delta x_{con.}}{k_{con.}} + \frac{\Delta x_{sand.}}{k_{sand}}}$$

$$= \frac{1}{0.15 + \frac{0.02}{1.2} + \frac{0.02}{0.16} + \frac{0.10}{1.05} + \frac{0.15}{1.75} + \frac{0.1}{0.7}}$$

$$= 1.62\ (\text{W}/m^2.\,°\text{C}).$$

5- For glass

From table (A-28) , $Ug = 3.2(\text{W}/m^2.\,°\text{C})$ for double glass aluminum frame.

6- For door

From Table (A-29) , $Ud = 3.6(\text{W}/m^2.\,°\text{C})$ for wood door type.

2.4 Outdoors and indoor design conditions:

These conditions include the dry bulb temperature, relative humidity, and the average air speed. These values were obtained from the Palestinian code and the psychometric chart.

Table 2.5: Outdoors design condition

Property	Inside design condition		outside design condition	
	summer	winter	summer	winter
Temperature (˚C)	24	24	30	4.7
Relative humidity (%)	45	30	57	72
Wind speed (m/s)	….	….	1.4	1.4

2.4.1 Heat loss calculations:

The main resources of heat loss come from the walls, floor, ceiling, doors, windows and also comes from the infiltration. To calculate each one of them the following equations are to be use:

$$\dot{Q} = A \times U \times (T_i - T_o) \quad (2.2)$$

Where:

$\dot{Q}$: Is the heat transfer rate.[kW]

A: Is the area of the layer which heat flow through it.[m^2]

ΔT: Is the difference between the inside and outside temperatures [C]

U: Is the overall heat transfer coefficient. [W/m.C]

2.4.2 Total heating load calculations:

Total heating load calculations for the sample room:

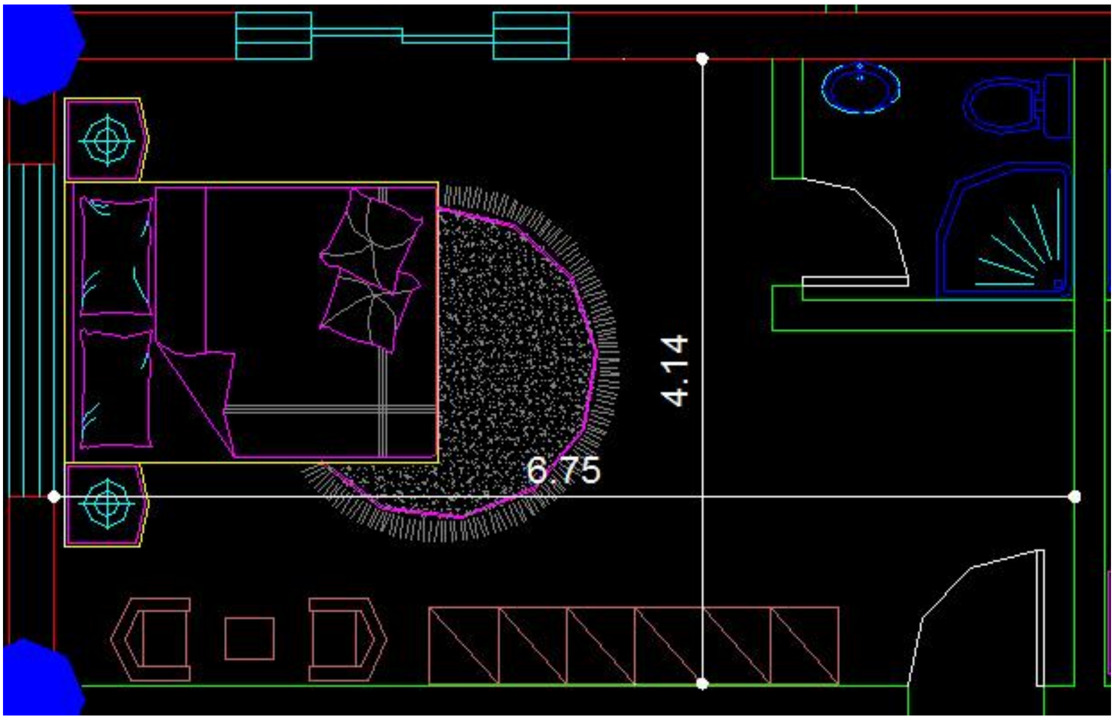


Figure 2.4: sample room

Heat loss through ceiling ($\dot{Q}_c$):

Because of its construction, the ceiling is divided into two areas which are area A_1 and area A_2 as showing in Figure (2.5).

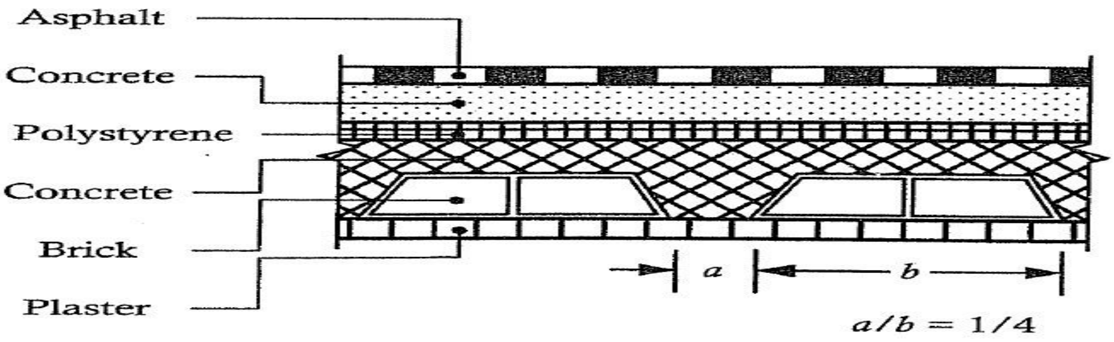


Figure 2.5: ceiling construction

The area A_1 is equal to:

$A_1 = \frac{4}{5} A_c$

$= \frac{4}{5}(4.15*6.75)$

$= 22.41\ m^2$

And the area A_2 is equal to:

$A_2 = \frac{1}{5} A_c$

$= \frac{1}{5}(4.15*6.75)$

$= 5.6\ m^2$

$\dot{Q}_c = U_c A_c (T_i - T_o)$

$= (U_1 A_1 + U_2 A_2)(T_i - T_o)$

$\dot{Q}_c = (0.836 \times 22.41 + 1.014 \times 5.6)(24 - 4.7)$

$\dot{Q}_c = 128.32$

Heat loss through walls ($\dot{Q}_w$):

The external wall area is

$A_{w,ex}1 = (4.15*2.75)-(2.2*1.6)$

$=7.89\ m^2$

The heat loss from external wall is

$\dot{Q}_{w,ex} = (U_{w,ex}\ A_{w,ex})(T_i - T_o)$

$= (0.83*7.89)\ (24-4.7)$

$= 126.4\ W$

$A_{w,ex}2 = (6.75*2.75)-(3.2)$

$=15.3\ m^2$

$\dot{Q}_{w,ex} = (U_{w,ex}\ A_{w,ex})(T_i - T_o)$

$= (0.83*15.3)\ (24-4.7)$

$= 246 W$

There are one spacebeside the sample room are unconditioned, so heat loss from unconditioned walls:

The unconditioned temperature is calculate by equation (2.3):

$T_{un.} = 0.5\ (T_i - T_o)(2.3)$

$= 0.5\ (24 - 4.7)$

$= 9.65°C$

The unconditioned area is

$A_{w,un.} = (17.1\times2.75)-3(0.9\times2)-2(1.8)$

$=8.1\ m^2$

$\dot{Q}_{w,un.} = (\ U_{un.}\ A_{w,un.})(Ti - T_{un.})$

$= (2.57 \times 8.1)(24-9.65)$

$= 298.7$ W

Now, the total heat loss from walls is

$\dot{Q}_{w,tot} = \dot{Q}_{w,ex} + \dot{Q}_{w,un.}$

$= 372.4 + 298.7$

$= 671.1$ W

Heat loss through windows ($\dot{Q}_g$):

$\dot{Q}_g = U_g A_g (T_i - T_o)$

$= (3.2)(2*0.8+3.52)(24-4.7)$

$= 316.2$W

Heat loss through external door ($\dot{Q}_d$):

$\dot{Q}_d1 = U_d A_d (T_i - T_{o.})$

$= (3.6)(2 \times 0.9)(24-9.65) = 93$ W

$\dot{Q}_d2 = U_d A_d (T_i - T_{o.})$

$= (3.6)(2*0.7+(1.2*2))(24-4.7)$

$=264$ W

Heat loss through infiltration ($\dot{Q}_{inf}$):

Infiltration is the leakage of outside air through cracks and clearances around the windows and doors. The amount of infiltration depends mainly on the tightness of the windows and doors on the outside wind velocity or the pressure difference between the outside and inside of the room.

The total heat load due to infiltration is given by the equation (2.4)

$$\dot{Q}_{inf.,g} = \frac{1250}{3600} \dot{V}f \ (T_i - T_o) \qquad (2.4)$$

Where:

T_{in}: inside design temperature (°C).

T_{out}: outside design temperature(°C)

$\dot{V}f$: The volumetric flow rate of infiltrated air in (m^3/h)

$$\dot{V}f = K \times L \ [0.613 \ (S_1 \times S_2 \times V_O)^2 \ ]^{2/3} (2.5)$$

Where:

K: the infiltration air coefficient.

L: the crack length in meter.

S_1: Factor that depends on the topography of the location of the building

S_2: Coefficient that depends on the height of the building.

V_O: measured wind speed (m/s)

The value of K, S_1 and S_2 is obtained from Tables (A-13), (A-19) and (A-20) respectively.

K =0.43

S_1 =1

S_2 =0.94

V_o= 1.4 (m/s)   from Palestinian code.

Calculate the length for the sliding windows and the doors :

L = [(2.2× 2) + (1.6*3)+2((0.5*2)+(0.8*2))+(1.2*2+6)+(0.9*2)+(2*2)]

= 28.6 m

Therefore;

$\dot{V}f$ = (0.43) (28.6) [0.613(1 × 0.94 × 1.4)^2] $^{2/3}$

= 12.7 m^3/h

The total heat loss due to infiltration is calculated by equation as follows:

Through window:

$\dot{Q}_{inf.,g} = \frac{1250}{3600}\dot{V}f\ (T_i - T_o)$

$= \frac{1250}{3600}$ (12.7) (24 – 4.7)

= 26.65W

Heat gain due to ventilation

The ventilation is used for maintaining a healthy indoor air by introducing a fresh air from outside of the building. And this kind of heat gain can be calculated by using the following equations:

$Q_{vent.}$=ṁ × $C_{p_{air}}$ × (T_o-T_{in})(2.6)

Where:

ṁ : mass flow rate of ventilation air (kg/s).

$$\dot{m} = \frac{Rate\ of\ ventilation\ air}{v_o} \quad (2.7)$$

Rate of ventilation = Room Area × Requirement outside ventilation air (2.8)

= 4.15×6.75×10 = 245 L/s = 0.280m^3/s.

v_o= 0.791 m^3/kg.

ṁ = 0.309kg/s.

$C_{p_{air}}$: Specific heat of air, $C_{p_{air}}$= 1.005 kJ/kg.°C.

$Q_{vent.}$ = 0.35×1.005 × (24- 4.7) = 6.7 W.

The total heat loss from the sample room is

$\dot{Q}_{tot} = \dot{Q}_{w,tot} + \dot{Q}_c + \dot{Q}_g + \dot{Q}_d + \dot{Q}_{inf.,tot} + \dot{Q}_{vn}$

= 671.1 + 128.32 + 316.2 + 357 + 26.65 + 6.7

= 1405.6W

Take a safety factor of 15 % for each space of the residence to cover the miscellaneous and emergency heating loads then :

$\dot{Q}_{tot}$ = 1405.6× 1.15= 1.62 kW.

Heating Load Summary is listed in the following Table:

Table 2.6: Heating load for each floor in the building

Floor	Q(kW)
Ground	82.3
First	31.6
Second	76
Third	76
Fourth	37.5

CHAPTER THREE

COOLING LOADCALCULATION

3.1 Introduction

3.2 Cooling load

3.3 Sample calculations

3.4 Variable Refrigerant Flow System

3.1 Introduction

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

To achieve the human comfort conditions it is needed to do some calculation to select the proper equipment to have the conditions that it is needed and the cooling load is the most important load that can helps in selecting the equipment's that needed correctly.

3.2 Cooling load calculations:

Total cooling load calculations for the sample room:

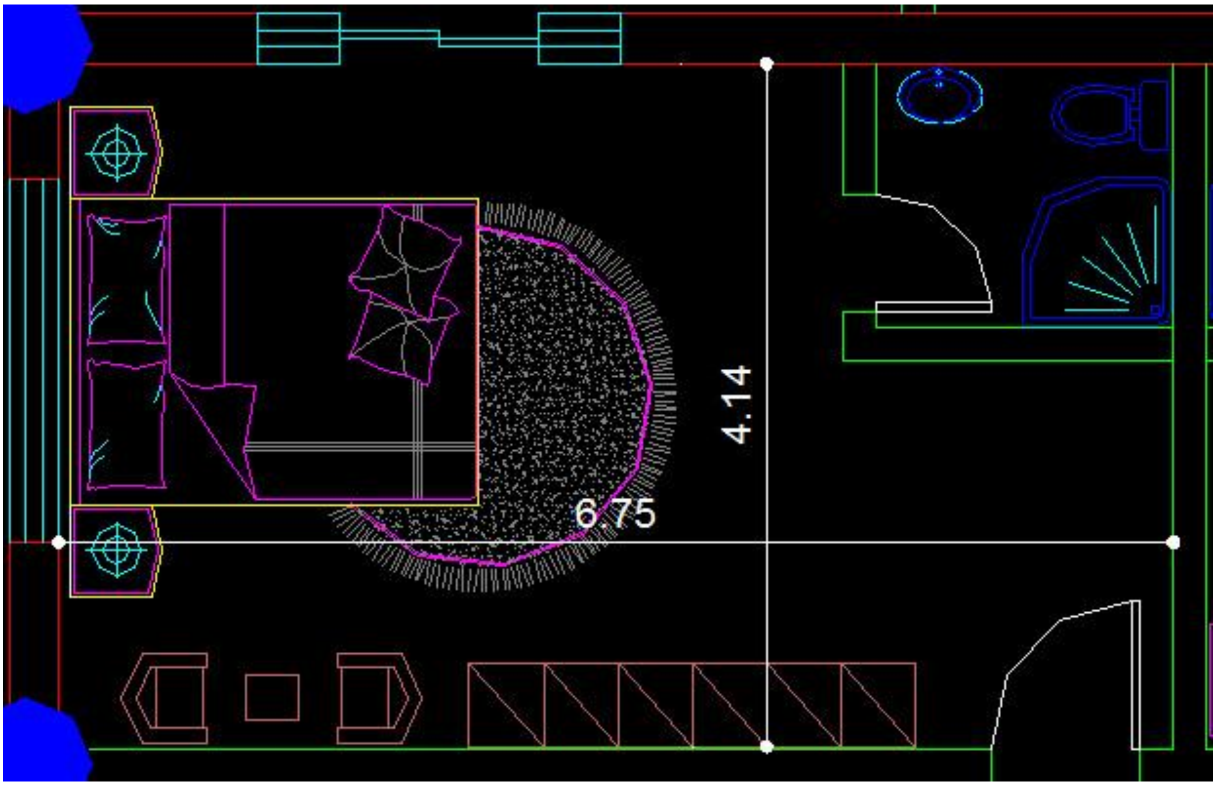


Figure 3.1: Sample room

Direct and diffused solar radiation that absorbed by walls and roofs result in raising the temperature of these surfaces. Amount of radiation absorbed by walls and roofs depends upon time of the day, building orientation, types of wall construction and presence of shading.

The heat transfer rate through sunlit walls or sunlit roofs are calculated from the following equation:

$$Q = UA\,(CLTD)_{corr.} \qquad (3.1)$$

Where:

$(CLTD)_{corr.}$: corrected cooling load temperature difference, ˚C

$$(CLTD)_{corr.} = (CLTD + LM)\,k + (25.5 - T_{in}) + (T_{o,m} - 29.4)\,f \qquad (3.2)$$

Where:

CLTD: cooling load temperature difference, ˚C

LM: latitude correction factor.

k: color adjustment factor.

T_{in}: inside comfort design temperature, ˚C

f: attic or roof fan factor.

$T_{o,m}$: outdoor mean temperature, ˚C

$$T_{o,m} = (T_{max} + T_{min})/2 \qquad (3.3)$$

Where:

T_{max}: maximum average daily temperature, ˚C

T_{min}: minimum average daily temperature, ˚C

T_{max} = 36.1˚C and T_{min} =13.7˚C are obtained from Palestinian Code.

Applying these values in equation (3.3) to obtain the outdoor mean temperature

$T_{o,m}$ = 24.9 ˚C.

3.3 Sample Calculation:

Calculation the heat gain from the Guest room in the last floor as a sample :

Heat gain through sunlit roof (Q_{Roof}):

CLTD = 14 ˚C

LM = 0.5

k = 0.83 for permanently light colored roofs.

f = 1 there is no attic or roof fan.

$(CLTD)_{corr.} = (14 + 0.5)\ 0.83 + (25.5 - 24) + (24.9 - 29.4)\ 1$

$= 9˚C$

$$\dot{Q}_{Roof} = (U_1 A_1 + U_2 A_2)\ (CLTD)_{corr} \qquad (3.4)$$

$\dot{Q}_{Roof} = ((0.836\times22.41) +(.014\times5.6)(\ 9)$

$= 219.6\ W$

Heat gain through sunlit walls (Q_{Wall}):

CLTD at 14:00 o'clock … from Table (A-8)

CLTD =15 c

LM =0

N = 0.0

k = 0.83 for permanent medium color walls.

