# Palestine Polytechnic University

## College of Engineering

# Design of Mechanical Systems for a Hotel building in Hebron city


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Abstract

The aim of the project is to design a complete mechanical system for a hotel which is located in Hebron city. This building consists of four floors with an area of 7500 . These services are certainly designed to verify human comfort. The project is going to provide an integrating service to that building in regard to the air conditioning, firefighting and plumbing systems ,In this project, air conditioning system type (VRF) is used since it is efficient and economical

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# CHAPTER ONE

# INTRODUCTION

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**1.1 Introduction**

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## 1.1 Introduction:

Throughout the ages the human beings tried to improve their lives to be easier and more comfortable, and as the Wisdom say: “The necessity is the mother of invention” the engineers always try to meet the needs of humans to achieve the welfare of their lives.

So HVAC engineers develop the mechanical services systems and technologies to achieve the comfort, which the humans need in the buildings.

For this reason the mechanical system will be designed and documented in this project for FOURSEASONS hotel in Hebron city in Palestine.

## 1.2 Project overview:

Due to hot summer and cold winter, and sometimes the extreme weather in Hebron, air conditioning system must be installed in each building in order to people feel comfortable.

Water in Palestine is not abundant and it is vital for every living thing especially human beings. The daily consumption of water is very high and some of it goes useless. So, in this project, the outlet water that goes from all fixture units except water closet and urinal are treated and reused for toilet flushing which consumes is 35% of the total daily consumption.

Because the safety is first in all places. Without fire alarms, a lot of things may be lost like people and expensive things. In this case, fire-fighting system should be installed in the building.

## 1.3 Project objectives:

The objectives of the project is to study and design the different mechanical systems needed inside the hotel building, and swimming pool, this includes the following main topics:

1) Design the mechanical systems inside the hotel building.
2) Theoretical calculations and design of HVAC system.
3) Theoretical calculations and design of plumping system.

4) Theoretical calculations and design of swimming pool system.
5) To be familiar with the mechanical drawings for different mechanical systems.
6) Firefighting, hot & cold water system.

### 1.4 Project choice and justifications:

1. This project will create sufficient experiences for the students, which would assist them to have an employment opportunity after graduation.
2. Such projects provide the opportunity to review what have been studied in the last five years in college of engineering.

### 1.5 Symbols:

- HVAC: Heating Ventilation and Air Conditioning.
- VRV: Variable Refrigeration Flow.
- WSFU: is water supply fixture unit it's used to calculate the portable maximum water demand for the building.
- Dfu: Drainage fixture unit it's used to calculate the provision of drainage system.
- Gpm: gallon per minute.
- COP: coefficient of performance

## 1.6 Time table:

**Table 1.1: Time Table**

| Activity / Week | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Selection of the project | | | | | | | | | | | | | | | |
| Search about information | | | | | | | | | | | | | | | |
| Search for previous projects | | | | | | | | | | | | | | | |
| Search for video for the systems in the website | | | | | | | | | | | | | | | |
| Heating & Cooling Load Calculations | | | | | | | | | | | | | | | |
| WSFU Calculations | | | | | | | | | | | | | | | |
| Studying the Fire Fighting Systems | | | | | | | | | | | | | | | |
| Project Documentation | | | | | | | | | | | | | | | |
| Project Printing | | | | | | | | | | | | | | | |

# CHAPTER TWO

# HEATING LOAD CALCULATIONS

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**2.1 Introduction**

**2.2 Human comfort**

**2.3 Calculation of overall heat transfer coefficient (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:

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

Where:

$\Delta X$: 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** | 0.1 | 1.75 | 0.057 |
| 3 | **Polyurethane** | 0.03 | 0.04 | 0.750 |
| 4 | **Cement break** | 0.07 | 0.9 | 0.077 |
| 5 | **Plaster** | 0.02 | 1.4 | 0.014 |

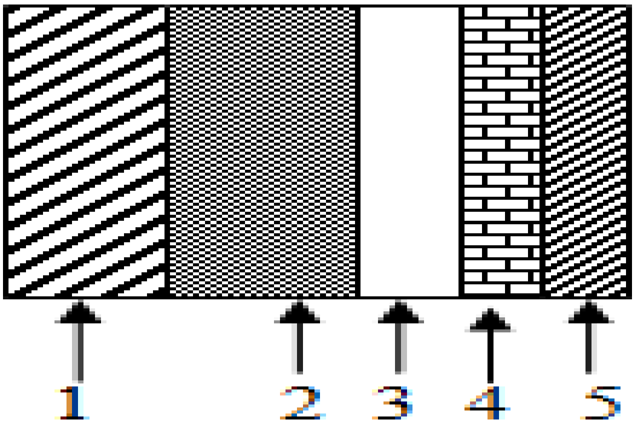


**Figure 2.1: External wall construction**

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

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

$$= \frac{1}{0.13 + \frac{0.05}{2.2} + \frac{0.1}{1.75} + \frac{0.03}{0.04} + \frac{0.07}{0.9} + \frac{0.02}{1.4} + 0.04}$$

$=0\ .91(W/m^2.°C)$.