$A_{E1} = 7.88\ m^2$

$(CLTD)_{corr., E} = (15+0)\ 0.83+ (25.5-24) + (24.9-29.4)\times1$

$= 9.45\ ˚C$

$\dot{Q}_{Wall1} = \dot{Q}_E = .83\times 11.4 \times 9.45$

$= 61.8\ W$

$A_{E2} = 15.36\ m^2$

$(CLTD)_{corr., E} = (15+0)\ 0.83 + (25.5-24) + (24.9-29.4)\times 1$

$= 9.45\ ^\circ C$

$Q^\cdot_{Wall2} = Q^\cdot_E = .83\times 15.36 \times 9.45$

$Q^\cdot_{Wall\ total} = Q^\cdot_{Wall1} + Q^\cdot_{Wall2} = 61.8\ W + 120.4\ W = 182.2\ W$

Heat gain due to glass (Q_{Glass}):

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

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

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

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

The amount of solar radiation depends upon the following factors:

1) Type of glass (single, double or insulation glass) and availability of inside shading.
2) Hour of the day, day of the month, and month of the year.
3) Orientation of glass area. (North, northeast, east orientation, etc).
4) Solar radiation intensity and solar incident angle.
5) Latitude angle of the location.

The maximum cooling load due to the glass window $Q_{Glass,}$ consists of transmitted ($Q_{tr.}$) and convected ($Q_{conv.}$) cooling loads as follows:

$$Q_{Glass} = Q_{tr.} + Q_{conv.} \qquad (3.5)$$

Where:

$Q_{tr.}$: transmission heat gain, W

$Q_{conv.}$: convection heat gain, W

SHC : Solar heat gain factor : this factor represents the amount of solar energy that would be received by floor, furniture and the inside walls of the room and can be extracted from Table (A-12).

SC : Shading coefficient : this factor accounts for different shading effects of the glass wall or window and can be extracted from Table (A-10)for single and double glass without interior shading or from Table (A-11)for single and double glass as well as for insulating glass with internal shading.

CLF : Cooling load factor : this represent the effects of the internal walls, floor, and furniture on the instantaneous cooling load, and can be extracted from Table(A-8), and (A-9)for glass, and from Table (A-5) and (A-6),for lights and occupants respectively.

The transmitted cooling load is calculated as follows:

$$Q_{tr.} = A\,(SHG)\,(SC)\,(CLF) \qquad (3.6)$$

SHG in W/m^2 … from Table (A-12)

$A = 6.72\ m^2$

$SHG = 691\ W/m^2$

SC = 0.57… reflective double from Table(A-14)

CLF = 0.31 at 14:00 o'clock … from Table (A-16)

$Q_{tr.\,N} = 6.72 \times 691 \times 0.57 \times 0.31$

$= 820.5$ W

$$Q_{conv.} = UA\,(CLTD)_{corr.} \qquad (3.7)$$

Where:

U: Over all heat transfer coefficient of glass ($W/m^2.K$).

A: Out windows Area of heat conduction. (m^2).

$(CLTD)_{corr.}$: is calculated as the same of walls and roofs and the CLTD value for glass is obtained from Table (A-7)

CLTD = 7 ˚C at 14:00 o'clock

k = 1 for glass

f = 1 for glass

$Q_{conv.\ N}$ = 151.2 W

Q_{Glass} = 151.2 + 820.5

= 971.7 W

Heat gain due to lights ($\dot{Q}_{Lt.}$):

Heat gains due to lights are sensible loads and is calculated by the following equation:

$$\dot{Q}_{Lt.} = \text{light intensity} \times A \times (CLF)_{Lt.} \quad (3.8)$$

Where:

light intensity = 10-30 W/m^2 for apartment, so we will take $30W/m^2$

A: floor area = 18.56 m^2

$(CLF)_{Lt.}$: cooling load factor for lights.

$(CLF)_{Lt.}$ = 0.82 … from Table (A-5)

$Q_{Lt.}$ = 30 ×18.56× 0.82

= 456.57 W

Heat gain due to infiltration (Q_f):

As the same way in heating load

$\dot{Q}_{inf.,g} = \frac{1250}{3600} \dot{V}f$ (T_i - T_o)

(3.9)

Where:

$\dot{V}f$: The volumetric flow rate of infiltrated air in (m^3/s)

$\dot{V}f$ = K × L [0.613 (S_1× S_2× V_o)^2]$^{2/3}$(3.10)

Where :

K = the infiltration air coefficient.

L: the crack length in meter.

S_1: factor that depends on the topography of the location of the building

S_2: coefficient that depends on the height of the building.

V_o: measured wind speed (m/s)

The value of K, S_1 and S_2 is obtained from Tables (A-12), (A-19) and (A-20) respectively.

K =0.43

S_1 =1

S_2 =0.94

V_o= 1.4 (m/s) from Palestinian code

Through door and glass:

L_{total} = 28.6 m

Therefore ;

$\dot{V}f$ = (0.43) (28.6) [0.613(1 × 0.94 × 1.4)^2] $^{2/3}$

= 12.7 m^3/h

$\dot{Q}_{inf.,g.d} = \frac{1250}{3600} \dot{V}f \; (T_i - T_o)$

$= \frac{1250}{3600}$ (12.7)(30–24)

= 26.65 W

Heat gain due to occupants ($Q_{oc.}$):

Sensible and latent heat gains from occupants must be removed from the conditioned space. The heat gain due to occupants is the following:

$Q_{oc.} = Q_{sensible} + Q_{latent}$ (3.11)

$Q_{sensible}$ = heat gain sensible × No. of people × $(CLF)_{oc.}$ (3.12)

Where:$(CLF)_{oc.}$: cooling load factor due to occupants.

heat gain sensible = 70 very light work … from Table (A-18)

No. of people = 2

$(CLF)_{oc.}$ = 0.84 at 9 hours after each entry into space is obtained from Table (A-21)

$Q_{sensible}$ = 70 ×2× 0.84

= 117.6 W

Q_{latent} = heat gain latent × No. of people (3.13)

heat gain latent = 44… very light work from Table (A-21)

$Q_{latent} = 44 \times 2$

$= 88W$

$Q_{oc.} = 117.6 + 88$

$= 205.6$ W

Heat gain due to ventilation ($Q_{vn.}$):

Mechanical ventilation is required for places in which the inside air is polluted due to activities that place in these spaces as factories, restaurants, closed parking areas, etc. The amount of outside fresh air recommended for mechanical ventilation for different applications. The sensible and total cooling loads required to cool the ventilated air to the inside room temperature is calculating by the following equation:

$$\dot{Q}_{vn.} = \dot{m} \times Cp_{air} \times (T_{out} - T_{in}) \quad (3.14)$$

Where:

$\dot{m}$: mass flow rate of ventilation air, kg/s

Cp_{air}: specific heat of air = 1.005 kJ/kg .k

$$\dot{m} = \frac{\text{rate of ventilation air}}{\text{vo}} \quad (3.15)$$

rate of ventilation air = $A_{room} \times$ requirement outside ventilation air(3.16)

$A_{room} = 28\ m^2$

requirement outside ventilation air = 10 $L/s/m^2$ … from Table A(A-26)

rate of ventilation air = 28×10

= 280 L/s

= 0.28 m^3/s

$v_o = 0.879 m^3/kg$

$\dot{m}$ = 0.28/0.879

= 0.318 kg/s

$Q_{vn.}$ = 0.318× 1.005 × (30 - 24)

= 1.92 W

The total heat loss from Sample Room is:

$$Q_{Tot} = Q_{Roof} + Q_{Wall} + Q_{Glass} + Q_{Lt} + Q_f + Q_{oc.} + Q_{vn.} \quad (3.17)$$

=2.089 KW

Take a safety factor of 15 % for each space of the residence to cover the miscellaneous and emergency cooling loads then :

Q_{Tot} = 2.089*1.15

= 2.41 KW

Cooling Load Summary is listed in the following table:

Table 3.1: Cooling load for each floor in the building

Floor	Q(kW)
Ground	117.1
First	64.7
Second	112.64
Third	112.64
Fourth	71.45

3.4 Variable Refrigerant Flow System

Overview

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-conditioning system configuration where there is one 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 indifferent zones.

Currently widely applied in large buildings especially in Japan and Europe, these systems are just starting to be introduced in the U.S. The VRF technology/system was developed and designed by Daikin Industries, Japan who named and protected the term variable refrigerant volume (VRV) system so other manufacturers use the term VRF "variable refrigerant flow". In essence both are same.

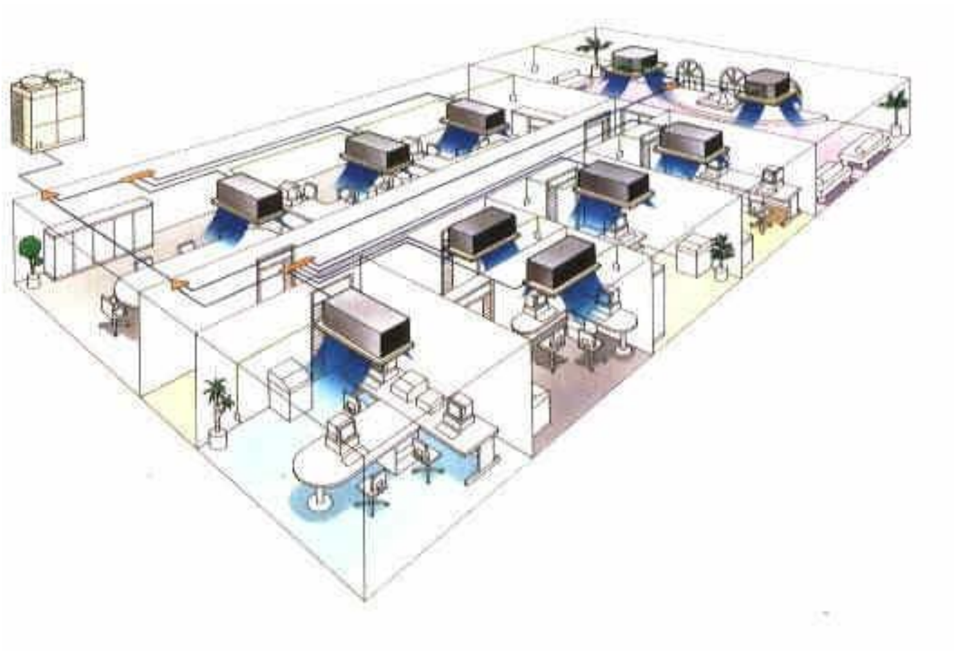


Figure 3.2: Sample for VRF system

Refrigerant modulation in a VRF system

VRV/VRF technology is based on the simple vapour compression cycle (same as conventional split air conditioning systems) but gives you the ability to continuously control and adjust the flow of refrigerant to different internal units, depending on the heating and cooling needs of each area of the building. The refrigerant flow to each evaporator is adjusted precisely through a pulse wave electronic expansion valve in conjunction with an inverter and multiple compressors of varying capacity, in response to changes in the cooling or heating requirement within the air conditioned space.

VRF systems are engineered systems and use complex refrigerant and oil control circuitry. The refrigerant pipe-work uses a number of separation tubes and/or headers.

A separation tube has 2 branches whereas a header has more than 2 branches. Either of the separation tube or header, or both, can be used for branches. However, the separation tube is never provided after the header because of balancing issues.

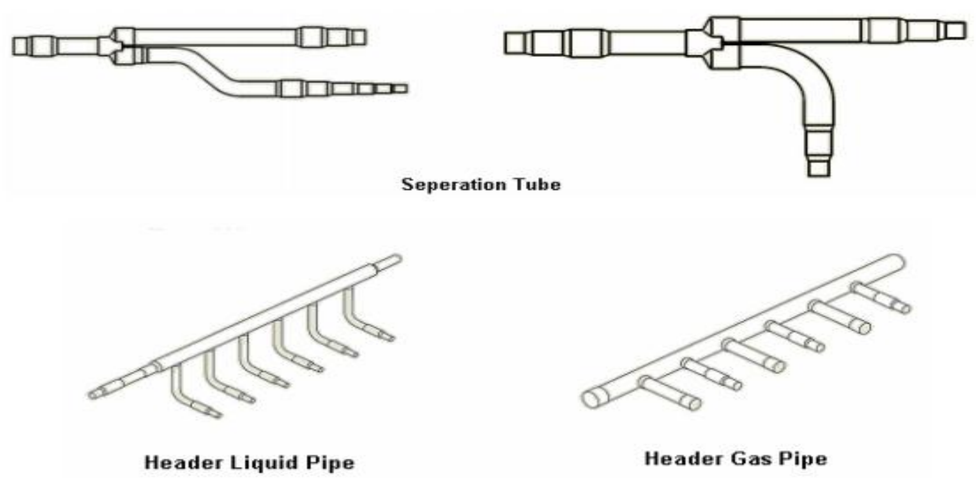


Figure 3.3: Separation and header tubes

Building Load Profile

When selecting a VRF system for a new or retrofit application, the following assessment tasks should be carried out:

- Determine the functional and operational requirements by assessing the cooling load and load profiles including location, hours of operation, number/type of occupants, equipment being used, etc.
- Determine the required system configuration in terms of the number of indoor units and the outdoor condensing unit capacity by taking into account the total capacity and operational requirements, reliability and maintenance considerations

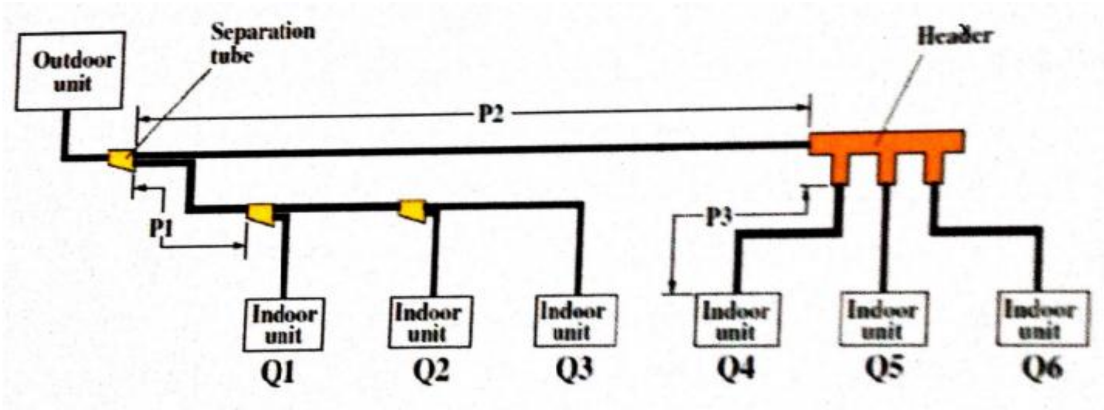


Figure 3.4: Indoor and outdoor capacity

- Size of P1: Depends on the total capacity of (Q1+Q2+Q3)
- Size of P2: Depends on the total capacity of (Q4+Q5+Q6)
- Size of P3: Depends on the total capacity of (Q4)

VRF systems have several key benefits, including:

1. Installation Advantages.
   VRF systems are lightweight and modular. Each module can be transported easily and fits into a standard elevator.
2. Design Flexibility.
   A single condensing unit can be connected to many indoor units of varying capacity (e.g., 0.5 to 4 tons [1.75 to 14 kW]) and configurations (e.g., ceiling recessed, wall mounted, floor console). Current products enable up to 20 indoor units to be supplied by a single condensing unit. Modularity also makes it easy to adapt the HVAC system to expansion or reconfiguration of the space, which may require additional capacity or different terminal units.
3. Maintenance and Commissioning**.**
   VRF systems with their standardized configurations and sophisticated electronic controls are aiming toward near plug-and-play commissioning.
4. Comfort.
   Many zones are possible, each with individual set point control. Because VRF systems use variable speed compressors with wide capacity modulation capabilities, they can maintain precise temperature control, generally within ±1°F (±0.6°C), according to manufacturers' literature.
5. Energy Efficiency.
   The energy efficiency of VRF systems derives from several factors. The VRF essentially eliminates duct losses, which are often estimated to be between (10-20) % of total airflow in a ducted system.VRF systems typically include two to three compressors, one of which is variable speed, in each condensing unit, enabling wide capacity modulation. This approach yields high part-load efficiency, which translates into high seasonal energy efficiency, because

HVAC systems typically spend most of their operating hours in the range of 40% to 80% of maximum capacity.

6. Refrigerant piping runs of more than 200 feet (60.96 m) are possible and outdoor units are available in sizes up to 240,000 Btu/ h (60478.98 kW).

3.1.4 Selection units

This section talks about selection of outdoor and indoor units of VRF system, depending on the “Samsung VRFcatalogue”, since this company product exists in Hebron.

Outdoor and indoor units are selected according to the thermal load of the building.

Outdoor unit

Table 3.2: Outdoor Unit Details for Ground Floor

Unit	Cooling Load (HP)	Cooling load (kW)	Outdoor Unit Name	Dimension
Unit g-1	22	317.3	-	(880x1703x765)x2
Unit g-2	22		-	(880x1703x765)x2
Unit g-2	22		-	(880x1703x765)x2
Unit g-2	22		-	(880x1703x765)x2

Table 3.3: Outdoor Unit Details for First Floor

Unit	Cooling Load (HP)	Cooling load (kW)	Outdoor Unit Name	Dimension
Unit f-1	16	134	RD160HHXGA	1295 x 1695 x 765
Unit f-2	18		RD180HHXGA	(880x1703x765)x2

Table 3.4: Outdoor Unit Details for Second Floor

Unit	Cooling Load (HP)	Cooling load (kW)	Outdoor Unit Name	Dimension
Unit s-1	10	140.4	RD100HHXGA	(880x1703x765)
Unit s-2	10		RD100HHXGA	(880x1703x765)
Unit s-3	10		RD100HHXGA	(880x1703x765)
Unit s-4	10		RD100HHXGA	(880x1703x765)

Table 3.5: Outdoor Unit Details for Third Floor

Unit	Cooling Load (HP)	Cooling load (kW)	Outdoor Unit Name	Dimension
Unit s-1	10	140.4	RD100HHXGA	(880x1703x765)
Unit s-2	10		RD100HHXGA	(880x1703x765)
Unit s-3	10		RD100HHXGA	(880x1703x765)
Unit s-4	10		RD100HHXGA	(880x1703x765)

Table 3.6: Outdoor Unit Details for Forth Floor

Unit	Cooling Load (HP)	Cooling load (kW)	Outdoor Unit Name	Dimension
Unit f-1	10	87.6	RD100HHXGA	880x1703x765
Unit f-2	14		RD140HHXGA	1200x1703x765

Indoor unit

In this project there are two types of indoor units selected, which are vivace wall mounted and 4way cassette units.

The figure below shows the two types of selected units:

Figure 3.5: 4 way cassette

Figure 3.6: vivace wall mounted

CHAPTER FOUR

PLUMBING SYSTEM

4.1 Introductions

4.2 Water supply system

4.3 Pipe size calculations

4.4 Pump selection

4.5 Sanitary Drainage System

4.1 Introduction

There are two main functions of using plumping systems:

1- Water supply system; which provides the building with the required amount of water.

2- Sanitary drainage system; which removes all the usable water from the building.

It is the plumbing technologists' responsibility to design the entire water service and distribution systems for all use,recognizing the pressure and flow limitations.

In the project up feed distribution system will be used for both cold and hot water systems. Fixture units at the building are designed for private and general uses, flush tanks used for water closets because it needs low pressure, steel pipes will be used for hot and cold water systems, seven risers will be used for cold and hot water supply systems, The critical fixture unit in the system is the lavatory fixture unit which is located at the fourth floor of the building.

4.2 Water Supply system:

4.2.1 Introduction

The main objective of water supply system is to provide the building with the needed amount of water for daily use, such as drinking, cooking, washing and flushing, firefighting, bathing, and irrigation.

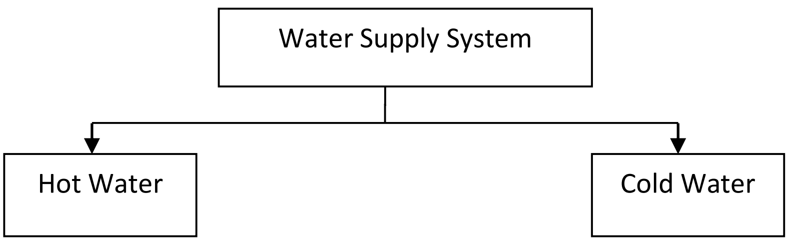


Figure 4.1: Water supply system

4.2.2 Design procedure

Step1: Determine if the suitable system is up-feed or down-feed.
Step2: Determine the number of riser needed and their location.
Step3: Calculate the total water supply fixture unit (WSFU), and then convert to gallon per minute (gpm).From Table(A-16).
Step4: Determine the minimum flow pressure for the critical fixture unit (fu).
From Table(A-22).
Step5: Calculate the total static head.
Step6: Calculate the pipe friction and equivalent length of the system.
Step7: Use the chart to determine the recommended pipe size.

4.2.3 Calculation of hot and cold water supply system

Water supply fixture units load (WSFU)

The total amount of water required for the building is calculated by using the water supply fixture unit technique (WSFU). This technique is used because there are a large number of fixture units in the system and this makes the technique more accurate.

Total WSFU for the first riser

Tables (4.1, 4.2) below show the total number of fixture units and the total water supply fixture unit (WSFU) for the first riser.

Table 4.1: Total number of fixture units of the first riser in each floor

Fixture type / Floor	Kitchen sink	Lavatory	Water closet	bathtub
Ground floor	2	4	4	0.0
First floor	0.0	9	7	0.0
Second floor	2	4	4	4
Third floor	2	4	4	4
Forth floor	3	3	3	3
Total	9	24	22	11

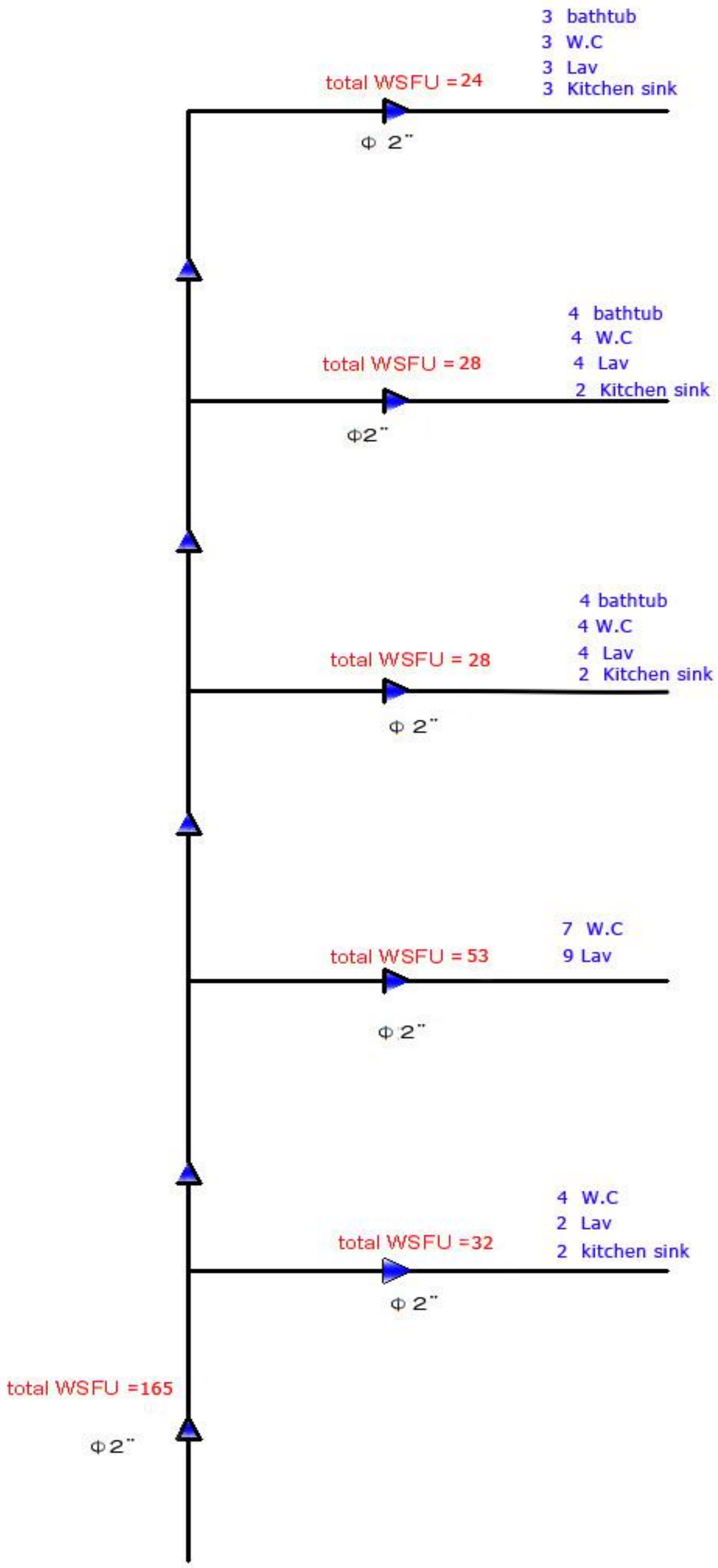


Figure 4.2: First riser diagram

Table 4.2: Total WSFU of the first riser

Fixture Type	No .OF FU	WSFU	Total WSFU	Cold WSFU	Hot WSFU	Total Cold	Total Hot
Kitchen sink	9	2	18	$2 \times \frac{3}{4}$=1.5	$2 \times \frac{3}{4}$=1.5	13.5	13.5
Water closet general	11	5	55	55	0.0	55	0.0
Water closet private	11	3	33	33	0.0	33	0.0
Lavatory general	13	2	26	$2 \times \frac{3}{4}$=1.5	$2 \times \frac{3}{4}$=1.5	19.5	19.5
Lavatory private	11	1	11	$1 \times \frac{3}{4}$= 0.75	$1 \times \frac{3}{4}$= 0.75	9	9
Bathtub	11	2	22	$2\times \frac{3}{4}$= 1.5	$2\times \frac{3}{4}$= 1.5	16.5	16.5
Total WSFU			165			147	59

Table 4.3: Total WSFU of each cold water riser

Riser	Total WSFU
1strisersection	147
2ndriser section	134
3rd riser section	84
4th riser section	62
5th riser section	43
6th riser section	41
7th riser section	44
8th riser section	66
9^{h} riser section	66
10th riser section	76
11th riser section	57
12th riser section	89
13th riser section	45
14th riser section	62
15th riser section	38
16th riser section	38
17th riser section	42
18th riser section	58
Total	1149

Table 4.4: Total WSFU of each hot water riser

Riser	Total WSFU
1strisersection	59
2ndriser section	54
3rd riser section	42
4th riser section	37
5th riser section	34
6th riser section	29
7th riser section	29
8th riser section	56
9^{h} riser section	56
10th riser section	44
11th riser section	46
12th riser section	73
13th riser section	32
14th riser section	26
15th riser section	34
16th riser section	22
17th riser section	22
18th riser section	36
Total	731

4.3 Pipe Size calculation:

In order to calculate the size of each pipe in the water supply system, friction head must be calculated by using the up-feed distribution system equation:

Main pressure (pump pressure) = Static head + Pipe friction + Flow pressure (4.1)

Where:

Static head: is to overcome the height from the source to the critical fixture unit outlet.

Pipe friction: caused by the friction of the moving water inside pipes.

Flow pressure: to overcome the minimum flow pressure, and to impart kinetic energy to the water.

But, some of the above equation parameters can be determined or estimated as following:

1-It is indicatedthat the minimum flow pressure required for the critical fixture unit (lavatory) is 8.0 psi.

2- It is indicated that main pressure (pump pressure) is 50.0 psi.

3- The estimated water meter loss is 5.0 psi

Static pressure:

As indicated previously that the building consists offive floors and two basement(floor to floor height is 3 meters), then as shown in the figure below it appears that the total vertical length from the pump source to the critical fixture (lavatory) is 20.4m.

The figure (4.3) shows the static head of the building

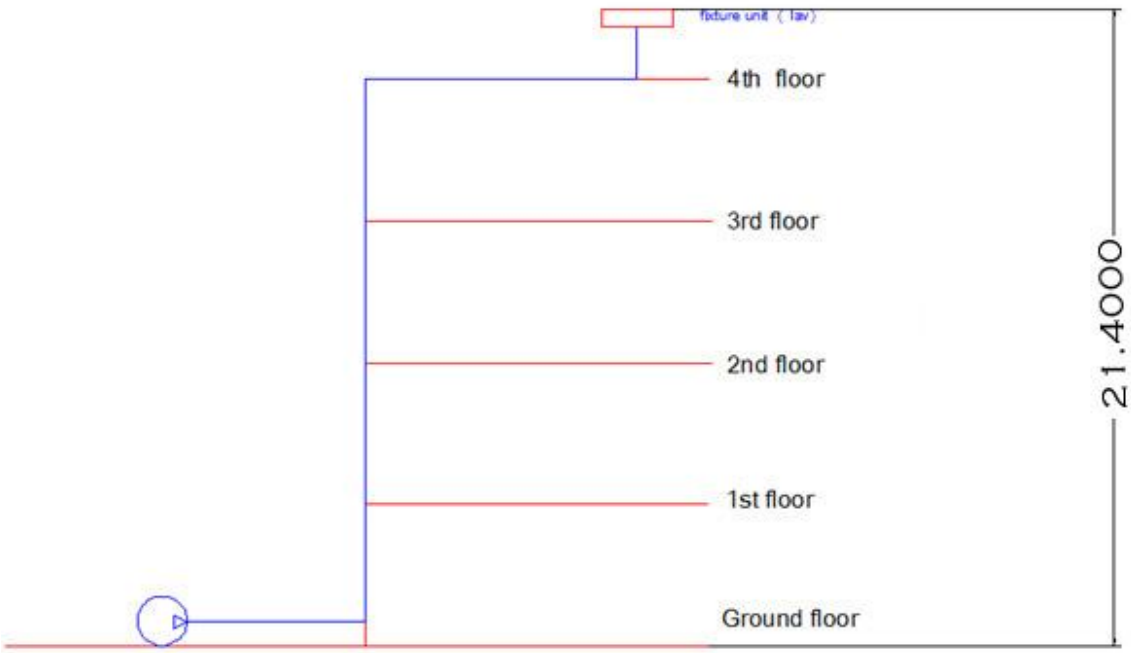


Figure 4.3: Static head of the building

$$\text{Static pressure} = 21.4 \times \frac{0.433}{0.33} = 28 \text{ psi} \qquad (4.2)$$

By using the above equation, the pipe friction can be calculated by moving some terms from right to lift to get the following equation:

Pipe friction = Main pressure (pump pressure) - Static head - Flow pressure (4.3)

= 50.0 – 28– 8.0 = 14 psi

The estimated water meter loss is 5.0 psi, so:

Friction head= Pipe friction – Water meter loss

=14 – 5.0 =9 psi (4.4)

On the other hand, One more thing must be calculated which is the total equivalent length (TEL). It appears from the mechanical drawings that the length of the first riser is 59 meter.

$$TEL= \frac{Totallength(m)\times1.5}{0.33} = 59\times1.5 / 0.33 = 268.1 \text{ ft} \quad (4.5$$

$$\text{Uniform design friction loss} = \frac{9\times100}{268.1} = 3.35 \ \frac{\text{psi}}{100\text{ft}} \quad (4.6)$$

Table 4.5:Properties of cold water riser

No. of Riser	Total WSFU	Total gpm	Diameter (inch)	Velocity (fps)
First riser	147	54.4	2"	4
Second	134	51.8	2"	4
Third	84	40	2"	4
Fourth	62	33.6	2"	4
Fifth	43	26.2	1.5"	4
Sixth	41	25.4	1.5"	4
Seventh	41	25.4	1.5"	4
Eighth	66	34.8	2"	4
Ninth	66	34.8	2"	4

Table 4.6: Properties of hot water riser

No. of Riser	Total WSFU	Total gpm	Diameter (inch)	Velocity (fps)
First riser	59	32.6	2"	4
Second	54	30.6	1.5"	4
Third	42	25.8	1.5"	4
Fourth	37	23.5	1.5"	4
Fifth	34	22	1.5'	4
Sixth	29	19.4	1.25"	4
Seventh	29	19.4	1.25"	4
Eighth	56	31.4	2"	4
Ninth	56	31.4	2"	4

4.4 Pump selection

Pumps selection depends on two main properties and these properties are: head (H) and flow rate (Q). Starting selection with:

1) Cold water pump.

By converting WSFU to GPM to m^3/hour, the 840WSFU equal 184.4 Gpm from all the cold water risers equals 50.3 m^3/hour.