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 | 0.100 |
| 3 | **Plaster** | 0.02 | 1.4 | 0.014 |

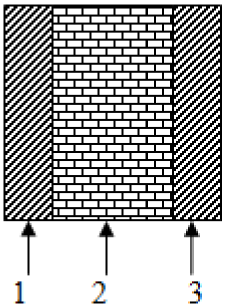


**Figure 2.2: internal wall construction**

$$U_{in} = \frac{1}{R_{in} + \frac{\Delta x_{Brick}}{k_{Brick}} + 2 * \left(\frac{\Delta x_{plaster}}{k_{plaster}}\right) + R_{in}}$$

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

$$= 2.57 (W/m^2.\ °C).$$

3- For celling

**Table 2.3: Construction of celling**

| Material | $\Delta X$(m) | k(W/m.°C) | R($m^2$. °C/W) |
|---|---|---|---|
| Asphalt mix | 0.02 | 0.70 | 0.028 |
| Concrete | 0.05 | 1.75 | 0.028 |
| Reinforced concrete | 0.05 | 1.75 | 0.028 |
| Plaster | 0.02 | 1.4 | 0.014 |
| Hollow brick | 0.2 | 0.95 | 0.210 |
| Polyurethane | 0.03 | 0.04 | 0.750 |

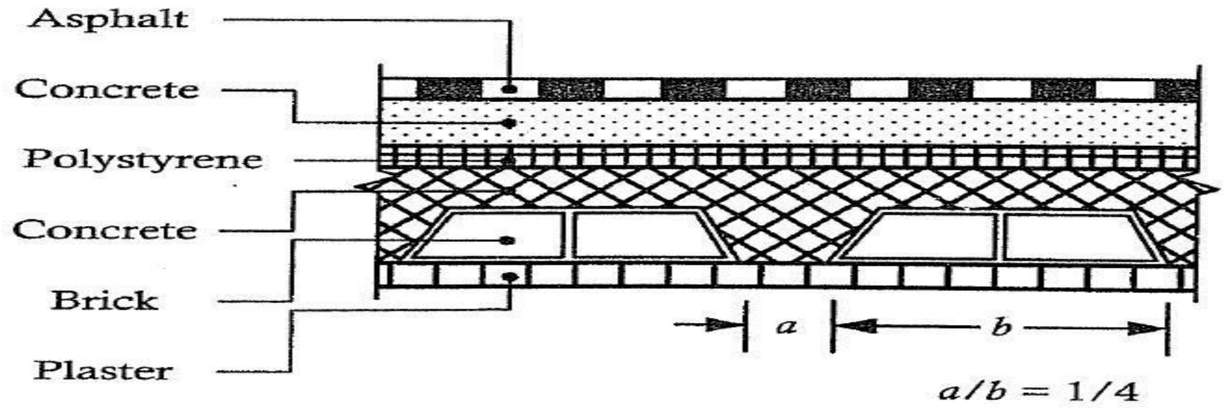


**Figure 2.3: Ceiling construction**

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).

$$U_1 = \frac{1}{R_{in} + \frac{\Delta x_{asph.}}{k_{asph.}} + \frac{\Delta x_{conc.}}{k_{conc.}} + \frac{\Delta x_{poly.}}{k_{poly.}} + \frac{\Delta x_{conc.}}{k_{conc.}} + \frac{\Delta x_{Brick}}{k_{Brick}} + \frac{\Delta x_{Plaster}}{k_{Plaster}} + R_{out}}$$

$$= \frac{1}{0.1 + \frac{0.02}{0.70} + \frac{0.05}{1.75} + \frac{0.03}{0.04} + \frac{0.05}{1.75} + \frac{0.2}{0.95} + \frac{0.02}{1.4} + 0.04}$$

= 0.832 (W/$m^2$. °C).

Similarly, $U_2$ = 1.01(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 | 0.10 | 1.05 | 0.095 |
| Mortar | 0.02 | 0.16 | 0.125 |
| Sand layer | 0.1 | 0.7 | 0.142 |

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

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

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

$$= 1.62\ (W/m^2.\,°C).$$

5- For glass

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

6- For door

From table (A-29) , $Ud = 3.6\ (W/m^2.\,°C)$ 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:

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

Where:

$Q$ : Is the heat transfer rate. [kW]