Head estimation

Height of the building = 20.4m convert to psi equals 29 psi

then convert from psi to bar : 29 psi = 1.99 bar

Adding 1 bar for fittings losses the value is almost 2.99 bar

Head = 2.99 bar

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

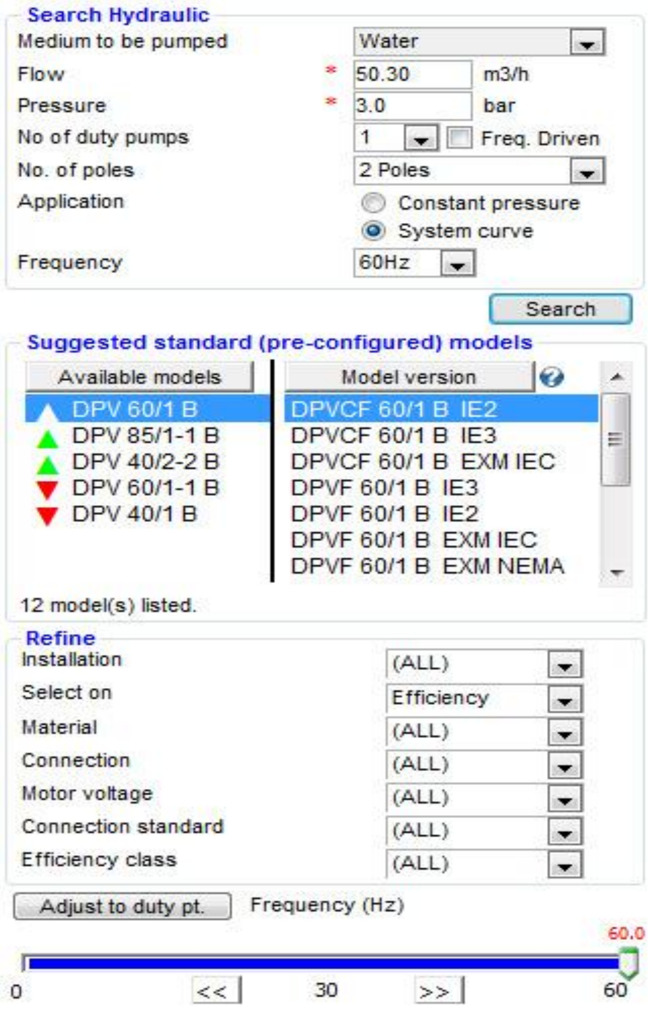


Figure 4.4:Cold pump data

The pump model selected “ DPV40/2-2B”

The characteristic curves of this pump as follow :

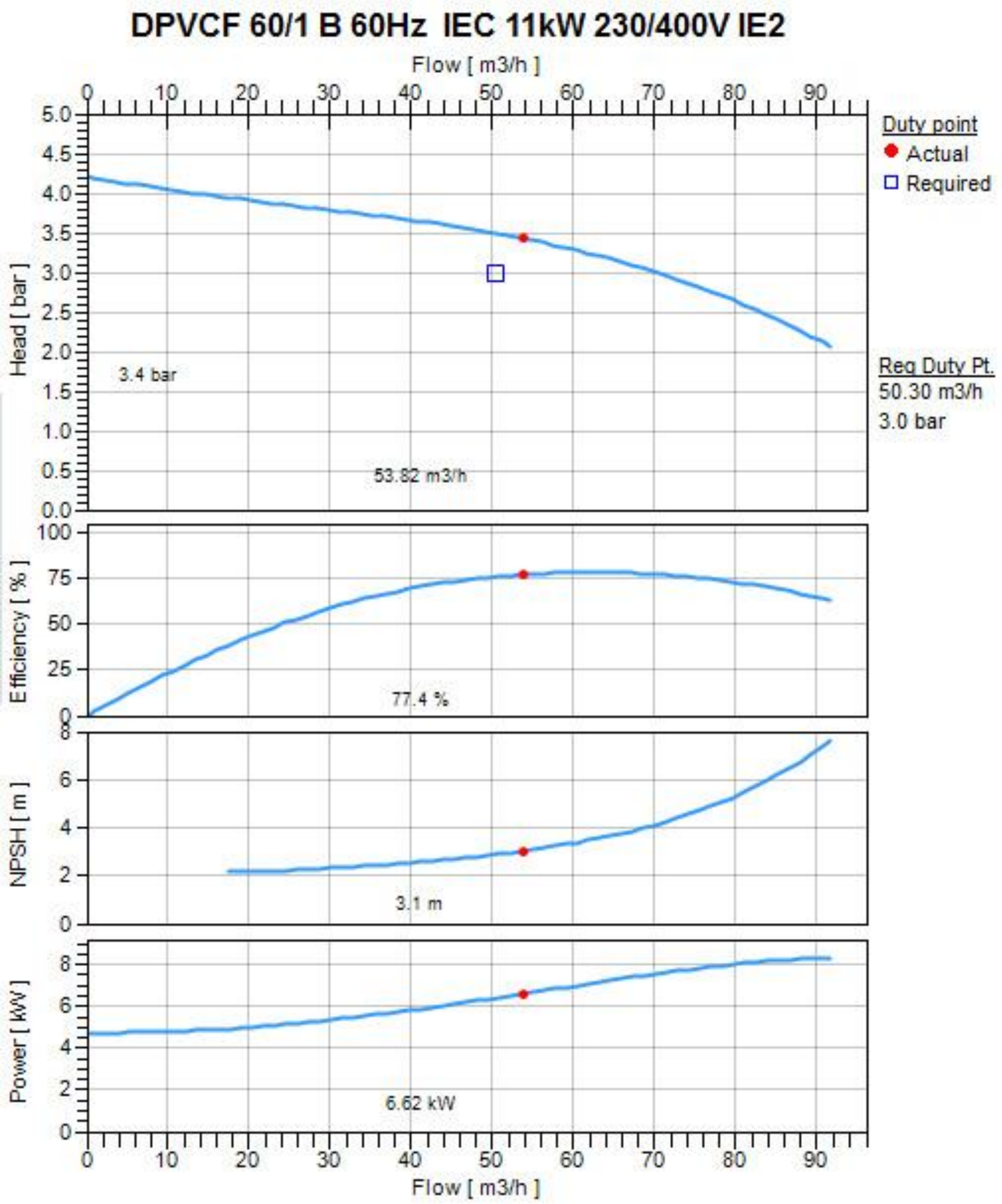


Figure 4.5:Coldpump characteristic curves

2) Hot water pump

By converting WSFU to GPM to m^3/hour, the 559WSFU equal 138.27 Gpm from all the cold water risers equals 31.4 m^3/hour.

Total flow rate = 31.4 m^3/hour.

Head = 2.99 bar.

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

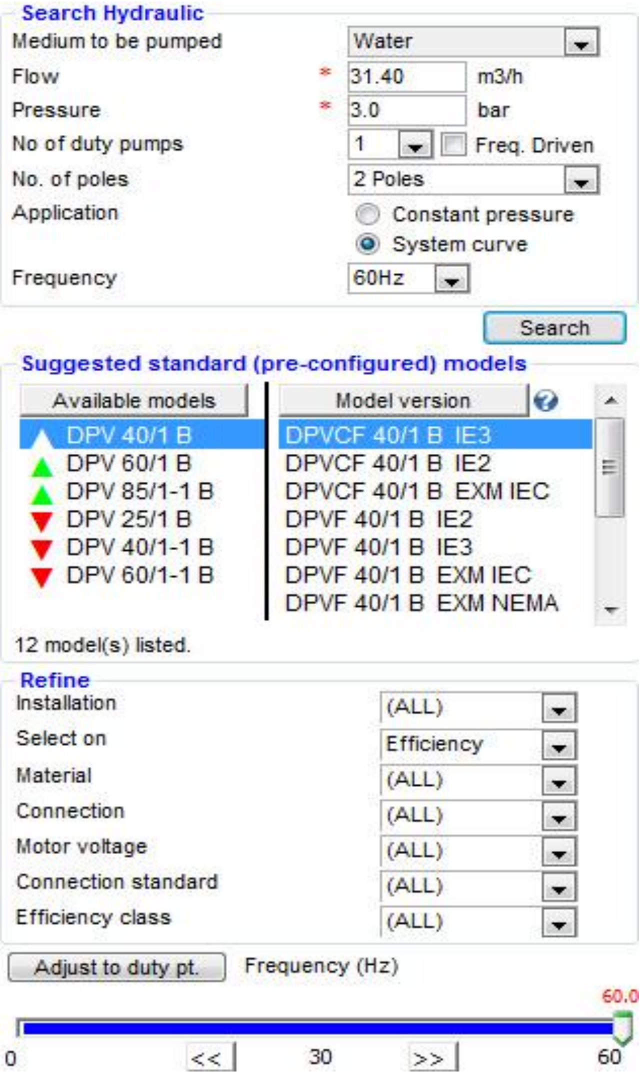


Figure 4.6 Hot pump data

The pump model selected " DPV40/2-2B"

Characteristic curves of this pump as follow :

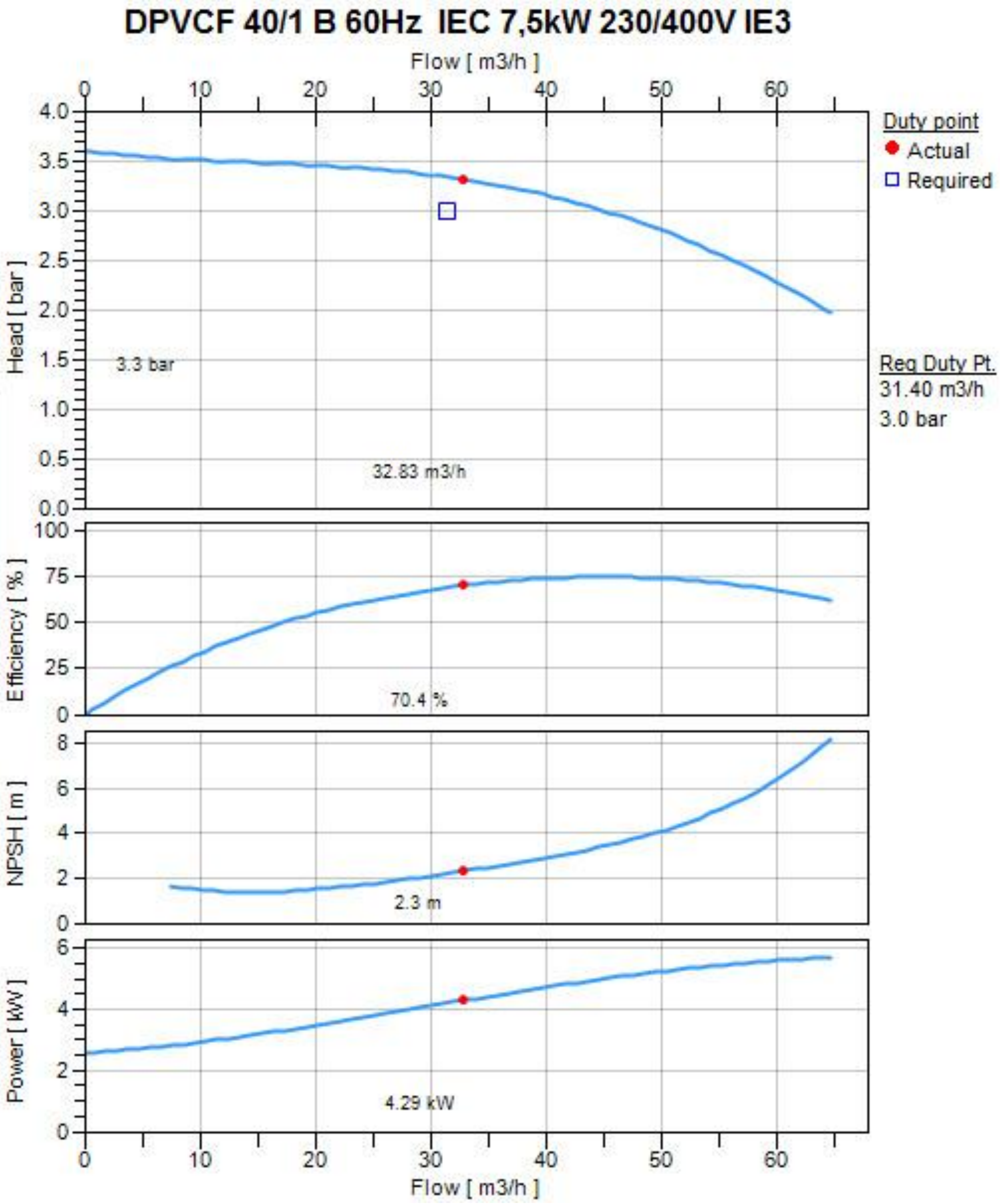


Figure 4.7:Hot pump characteristic curves

4.5 Domestic Hot Water Load Calculation:

- Assuming that the daily hot water consumption is 3960 L/day the hotel .

- $Q_{HW} = M_W * Cp *(T_{HW} – T_{CW})$

- Assuming $(T_{HW} – T_{CW}) = 40$ C, then :

$Q_{HW} = (3960 * 4.18 * 40) = 662.112$ KW

4.6 Boiler selection:

THW-I HTE
Industrial hot water boiler for oil and gas firing

Hoval

■ Technical data

THW-I HTE (10/05 - 34/25)

Technical data

Type		(10/05)	(13/08)	(17/10)	(22/15)	(27/20)	(34/25)
• Nominal output	kW	1000/ 500	1300/ 800	1700/ 1000	2200/ 1500	2700/ 2000	3400/ 2500
• Operating temperature max. (SBT)[1]		depending on net pressure					
• Temperature level flow/ return		depending on net pressure					
• Safety valve pressure	bar	10	10	10	10	10	10
	bar	13	13	13	13	13	13
	bar	16	16	16	16	16	16
• Boiler efficiency at 120 °C (Natural gas	%	88.7/ 91.5	89.1/ 91.2	89.9/ 91.9	89.7/ 91.3	89.6/ 90.9	89.8/ 91.8
• Boiler efficiency at 120 °C (Diesel oil)	%	88.8/ 91.5	89.5/ 91.5	90.1/ 90.0	89.9/ 91.5	89.9/ 91.1	90.1/ 91.3
• Flue gas resistance	mbar	9.5/ 5.5	10.5/ 6.5	11.5/ 6.5	11.0/ 7.0	11.0/ 8.0	13.0/ 8.0
• Water content	l	1700	1900	2100	2800	3500	4500
• Flue gas temperature after boiler (Natural gas)	°C	278/ 210	238/ 219	242/ 199	255/ 219	257/ 227	251/ 222
• Flue gas temperature after boiler (Diesel oil)	°C	265/ 203	254/ 210	241/ 198	244/ 210	245/ 218	240/ 213

[1] Country and equipment specific

Dimensions and weights

Type			(10/05)	(13/08)	(17/10)	(22/15)	(27/20)	(34/25)
• Flame tube diameter	10 bar	mm	600	650	700	750	800	850
	13 bar	mm	600	650	700	750	800	850
	16 bar	mm	600	650	700	750	800	850
• Flame tube length with turning chamber		mm	1900	2200	2400	2800	3300	3650
• **Boiler length** with insulation, without burner		mm	2580	2880	3080	3480	3980	4330
• **Boiler width** with insulation, without armatures		mm	1550	1600	1700	1750	1850	1950
• **Boiler height** with insulation, with assembly tube		mm	2150	2285	2360	2430	2530	2630
• Diameter flue gas outlet		mm	300	350	400	450	500	500
• Transport weight **without** burner incl. equipment	10 bar	kg	2500	2900	3500	4500	6000	7000
	13 bar	kg	2700	3300	4000	5000	6500	8500
	16 bar	kg	3000	3500	4500	5500	7000	9000

Figure 4.8: Boiler Specefication

To more information see catalogue in appendix

4.7 Fuel tank selection:

Figure 4.9: Fuel Tank

Made From: **Aluminium**

Suitable For Fuel: **Diesel, Gas Oil**

Tank Type: **Single Skin, Transportable**

UN Certified / Approved for Transport under ADR: **Yes**

Capacity: **250 litres**

Weight: **37.00kg**

Dimensions (l x w x h): **750mm x 895mm x 770mm**

Comes supplies with 12/24v pump,4m hose and auto nozzle

Figure 4.10: Fuel Tank

4.8 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 sewagesystem.

The provision of drainage systems:

- Sanitary drainage
- Storm drainage

Drainage system components

Themaincomponents of drainage system are:

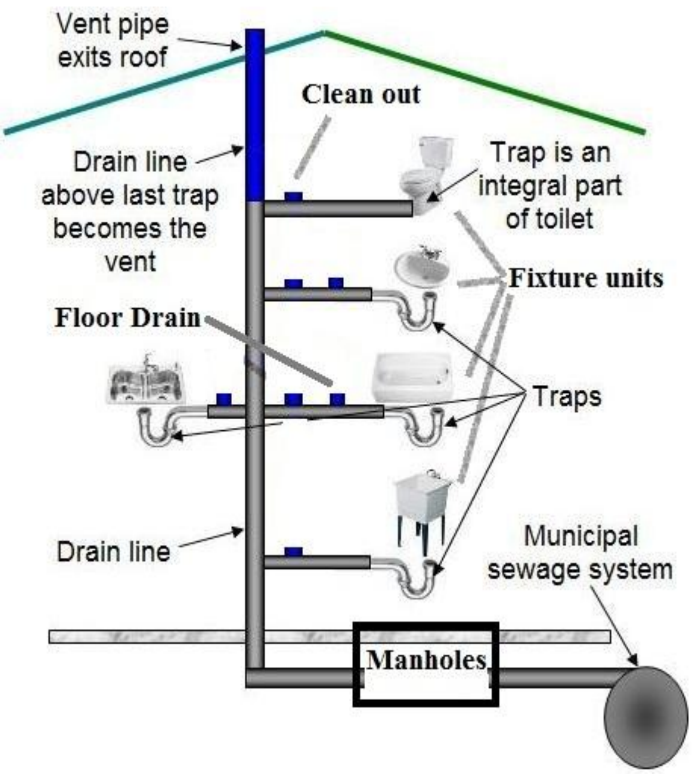


Figure 4.11: Drainage system components

1) Fixture units
2) Trap
3) Clean out
4) Drainage pipe
5) Stack and vent pipes
6) Manholes
7) Septic tank or municipal sewagesystem
8) Accessories

Sanitary drainage

Design procedure and pipe sizing

Pipe size is calculated by using a concept of fixture units (DFU) instead of usinggpmof drainage water. This unit takes into account not only the fixtures water use but also its frequency of use, which is the DFUhas 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 (A-23), (A-24).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 andswear 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 is1/4”/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 (A-23)
2) Calculation of the number of DFU for each stack
3) Choosing the branch pipe diameterby using Table(A-18)
4) Choosing the stack pipe diameterby using Table (A-18)
5) Comparing the stack pipe diameter with branch diameter
6) Choosing the building drain pipe diameter by using Table (A-17)

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-17)

The following figure and tables shows the sizing of stacks:

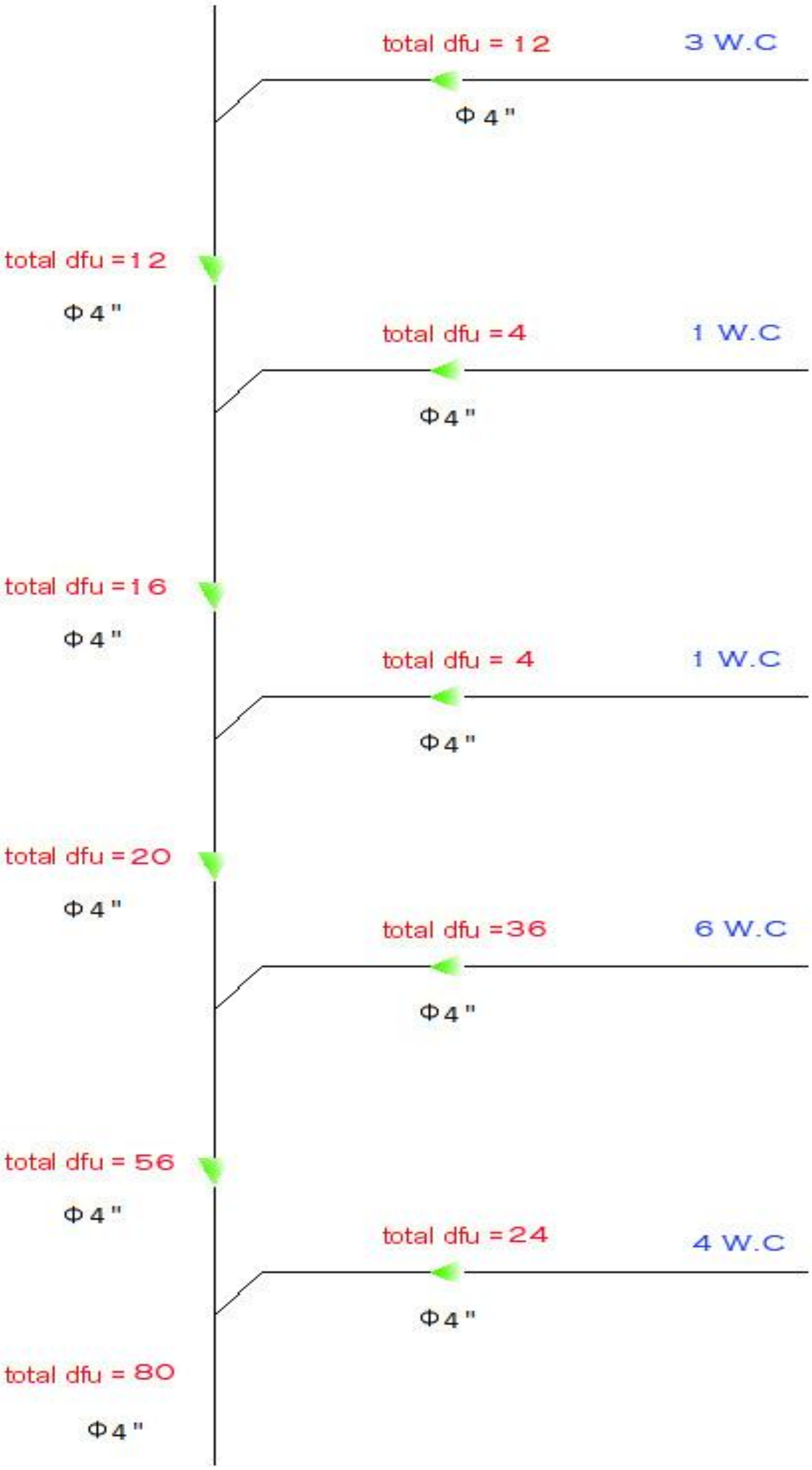


Figure 4.12: Sample of black water stack 1

Table 4.7: Sizing of black water stack 1

Stack 1	Total dfu value	Diameter (inch)
From Fourth floor (branch)	12	4
From Fourth to third floor (stack)	12	4
From third floor (branch)	4	4
From third floor to second floor (stack)	16	4
From second floor (branch)	4	4
From second floor to first floor (stack)	20	4
From first floor (branch)	36	4
From first floor to ground(stack)	56	4
From ground floor (branch)	24	4
From ground floor to building drain (stack)	80	4

Table 4.8:Sizing of black water stacks and building drain

#of stack	Total Dfu	Diameter (in)	Diameter of building drain	Slope %	Velocity ft/s
Stack 1	80	3	3	¼	2.25
Stack 2	74	3	3	¼	2.25
Stack 3	66	2.5	2.5	¼	2.25
Stack 4	54	2.5	2.5	¼	2.25
Stack 5	42	2.5	2.5	¼	2.25
Stack 6	26	2	2	¼	2.25
Stack 7	26	2	2	¼	2.25
Stack 8	38	2	2	¼	2.25
Stack 9	38	2	2	¼	2.25
Stack 10	22	2	2	¼	2.25
Stack 11	24	2	2	¼	2.25
Stack 12	14	2	2	¼	2.25
Stack 13	18	2	2	¼	2.25
Stack 14	12	2	2	¼	2.25

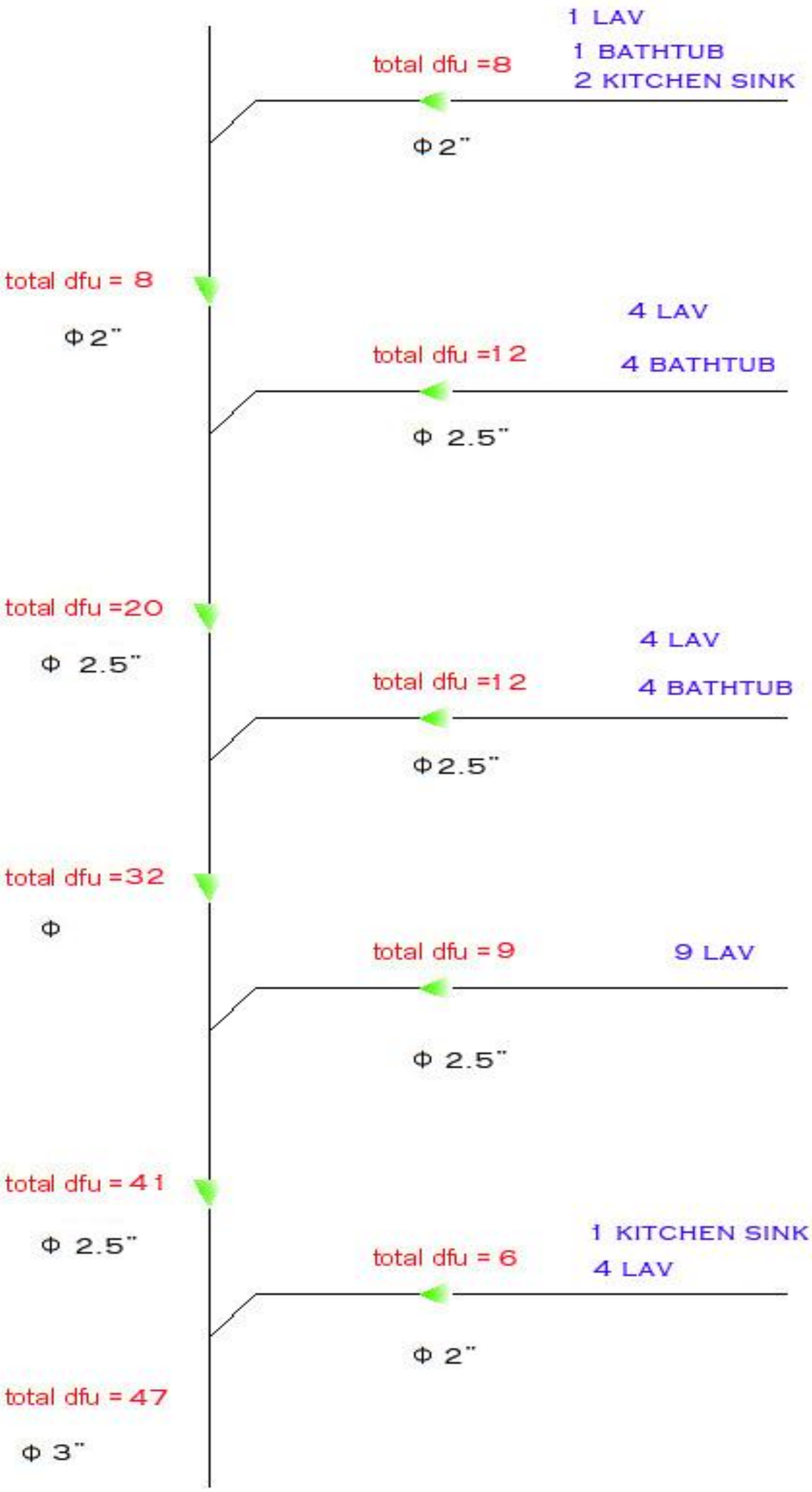


Figure 4.13: Sample of gray water stack 1

4.9 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.

CHAPTER FIVE

FIRE FIGHTING SYSTEM

5.1 Introduction

5.2 Types of firefighting system

5.3 Select the most effective type

5.4 Fire hose cabinet

5.5 Flow rate and head calculations

5.6 Pump selection

5.1 Introduction

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

5.2 Types of fire fighting system

1) Fire extinguishers.
2) Fire hose reels.
3) Fire hydrant systems.
4) Automatic sprinkler systems.

1) Fire extinguishers

Fire extinguishers are provided for a 'first attack' fire fighting 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:

1) Water
2) Foam
3) Dry powder
4) CO_2
5) Wet Chemical

Fire Extinguisher Types							
Extinguisher		Type of Fire					
Colour	Type	Solids (wood, paper, cloth, etc)	Flammable Liquids	Flammable Gasses	Electrical Equipment	Cooking Oils & Fats	Special Notes
	Water	Yes	No	No	No	No	Dangerous if used on 'liquid fires' or live electricity.
	Foam	Yes	Yes	No	No	Yes	Not practical for home use.
	Dry Powder	Yes	Yes	Yes	Yes	No	Safe use up to 1000v.
	Carbon Dioxide (CO2)	No	Yes	No	Yes	Yes	Safe on high and low voltages.

Figure 5.1: Fire extinguishers

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 5.2: Fire hose reel

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 fire fighting process.

Fire hydrants are for the sole use of trained fire fighters (which includes factory fire fighting 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 5.3: Fire hydrate system

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.

Figure 5.4: Fire sprinkler

5.3 Select the most effective type

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

The number of hose reels to be used in hotel is 12 firehouse reels for all floors most fire hose is designed to be stored flat to minimize the storage space required.

5.4Fire hose cabinet

Fire hose cabinet is located at the following places:

A- Exit stairs.

B- Entrance of buildings.

C- Garages entrance.

D- Wherever travel distance exceeded 36 meter from another fire hose cabinet.

It consists of :

1) Cabinet (wall mounted-recessed), there are three types of cabinets:

A- Exposed: be prominent from the wall and out of it a distance of 25 cm, and Fund riding on the surface of the wall.

B- Semi predated: be prominent from the wall a distance of 10 cm, and inside the wall 15 cm.

C- Recessed: be inside the entire wall.

2) Landing valve, valve to control the water stream, located inside or outside the building.

3) Hose (30 meter).

4) Discharge nozzle.

5) Fire extinguisher (optional).

Fire hose cabinet classes:

1) Class 1: standpipe system provides 65-mm (2½-in.) hose connections to supply water for use by fire departments and those trained in handling heavy fire streams.

System limitations are pressure reach 7 bars, flow rate 250 gpm, located at all main entrance and exits of the buildings and garages, around the wall buildings and the travel distance is 45.7m with throw distance.

2) Class 2: standpipe system provides 38-mm (1½-in.) hose stations to supply water for use primarily by the building occupants or by the fire department during initial response.

System limitations are pressure reach 4.5 bars, flow rate 100 gpm, 30m travel distance and located corridors, theaters, colleges and near elevators.

3) Class 3:standpipe system provides 38-mm (1½-in.) hose stations to supply water for use by building occupants and 65mm (2½-in.) hose connections to supply a larger volume of water for use by fire departments and those trained in handling heavy fire streams.

Class two didn’t need any experience to deal with a system for any user on contrast with class one, for this reason class 2 is more popular and that is the selected class for cabinet.

Technical specifications of fire hose cabinet :

The following specifications are installed according to code NFPA 14 for class 2 F.H.C:

- The maximum pressure at any point in the system at any time shall not exceed 24.1 bar (350 psi).
- Maximum Residual Pressure for (1½-in.) Diameter F.H.C=6.9 Bar.
- Hydraulically designed standpipe systems shall be designed to provide the water flow rate required at a minimum residual pressure of4.5 bar (65 psi) at the outlet of the hydraulically most remote 38-mm (1½-in.) hose station.
- Standpipes size shall be at least 100 mm (4 in.) (Main riser).
- Hose stream demand and water supply duration requirement for hydraulic calculation system as in the NFPA14 code.

Firefighting pumps

A 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 discharged to a discharge header (to firefighting network)[8].

Pumping stations should include:

1. Electrical firefighting pump.

2. Stand-by Diesel Firefighting Pump (No need if an extra electric pump is connected to an electric generator).

Diesel pump works if:

- The electrical pump is out of service, or if there is a lack of electricity.
- The electrical pump is working but can’t satisfy system water requirements.

3. Jockey Pump: works to make up the system pressure in case of leakage or during the first seconds of fire.

Pumps are selected to supply the system demands on the basis of three key points relative to their rated flow and rated pressure most fire pumps are sized to exceed its duty point requirement.

Types of pumps

1- Horizontal split case pumps:

This is also called a double suction fire pump because the water pathways direct water to both sides of the impeller. It is also the most common fire pump on the market partly because of the ratings available in this style of pump 250 GPM through 5000 GPM.

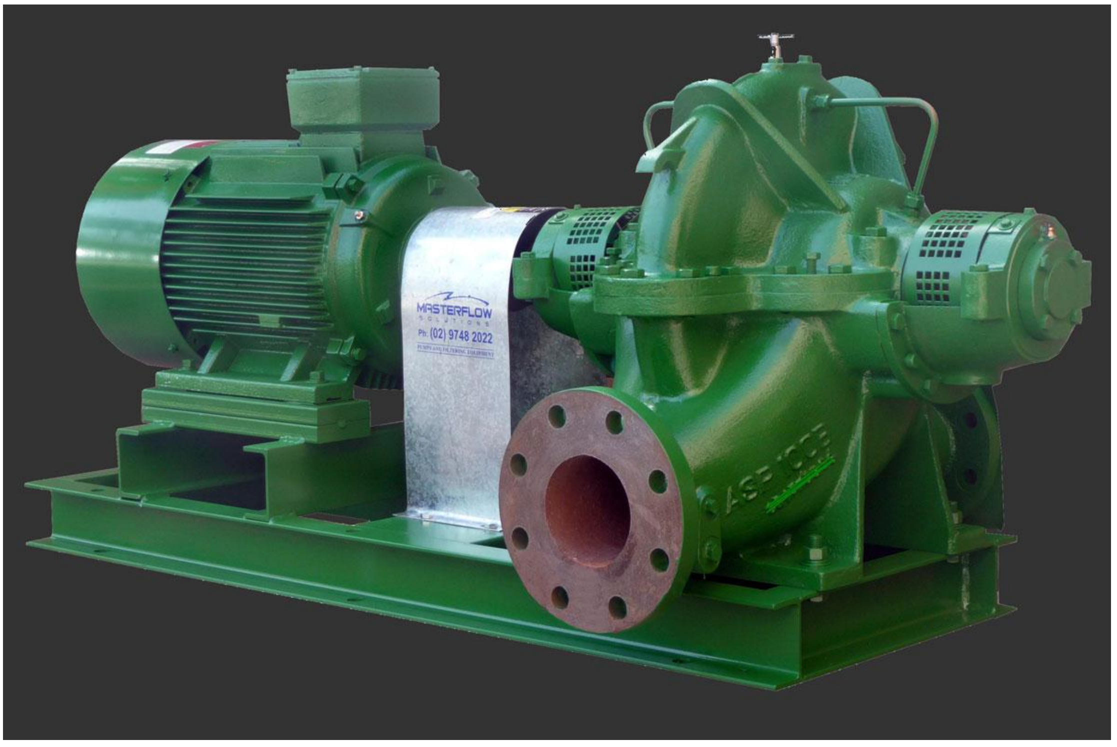


Figure 5.5: Horizontal split case pump

2- Inline fire pumps

These pumps have expanded in use in the last five years for several reasons, space savings, Increase in ratings allowable by NFPA 20 from max of 499 GPM, and then to 750 GPM, to today which is unlimited rating. The largest currently available is 1500 GPM, Cost of installation –these are typically less expensive to install because there is no base plate that requires grouting.

Figure 5.6: Inline fire pump

3- End suction pumps

End suction fire pumps not widely used mostly because they are limited in size per code ,They are also slightly more expensive than inline pumps ,The one pump application where it is used is small diesel driven applications 500 GPM or l less.

Figure 5.7: End suction pump

4- Vertical turbine pumps

These are used for water supplies that are below the suction flange of a fire pump; NFPA 20 states that you have to have a positive suction pressure to a fire pump.

Figure 5.8: Vertical turbine pump

5.5 Flow rate and head calculations

There are two main factors in GPM calculations:

1. Area calculation

2. Standpipe calculation

The standpipe calculation is the selected calculation, so according to NFPA 14 states that the

GPM required for the first standpipe is 500 GPM

Each additional standpipe requires 250 GPM with a maximum GPM of 1000 GPM

If a building has 2 standpipes the pump GPM would be 750 GPM, 500 GPM for the first and 250 for the second.

If a building has 3 standpipes the pump GPM would be 1000 GPM, 500 GPM, 250 for thesecond, and 250 for the third.

Any building with more standpipes would be 1000 GPM as that is the maximum allowable bycode.

So, this building need 500 GPM according to code, with two standpipes the amount of flow rate equal to 750 GPM.

Flow rate calculation:

= No of FHC * 250 GPM for each FHC

2*250 = 500 GPM = 113.56 m^3/h

Pressure head calculation:

H_{Pump} = $H_{St.}$ + $H_{Res.}$ + H_f (4.1)

H_{Pump}= the pressure of the pump.

$H_{Res.}$ = the residential building FHC = 4.5bar.

H_f = the friction head.

$$H\,f = \frac{4.5 * Q^{1.85}}{C^{1.85} * D^{4.85}} = \frac{4.5 * 500^{1.85}}{120^{1.85} * 0.101^{4.85}}$$

= 1 bar

$H_{St.}$= the static head.

$H_{St.}$= 15 m = 1.5 bar.

So:

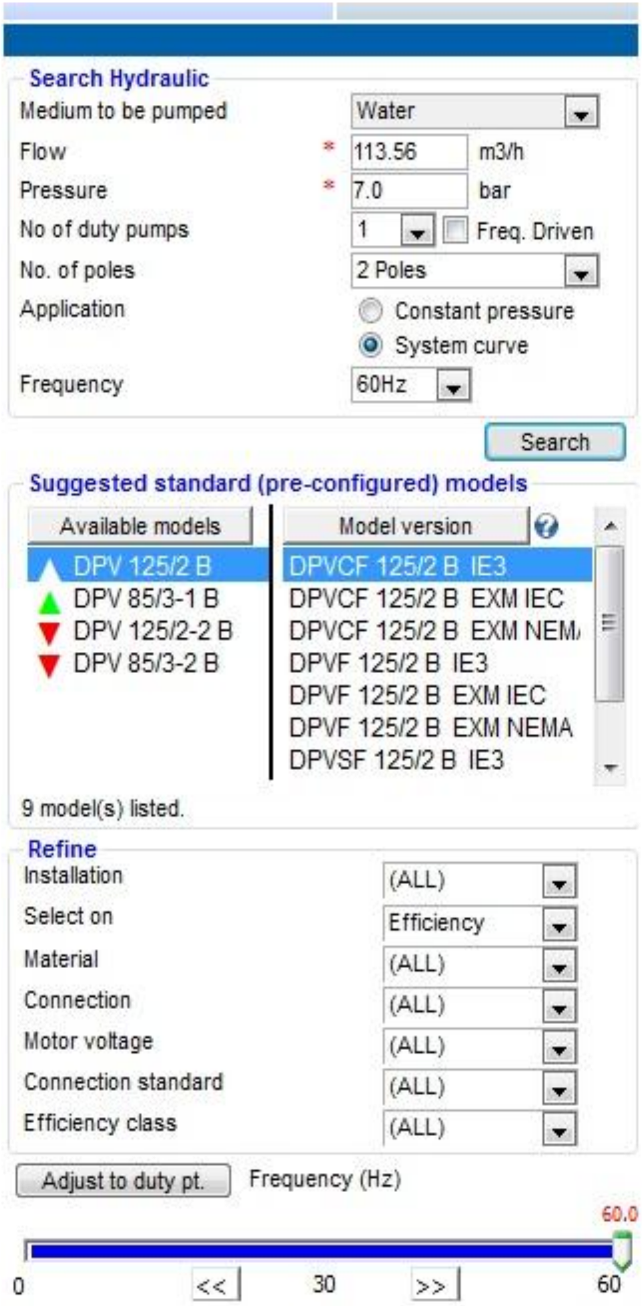
H_{Pump}= 4.5 + 1.5 + 1 = 7 bar.

5.6 Pump selection

Total flow rate 500 GPM equal to 113.5 m^3/h and amount of head 7. bars.

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

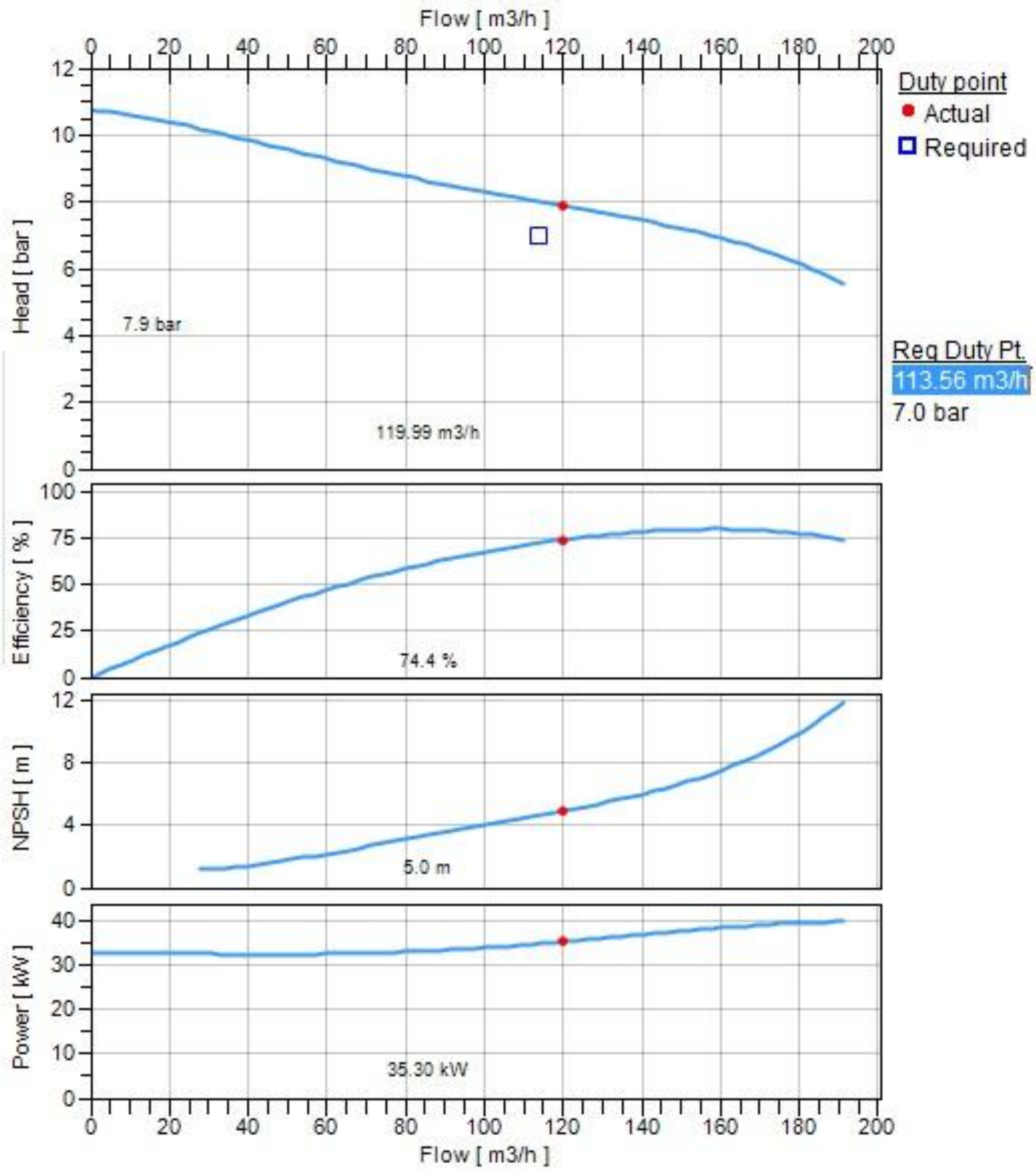
Figure 5.9: Pump details



The pump model selected " DPVC85/3 B"

The characteristic curves of this pump as follow :

Figure 5.10: Pump characteristic



CHAPTER SIX

REFREGRATORS

7.1 Cooling Load Calculation for refrigeration

7.1.1 The Overall heat transfer coefficient

7.1.2 Cooling Load Calculation For rooms

7.1.3 Compressor selection

7.1.4 Condensers selection

7.2 Cooling Load calculation for freezer

7.2.1 Use this law to find Cooling Load Calculation

7.2.2 Cooling Load Calculation For rooms

7.2.3 Compressor selection

7.2.4 Condensers selection

7.1 Cooling Load Calculation for refrigeration

Use this law to find Cooling Load Calculation:

$Q=U\ A\ \Delta T$

Q : Cooling Load in [kW] .

U : Overall heat transfer coefficient in [$W/m^2.\ ^\circ C$] .

$$U = \frac{1}{\frac{1}{h_{in}} + \sum \frac{\Delta X}{K} + \frac{1}{h_{out}}} \tag{6.1}$$

h_{in} : is the Inside Convection Coefficient { 9.37 $W/m^2.^oC$ } .

h_{out} : is the Outside Convection Coefficient { 22.7 $W/m^2.^oC$ } .

K: is the thermal conductivity for material in [$W/m.^oC$] .

ΔX: is the Thickness of the material in [m] .

A: Surface area in [m^2] .

A=Length * Width.

ΔT: The difference in temperature [^oC] .

Temperature surrounding {Tsur} :

$T_{sur} = 30\ ^oC$

Room Temperature {TRoom} :

$T_{Room} = T_{in} + 2/3\ (T_{sur} + T_{in})$

$T_{in:}$ is the storage temperature of product = 5 ^oC .

$T_{Room} = 5 + 2/3\ (30 + 5)$

$T_{Room} = 28.3\ ^oC$.

7.1.1 The Overall heat transfer coefficient

1. External Wall:

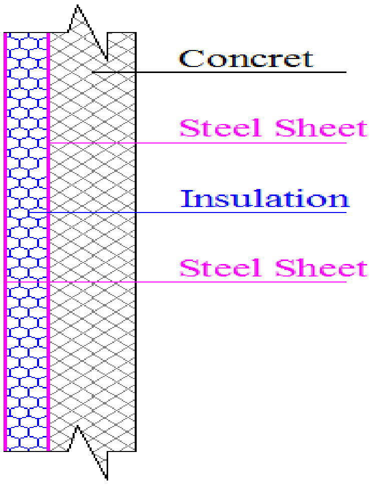


Figure 7.1:External wall details

Table 7.1: variable of heat transfer coefficient for External wall

Material	K (W/m.℃)	Thickness (m)
Concrete	1.750	0.300
Steel Sheet	16.00	0.002
Insulation	0.050	0.070
Steel Sheet	16.00	0.002

Thickness of the wall = 0.37 m .

$$U = \frac{1}{\frac{1}{9.37}+\frac{0.3}{1.75}+\frac{0.002}{16}+\frac{0.07}{0.05}+\frac{0.002}{16}+\frac{1}{22.7}}$$

$$= 0.58/m^2.^oC .$$

$\Delta T = T_{sur} - T_{in}$

$= 30 – 5 = 25\ ^oC$.

$A_{External\ Wall} = 3.8 * 4 = 15.2 m^2$.

$Q_{External\ Wall-1} = 0.58 * 25 * 15.2 = 220\ W = 0.220\ kW$

2. Internal Wall-1:

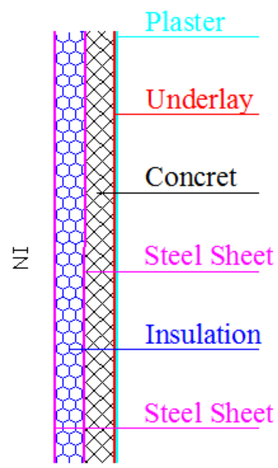


Figure 7.2: internal wall details

Table 7.2: variable of heat transfer coefficient for Internal Wall- 1

Material	K (W/m.℃)	Thickness (m)
Plaster	1.200	0.002
Underlay	0.980	0.008
brick	1.00	0.100
Steel Sheet	16.00	0.002
Insulation	0.050	0.10
Steel Sheet	16.00	0.002

Thickness of the wall = 0.214 m .

$$U = \frac{1}{\frac{1}{9.37} + \frac{0.002}{1.2} + \frac{0.008}{0.98} + \frac{0.1}{1.00} + \frac{0.002}{16} + \frac{0.1}{0.05} + \frac{0.002}{16} + \frac{1}{9.37}}$$

$= 0.43\ W/m^2.^oC.$

$\Delta T = T_{Room} - T_{in}$

$= 28.3 – 5 = 23.3\ ^oC$.

$A = A_{Internal\ Wall} – A_{Door}$

= (2 * 3.8)-(1 * 2)

$= 5.6 m^2$.

$Q_{Internal\ Wall\text{-}1}$ = 0.43 * 23.3 * 5.6 = 38W = 0.038kW .

3. Internal Wall-2 :

The same propriety of Internal Wall-1 but the aria is deferens

$A = A_{Internal\ Wall}$

= (4 * 3.8) $= 15.2\ m^2$.

$Q_{Internal\ Wall\text{-}1}$ = 0.43 * 23.3 * 15.2 = 152W = 0.152kW .

4. Internal Wall-3 :

The same propriety of Internal Wall-1 but the aria is deferens

$A = A_{Internal\ Wall\text{-}3}$

= (2 * 3.8

$= 7.6 m^2$.

$Q_{Internal\ Wall\text{-}3}$ = 0.43 * 23.3 * 7.6 = 76W = 0.076 kW.

5. Internal Wall-4 :

Consists of :

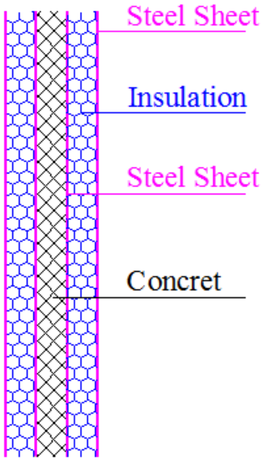


Figure 7.3: Internal wall -2

Table 7.3: variable of heat transfer coefficient for Internal Wall- 2

Material	K (W/m.℃)	Thickness (m)
Steel Sheet	16.0	0.002
Insulation	0.05	0.070
Steel Sheet	16.0	0.002
Concrete	1.75	0.100
Steel Sheet	16.0	0.002
Insulation	0.05	0.070
Steel Sheet	16.0	0.002

Thickness of the wall = 0.248 m .

$$U = \frac{1}{\frac{1}{9.37} + \frac{0.002}{16} + \frac{0.07}{0.05} + \frac{0.002}{16} + \frac{0.1}{1.75} + \frac{0.002}{16} + \frac{0.07}{0.05} + \frac{0.002}{16} + \frac{1}{9.37}}$$

$= 0.325\ W/m^2.^oC.$

$\Delta T = T_{Room} - T_{in}$

$= 5 - -18 = 23\ ^{o}C$.

$A = A_{\text{Internal Wall-2}}$

$= (4 * 3.8)$

$= 15.2\ m^2$.

$Q_{\text{Internal Wall-2}} = 0.325 * 23 * 15.2 = 114W = 0.114kW$.

6. Ground:

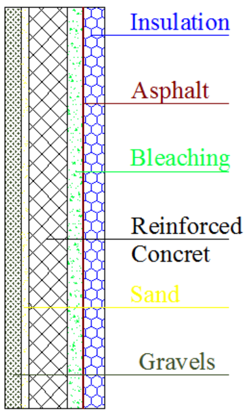


Figure 7.4:Ground Details

Table 7.4: variable of heat transfer coefficient for Ground

Material	K (W/m.℃)	Thickness (m)
Insulation	0.05	0.100
Asphalt	0.30	0.002
Bleaching	0.98	0.050
Reinforced Concrete	0.88	0.200
Sand	0.68	0.020
Gravels	0.58	0.050

Thickness of the wall = 0.377 m .

$$U = \frac{1}{\frac{1}{9.37} + \frac{0.1}{0.05} + \frac{0.002}{0.3} + \frac{0.05}{0.98} + \frac{0.2}{0.88} + \frac{0.02}{0.68} + \frac{0.05}{0.58}}$$

= 0.399 W/m^2.ºC .

A = (2 * 2)

= 4m^2.

Q_{ground} = 0.399 * 23.3 * 4= 38W = 0.020 kW.

7. Ceiling:

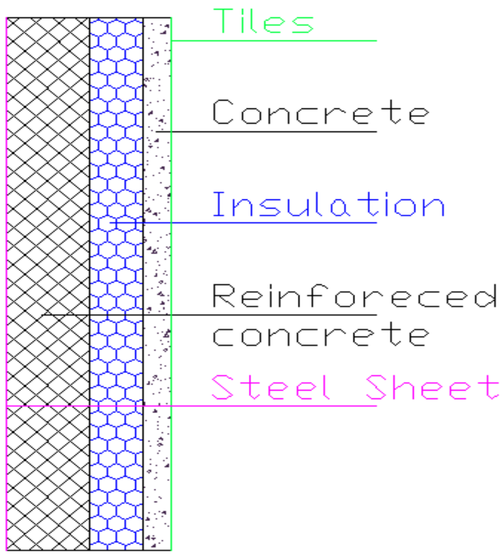


Figure 7.5: Ceiling details

Table 7.5:Variable of heat transfer coefficient for Celling

Material	K (W/m.°C)	Thickness (m)
Tiles	1.10	0.005
Concrete	1.75	0.050
Insulation	0.05	0.096
Concrete	1.75	0.15
Steel Sheet	16.0	0.002

Thickness of the Ceiling = 0.362 m .

$$U = \frac{1}{\frac{1}{9.37} + \frac{0.005}{1.1} + \frac{0.05}{1.75} + \frac{0.096}{0.05} + \frac{0.15}{1.75} + \frac{0.002}{16} + \frac{1}{9.37}}$$

= 0.444 $W/m^2.^oC$.

$\Delta T = 28.3 - T_{in}$

= 28.3– 5 =23.3 ^oC .

A =2* 2 = 4 m^2.

$Q_{Ceiling}$ = 0.444 * 23.3 * 4= 50W =0.050kW .

8. Door:

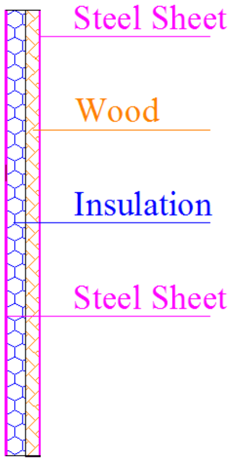


Figure 7.6: Door Details

Table 7.6: variable of heat transfer coefficient for Door

Material	K (W/m.°C)	Thickness (m)
Steel Sheet	16.0	0.002
Insulation	0.05	0.056
Wood	0.16	0.040
Steel Sheet	16.0	0.002

Thickness of the Door = 0.1 m .

$$U = \frac{1}{\frac{1}{9.37} + \frac{0.002}{16} + \frac{0.056}{0.05} + \frac{0.04}{0.16} + \frac{0.002}{16} + \frac{1}{9.37}}$$

$= 0.631 \ W/m^2.^{o}C$

$\Delta T = T_{Room} - T_{in}$

$= 28.3 - 5 = 23.3 \ ^{o}C$.

$A = 1 * 3.8 = 3.8 \ m^2$.

Q_{Door} = 0.631 * 23.3 * 3.8= 55 W = 0.055kW.

7.1.2 Cooling Load Calculation For rooms

Use this law to calculate cooling load for rooms:

$Q_{Total} = Q_{Envelope} + Q_{Product} + Q_{Air} + Q_{Service} + Q_{Respiration}$. (6.2)

For Refrigerator:

$Q_{Envelope}$ Calculation:

$Q_{Envelope}$: heat gain from walls, doors, windows, floor and ceiling.

$Q_{Envelope} = Q_1 + Q_{Solar}$.

$Q_{Wall} = Q_{External\ wall\text{-}1} + Q_{Internal\ Wall\text{-}1} + Q_{Internal\ Wall\text{-}3} + Q_{Internal\ Wall\text{-}4}$

= 0.022+0.038 + 0.076 +0.114 = 0.448.

$Q_1 = Q_{Walls} + Q_{Door} + Q_{Floor} + Q_{Ceiling}$. (6.3)

Q_1 = 0.448 + 0.055 + 0.038+ .050 = 0.6 kW.

$Q_{Solar} = 0$

$Q_{Envelope}$ = 0 + 0.6 = 0.6kW .

$Q_{Product}$ Calculation:

$Q_{Product} = Q_2^{*} + Q_2^{**} + Q_{Packaging}$. (6.4)

$Q_2^{*} = m^{o} cp\ \Delta T$.

When:

m^{o} = ($m_{Product}$ / Time Cooling)

Time Cooling: Working Time Per a Day .

$\Delta T = \Delta T_{sur} = 30\ ^{o}C$.

Table 7.7:Product used

Product	cp	m	m*	Q2*
Apple	3.64	40	0.000694	0.075833
Avocados	3.01	40	0.000694	0.062708
Bananas	3.35	40	0.000694	0.069792
Bass	3.43	30	0.000521	0.053594
Black Barry	3.64	20	0.000347	0.037917
Butter	2.72	30	0.000521	0.0425
Cabbage	3.94	50	0.000868	0.102604
Carrots	3.81	20	0.000347	0.039688
cheese	3.27	40	0.000694	0.068125
Chicken	2.72	80	0.001389	0.113333
cucumber	4.1	100	0.001736	0.213542
eggs	3.18	30	0.000521	0.049688
Eggplant	3.98	50	0.000868	0.103646
Grapes	3.6	50	0.000868	0.09375
Lemons	3.81	60	0.001042	0.119063
Milk	3.81	40	0.000694	0.079375
Tomatoes	3.98	120	0.002083	0.24875
Watermelon	3.94	100	0.001736	0.205208
	∑			1.653281

$Q_2^* = 1.65$ kW .

$Q_2^{**} = 0$ {Used to freeze}

$Q_{Packaging} = (m_{Material} / \text{Time Cooling}) * cp * \Delta T$. (6.4)

When:

$m_{Material} = m * N$.

m : is the mass of one pallet = 10 kg .

N: is the number of pallets in the room = 30.

$m_{Material}$ = 10 * 30 = 300 kg .

cp : is the Specific Heat for Pallet = 0.67 kJ/kg.K .

$\Delta T = \Delta T_{sur} = 30\ ^{o}C$.

$Q_{Packaging}$ = (300/ (4 * 16 * 3600)) * 0.67 * 30 = 0.105 kW .

$Q_{Product}$ = 1.65 + 0 + 0.105 = 1.755kW.

Q_{Air} Calculation:

$Q_{Air} = Q_{Infiltration} + Q_{Ventilation}$. (6.5)

$Q_{Infiltration}$ = 0 kW.

Prove it :

$Q_{Infiltration} = (1250 /3600) * v^{o} * (T_{Room} - T_{in})$

$v^{o} = K * L * \{ 0.613 * (S_1 * S_2 * v_o)^2 \}^{(3/2)}$

L : Perimeter of the door .

L = 2 * 3 + 2 * 3 = 12 m .

K : The infiltration air coefficient = 0.25 .

S_1 : Factor that depend on the topography of the location of the building = 0.9 .

S_2: Coefficient that depend on the height of the building and the term of its location = 0.74 .

Vo : The wind velocity = 0.5 mL / sec .

$v_o = 0.25 * 12 * 10^{-3} * \{ 0.613 * (0.9 * 0.74 * 0.5)^2 \}^{(3/2)}$

$= 5.3 * 10^{-5}$ mL /sec .

$Q_{Infiltration} = (1250 / 3600) * 5.3 * 10^{-5} * (25.1 - 0) = 0.0004 \approx 0$ kW .

$Q_{Ventilation} = Q_{Product} + Q_{People}$ (6.6)

$Q_{Product} = m^{o} * (hout - h_{in})$

From Psychometric Chart:

h_{out} = 72 J / kg.^{o}C @ T_{out} = 30 ^{o}C& R.H = 56 % .

h_{in} = 17 J/kg.^{o}C @ T_{in} = 5^{o}C & R.H =85 % .

$m^o = \rho_{Air} * v^o$

ρ_{Air}: it is the density of the air = 1.2 kg/m^2.

Vo = v * a.

V : Volume of the room in [m^3] .

V = 2 * 4 * 3.8 = 30.4m^3.

a : number of air change each second , it depend for the volume of the room .

from interpolation a = 11.3 L/s . [Table 10-7]

m^o = 1.2 * 30.4 * (11.3 / 1000) = 0.5 m^3/s .

$Q_{Product}$ = 0.5 * (72 – 17) = 27.5 W = 0.0275kW .

$Q_{People} = m^o * (h_{out} – h_{in}) * (\text{hour occupied} / 24) *a$

When:

a : The number of people inside the room = 2 .

$m^o = \rho_{Air} * v^o$

Vo = 20 m^3/h .

m^o = 1.2 * (20/3600) = 6.66 * 10^{-3} kg/s .

hour occupied: is the time needed to work in the room = 2 hours .

Q_{People} = 6.66 * 10^{-3} * 55* (2/24) * 2 = 0.061 W = 6.1 * 10^{-5} kW .

$Q_{Ventilation}$ = 0.0275+ 6.1 * 10^{-5} = 0.0276kW .

Q_{Air} = 0 + 0.0276 = 0.0276kW .

$Q_{Service}$ Calculation:

$Q_{Service} = Q_{People} + Q_{Light}$.

Q_{People} = n * Q_{Person} * (Working hours / 24)

Q_{Person} = 0.275. [Table 10-14] .

Q_{People} = 2 * 0.275 * (2 / 24) = 0.046 kW .

Q_{Light} = P_{Light} * CLF * N

P_{Light} = 24 W.

CLF: Cooling Load Factor of Lighting = 0.88 .

N: Number of Lights

N = 2

Q_{Light} = 24 * 0.88 * 2 = 42.24 W = 0.0422 kW

$Q_{Service}$ = + 0.046 + 0.0422 = 0.088 KW .

$Q_{Respiration}$ Calculation:

$Q_{Respiration}$ = m * q_{Rips}

$Q_{Respiration}$: is the rate of respiration .

m : is the mass of the product in the room in [kg] .

q_{Rips} : Rate of heat given off Breathing product .

q_{Rips} = 0.029 . [Table 10-12] .

$Q_{Respiration}$ = 0.029 * 1000 = 29 W = 0.029 kW .

Consequently:

Q_{Total} = 0.6 + 1.755+ 0.0276 +0.088+ 0.029 = 2.5kW .
Q_{Total} =2.5*F.S = 2.5*1.5 = 3.75 Kw

From Cool pack:

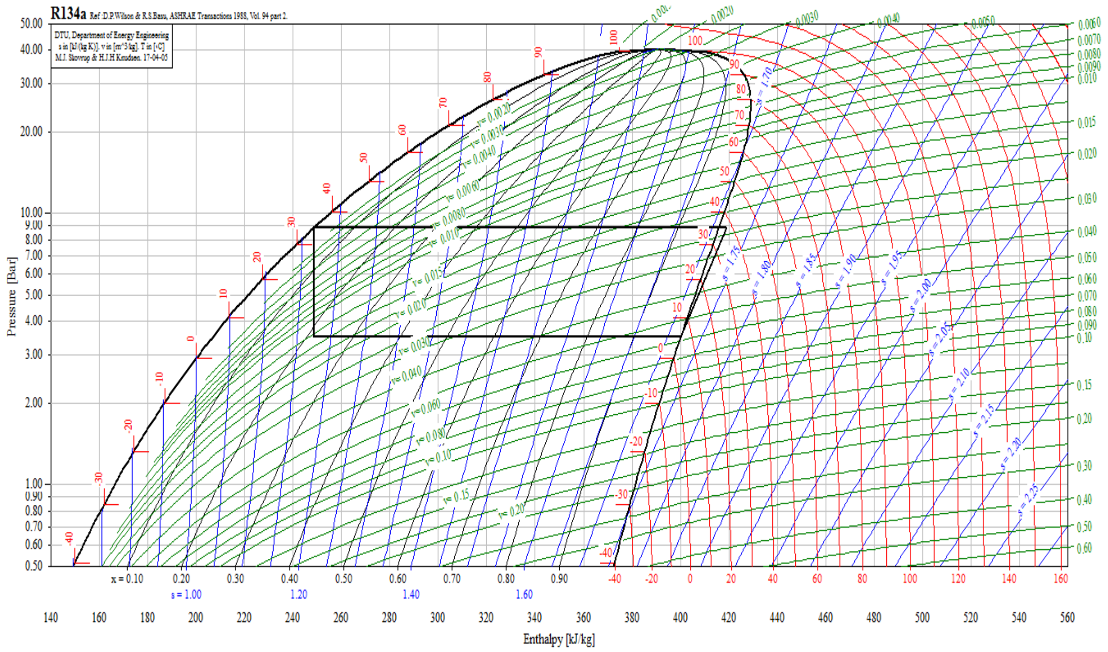


Figure 7.7: The cycle in the PH diagram

Table 7.8: TheValue from PH diagram

Values at points in cycle

Values at points 1-6,15 for the selected one stage cycle

Point	T	P	v	h	s
	[°C]	[bar]	[m^3/kg]	[kJ/kg]	[kJ/(kg K)]
1	4.999	3.496	0.058019	400.073	1.7194
2	37.960	8.868	0.023373	419.252	1.7194
3	37.960	8.868	0.023373	419.252	1.7194
4	35.000	8.868	N/A	248.748	N/A
5	N/A	3.496	N/A	248.748	N/A
6	5.000	3.496	0.058015	400.073	1.7194
15	N/A	8.868	N/A	248.748	N/A

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$q_e = h_1 – h_5$

$= 400.073 – 248.748 = 151.325$ k/kg .

$q_c = h_2 – h_4$

$= 419.252 – 248.748 = 170.504$ w .

$w_c = h_2 – h_1$

$= 419.252 – 400.073 = 19.179$ w

$Q_e = m^o{}_R q_e$

$m^o{}_R = Q_e/q_e = 3.75/151.315 = 0.02476$ kg/s .

$Q_c = m^o{}_R \ q_c$

$=0.02476 * 170.504 = 4.225$kW .

$P = m^o w_c$

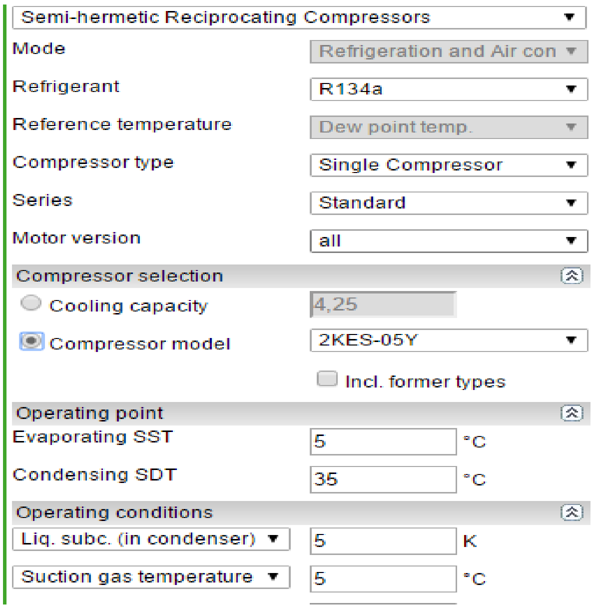
$=0.02476 * 19.179$

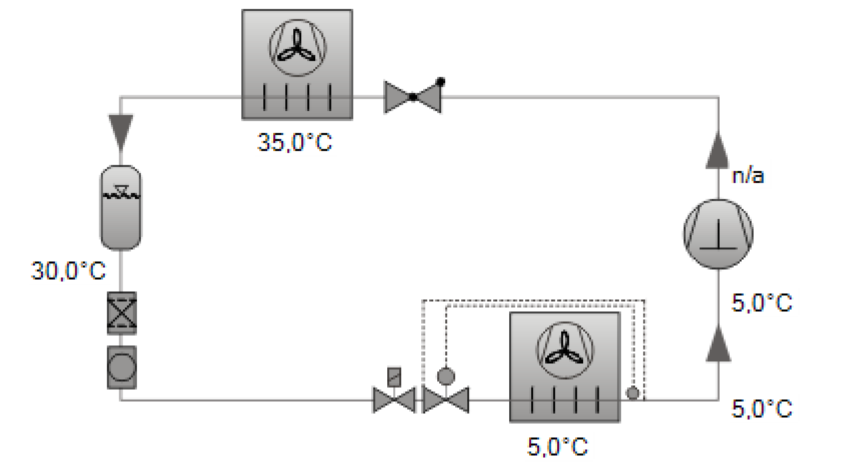
$= 0.474$ kW = 0.62hp {hp : horsepower } .

Coefficient of performance (cop) = q_e / w = 151.315/19.179 = 7.889

7.1.3 Compressor selection

By Using BITZER-Software





7.1.4 Condensers selection:

By Using BITZER-Software

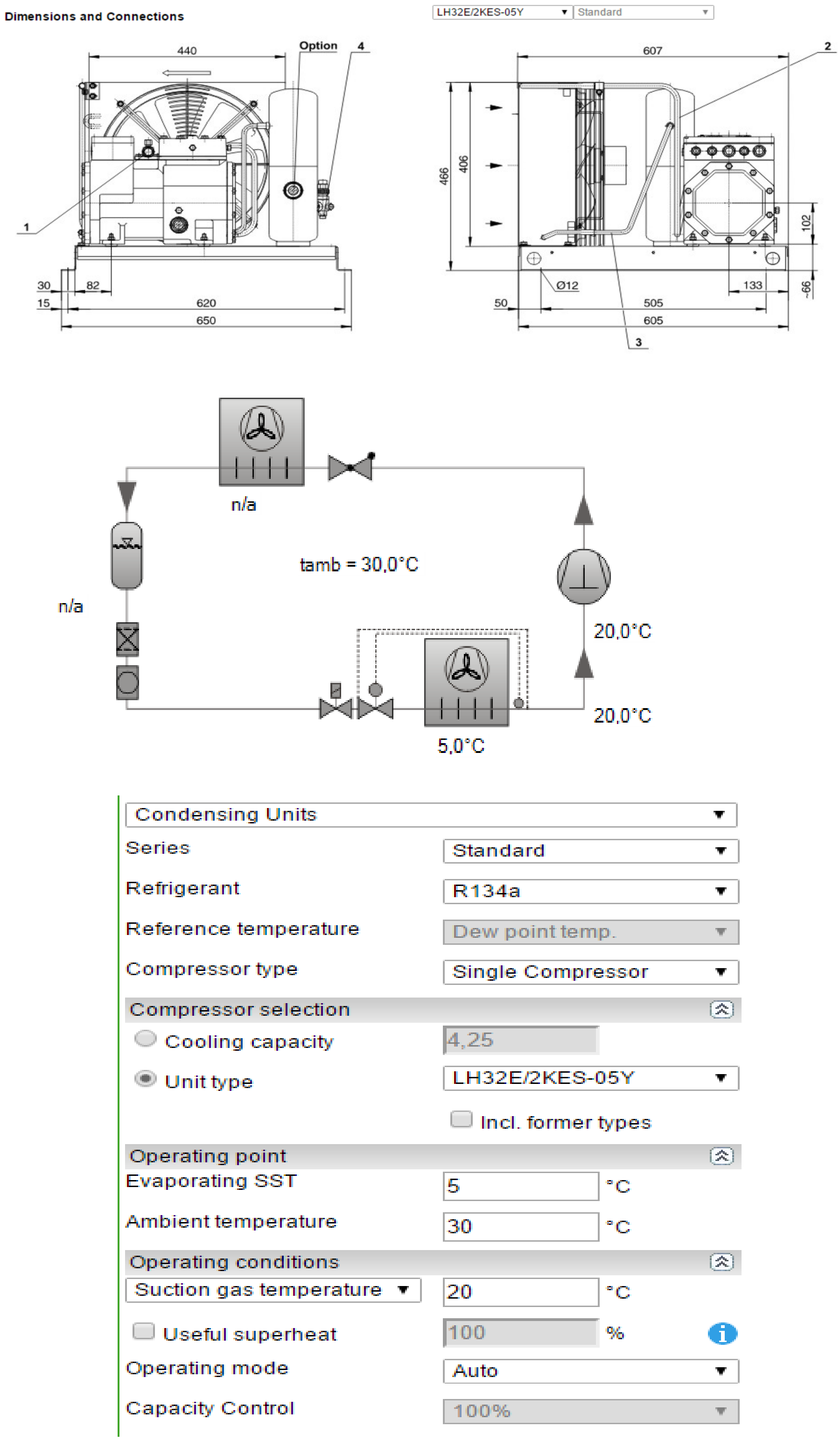


Figure 7.9: Condenser data sheet

7.2 Cooling Load Calculation for freezer

7.2.1 Use this law to find Cooling Load Calculation:

$Q = U\ A\ \Delta T$

When:

Q : Cooling Load in [kW] .

U: Overall heat transfer coefficient in [$W/m^2.\ ^\circ C$]

$$U = \frac{1}{\frac{1}{h_{in}} + \sum \frac{\Delta X}{K} + \frac{1}{h_{out}}}$$

h_{in} : is the Inside Convection Coefficient { 9.37 $W/m^2.^oC$ } .

h_{out} : is the Outside Convection Coefficient { 22.7 $W/m^2.^oC$ } .

K: is the thermal conductivity for material in [$W/m.^oC$] .

ΔX: is the Thickness of the material in [m] .

A: Surface area in [m^2] .

A=Length * Width.

ΔT: The difference in temperature [^oC] .

1. Internal Wall-1 :

$\Delta T = T_{Room} - T_{in}$

= 28– -18 = 46 ^oC .

$A = A_{\text{Internal Wall}} - A_{\text{Door}}$

= (2 * 3.8) -(2 * 1)

= 5.6m^2 .

$Q_{\text{Internal Wall-1}}$ = 0.038 * 46 * 5.6= 0.015 kW .

2. Internal Wall-2 :

$\Delta T = T_{Room} - T_{in}$

$= 24 - -18 = 42^oC$.

$A = A_{\text{Internal Wall-2}}$

$= (4 * 3.8)$

$= 15.2m^2$.

$Q_{\text{Internal Wall-2}} = 0.152 * 42 * 15.2 = 97W = 0.97\ kW$.

3. Internal Wall-3 :

$\Delta T = T_{Room} - T_{in}$

$= 24 - -18 = 42^oC$.

$A = A_{\text{Internal Wall-2}}$

$= (2 * 3.8)$

$= 7.6m^2$.

$Q_{\text{Internal Wall-2}} = 0.076 * 42 * 7.6 = 64W = 0.064\ Kw$

4. Internal Wall-4 :

$\Delta T = T_{Room} - T_{in}$

$= 5 - -18 = 23^oC$.

$A = A_{\text{Internal Wall-2}}$

$= (4 * 3.8)$

$= 15.2m^2$.

$Q_{\text{Internal Wall-2}} = 0.114 * 23 * 15.2 = 88W = 0.088\ kW$

5. Ground:

$\Delta T = T_{ground} - Tin$

$= 24 - -18 = 42^oC$.

A = (2 * 4)

$= 8m^2$.

$Q_{ground} = 0.399 * 42 * 8 = 0.134kW$.

6. Ceiling:

$\Delta T = 28 - T_{in}$

$= 24 - -18 = 42^oC$.

$A = 2 * 4 = 8\ m^2$.

$Q_{Ceiling} = 0.55 * 42 * 8 = 0.184kW$.

7. Door:

$\Delta T = T_{Room} - T_{in}$

$= 24 - -18 = 42^oC$.

$A = 2 * 1 = 2\ m^2$.

$Q_{Door} = 0.345 * 42 * 2 = 0.087kW$.

Use this law to calculate cooling load for rooms:

$Q_{Total} = Q_{Envelope} + Q_{Product} + Q_{Air} + Q_{Service} + Q_{Respiration}$.

$Q_{Envelope}$: heat gain from walls , doors , windows , floor and ceiling .

$Q_{Envelope} = Q_1 + Q_{Solar}$.

$Q_{Envelope} = Q_{Wall} + Q_{Door} + Q_{ground} + Q_{Ceiling} + Q_{Solar}$

$Q_{Envelope} = 0.015+0.074+0.088+0.134+0.184+0.087+0 = 0.6kW$.

$Q_{Product}$ Calculation :

$Q_{Product} = Q_2^* + Q_2^{**} + Q_{Packaging}$.

$Q_2^* = m^o cp\ \Delta T$.

m^o = (m $_{Product}$ / Time Cooling)

Time Cooling: Working Time Per a Day.

$\Delta T = \Delta T_{sur} = 30\ ^oC$.

Table 7.9: Product Used

Product	cp	m	m*	Q2*
Beef	1.59	120	0.002083	0.099375
Chicken	1.63	120	0.002083	0.101875
Clams	1.51	40	0.000694	0.031458
Codfish	1.63	70	0.001215	0.059427
Halibut	1.67	80	0.001389	0.069583
Ice cream	1.67	30	0.000521	0.026094
Lamp	1.55	50	0.000868	0.040365
Oysters	1.72	60	0.001042	0.05375
Reindeer	1.55	40	0.000694	0.032292
Salmon	1.55	80	0.001389	0.064583
Sausage	1.34	100	0.001736	0.069792
sword fish	1.67	80	0.001389	0.069583
Tripe	1.72	50	0.000868	0.044792
Veal	1.59	50	0.000868	0.041406
whitefish	1.63	60	0.001042	0.050938
	∑			0.855313

$Q_2^* = 0.855$ kW

$Q^{**}2 = (m/time)^*\Delta h + (m/time)^*cp^*\Delta T$

$= (1000/11^*3600)^*47+(1000/16^*3600)^*1.6^*(0--18)$

$=1.18$ KW $+0.5$KW $= 1.68$KW

Q $_{Packaging}$ = (m$_{Material}$ / Time Cooling) * cp * ΔT .

$m_{Material}$ = m * N .

m : is the mass of one pallet = 15 kg .

N : is the number of pallets in the room = 20.

$m_{Material}$ = 15 * 20 = 300 kg .

cp : is the Specific Heat for Pallet = 0.67 kJ/kg.K .

$\Delta T = \Delta T_{sur} = 30\ ^oC$.

$Q_{Packaging}$ = (300/ (4 * 16 * 3600)) * 0.67 * 30 = 0.105 kW .

$Q_{Product}$ = 0.855+ 1.68 + 0.105 = 2.535kW.

Q_{Air} Calculation :

$Q_{Air} = Q_{Infiltration} + Q_{Ventilation}$.

$Q_{Infiltration}$ = 0 kW.

$Q_{Ventilation} = Q_{Product} + Q_{People}$

$Q_{Product} = m^o * (hout - h_{in})$.

$Q_{Product}$ = 1.293 * (72 – 10) = 80.16 W = 0.08kW .

$Q_{People} = m^o * (h_{out} - h_{in})$ * (hour occupied / 24) *a

$Q_{People} = 6.66 * 10^{-3} * 55* (2/24) * 2 = 0.061\ W = 6.1 * 10^{-5}$ kW.

$Q_{Ventilation} = 0.08+ 6.1 * 10^{-5} = 0.08$ kW.

Q_{Air}= 0 + 0.08 = 0.08 kW.

$Q_{Service}$ Calculation:

$Q_{Service} = Q_{People} + Q_{Light}$.

$Q_{People} = n * Q_{Person}$ * (Working hours / 24)

Q_{People} = 2 * 0.275 * (2 / 24) = 0.046 kW .

$Q_{Light} = P_{Light} * CLF * N$

Q_{Light} = 24 * 0.88 * 2 = 42.24 W = 0.0422 kW

$Q_{Service}$ = + 0.046 + 0.0422 = 0.088 KW.

$Q_{Respiration}$ Calculation :

$Q_{Respiration} = m * q_{Rips}$

$Q_{Respiration}$: is the rate of respiration .

m : is the mass of the product in the room in [kg] .

q_{Risp} : Rate of heat given off Breathing product .

q_{Risp} = 0.029 . [Table 10-12] .

$Q_{Respiration}$ = 0.029 * 1000 = 29 W = 0.029 kW .

Consequently:

Q_{Total} = 0.9 + 2.535+ 0.08 +0.088+ 0.029 = 4.3kW .
Q_{Total} =4.3*F.S =4.3*1.5 = 6.5KW

From Cool pack:

Table 7.10: The cycle in the PH diagram

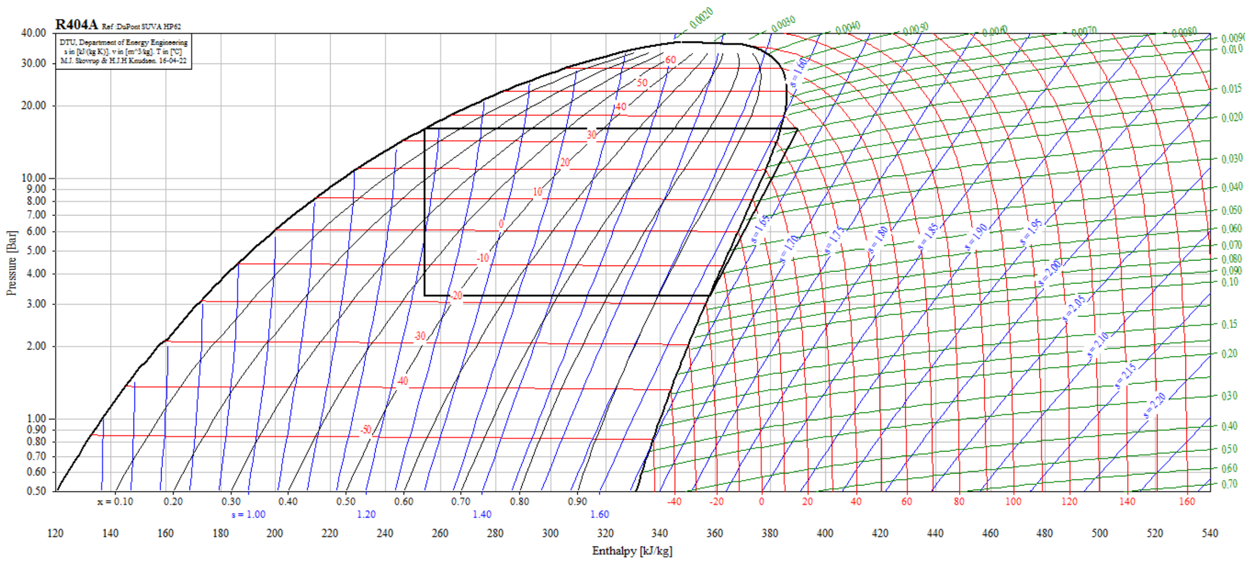


Table 7.11:The Value from PH diagram

Point	T	P	v	h	s
	[°C]	[bar]	[m^3/kg]	[kJ/kg]	[kJ/(kg K)]
1	-17.916	3.260	0.060907	357.822	1.6236
2	40.469	16.065	0.012189	389.924	1.6236
3	40.469	16.065	0.012189	389.924	1.6236
4	34.676	16.065	N/A	254.208	N/A
5	N/A	3.260	N/A	254.208	N/A
6	-17.916	3.260	0.060907	357.822	1.6236
15	N/A	16.065	N/A	254.208	N/A

$q_e = h_1 - h_5$

$= 357.822 - 254.208 = 103.14$ kJ/kg .

$q_c = h_2 - h_4$

$= 389.924 - 254.208 = 135.716$ kJ/kg .

$w_c = h_2 - h_1$

$= 389.924 - 357.822 = 32.102$ kJ/kg

$Q_e = m^o{}_R q_e$

$m^o{}_R = Q_e/q_e = 6.5/103.14 = 0.063$ kg/s .

$Q_c = m^o{}_R\ q_c$

$= 0.063 * 135.716 = 8.55$ kW .

$P = m^o w_c$

=0.063 *32.102

= 2.02 kW = 2.7hp{ hp : horsepower [electric] } .

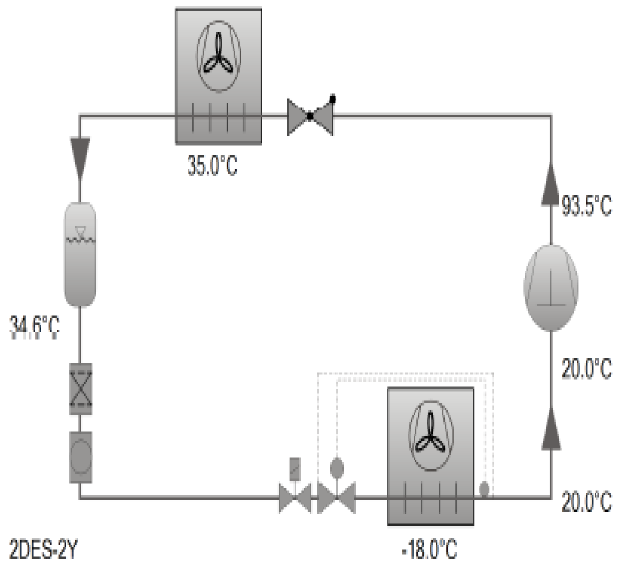
Coefficient of performance (cop) = q_e / w = 103.14/32.102 = 3.212

7.2.3Compressor selection:

By Using BITZER-Software

Input Values

Cooling capacity	6.50 kW
Mode	Refrigeration and Air conditioning
Refrigerant	R404A
Reference temperature	Dew point temp.
Evaporating SST	-18.00 °C
Condensing SDT	35.0 °C
Liq. subc. (in condenser)	0 K
Suction gas temperature	20.00 °C
Operating mode	Auto
Power supply	400V-3-50Hz
Capacity Control	100%
Useful superheat	100%



Result

Compressor	2DES-2Y-40S	2CES-3Y-40S
Capacity steps	100%	100%
Cooling capacity	5.89 kW	7.30 kW
Cooling capacity *	5.89 kW	7.30 kW
Evaporator capacity	5.89 kW	7.30 kW
Power input	2.46 kW	3.01 kW
Current (400V)	4.52 A	5.73 A
Voltage range	380-420V	380-420V
Condenser Capacity	8.35 kW	10.32 kW
COP/EER	2.40	2.42
COP/EER *	2.40	2.42
Mass flow	153.0 kg/h	189.6 kg/h
Operating mode	Standard	Standard
Discharge gas temp. w/o cooling	93.5 °C	92.9 °C

Figure 7.9: Compressor data sheet

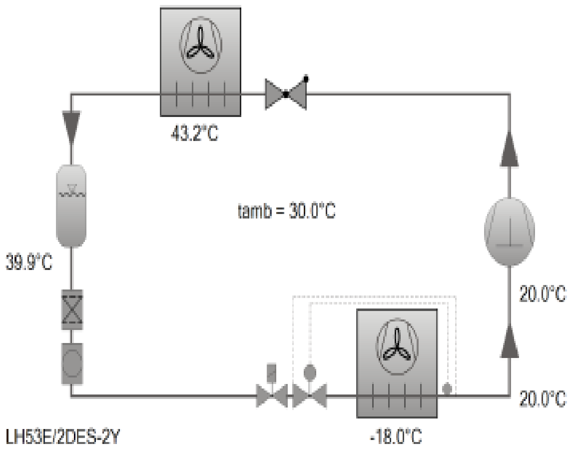
7.2.4Condensers selection:

By Using BITZER-Software

Compressor Selection: Condensing Units

Input Values

Cooling capacity	6.50 kW
Series	Standard
Refrigerant	R404A
Reference temperature	Dew point temp.
Evaporating SST	-18.00 °C
Ambient temp.	30.0 °C
Suction gas temperature	20.00 °C
Useful superheat	100%
Operating mode	Auto
Power supply	400V-3-50Hz
Capacity Control	100%



Result

Unit type	LH53E/2DES- 2Y-40S	LH64E/2DES- 3Y-40S	LH64E/2CES- 3Y-40S	LH84E/2CES- 4Y-40S
Capacity steps	100%	100%	100%	100%
Cooling capacity	5.22 kW	5.62 kW	6.72 kW	7.11 kW
Evaporator capacity	5.22 kW	5.62 kW	6.72 kW	7.11 kW
Power input *	2.79 kW	2.88 kW	3.56 kW	3.43 kW
Current (400V)	4.74 A	5.09 A	5.98 A	5.95 A
Voltage range	380-420V	380-420V	380-420V	380-420V
Mass flow	144.5 kg/h	148.6 kg/h	182.3 kg/h	185.9 kg/h
Condensing SDT	43.2 °C	39.5 °C	41.6 °C	38.5 °C
Liquid subcooling	3.00 K	3.00 K	3.00 K	3.00 K
Operating mode	Standard	Standard	Standard	Standard

Figure 7.9: Condenser data sheet