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

$\Delta T$: Is the difference between the inside and outside temperatures

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

### 2.4.2 Total heat load calculations

**Total heat load calculations for the sample room:**

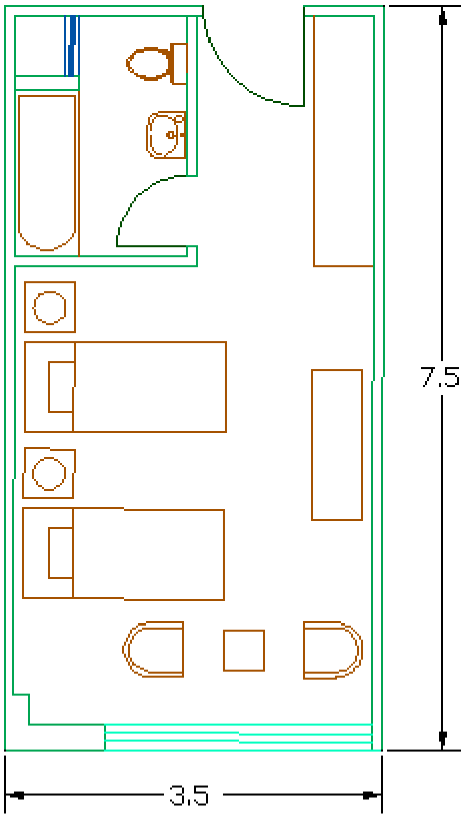


**Figure 2.4: Sample room**

**Heat loss through ceiling ($Q_c$):**

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

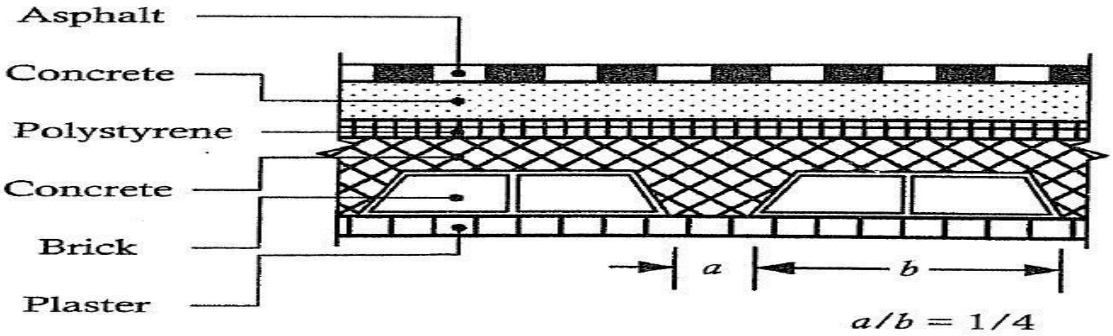


**Figure 2.5: Ceiling construction**

The area $A_1$ is equal to:

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

$$= \frac{4}{5}(3.5*7)$$

$$= 19.6 \text{ m}^2$$

And the area $A_2$ is equal to:

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

$$= \frac{1}{5}(3.5*7)$$

$$= 4.9 \text{ m}^2$$

$$Q_c = U_c A_c (T_i - T_o)$$

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

$$Q_c = (0.832 \times 4.9 + 1.01 \times 19.6)(24 - 4.7)$$

$$Q_c = 461.7 \text{ W}$$

**Heat loss through walls ($Q_w$):**

The external wall area is

$A_{w,ex}$ = (3.5×3.8)-(2×3.8)

=5.7 $m^2$

The heat loss from external wall is

$Q_{w,ex} = (U_{w,ex} A_{w,ex})(T_i - T_o)$

= (5.7×0 .91) (24-4.7)

= 100.10 W

There are two spaces beside the guest room are unconditioned, so heat loss from unconditioned walls:

$Q_{w,un.} = Q_{w,un.}$

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

$A_{w,un.}$ = (3.5× 3.8)-(0.9×2)

=11.5 $m^2$

$Q_{w,un.} = (U_{un.} A_{w,un.})(Ti - T_{un.})$

= (2.57×11.5) (24-9.65)

= 424.11 W

Now, the total heat loss from walls is

$Q_{w,tot} = Q_{w,ex} + Q_{w,un.}$

$= 100.10 + 424.11$

$= 524.21$ W

**Heat loss through windows ($Q_g$):**

$Q_g = U_g A_g (T_i - T_o)$

$= (3.2)(2\times3.8)(24-4.7)$

$= 469$ W

**Heat loss through external door ($Q_d$):**

$Q_d = U_d A_d (T_i - T_{un.})$

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

**Heat loss through infiltration ($Q_{inf}$):**

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

$$Q_{inf,g} = \frac{1250}{3600} Vf (T_i - T_o) \quad (2.4)$$

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)

$$Vf = K \times L[0.613(S_1 \times S_2 \times V_0)^2]^{2/3} \qquad (2.5)$$

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.

$V$ : 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

$V_0$=1.4(m/s) from Palestinian code

And the window is sliding, then:

L = [(1.5× 2) + (2×1)]

= 5 m

Therefore;

$\dot{V}f$ = (0.43) (5) $[0.613(1 \times 0.94 \times 1.4)^2]^{2/3}$

= 2.23 $m^3/h$

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

Through window

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

$$= \frac{1250}{3600} (2.23(\ )24 - 4.7)$$

$$= 14.9 \text{ W}$$

Through door

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

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

$$L = [(2 \times 0.9) + (2 \times 2)]$$

$$= 5.8 \text{ m}$$

Therefore;

$$\dot{V}f = (0.43) \ (5.8) \ [0.613(1 \times 0.94 \times 1.4)^2 \ ]^{2/3}$$

$$= 2.59 \text{ m}^3/\text{h}$$

$$Q_{inf,d} = \frac{1250}{3600} \dot{V}f \ (T_i - T_o)$$

$$= \frac{1250}{3600} (2.59(\ )24 - 4.7)$$

$$= 17.3\text{W}$$

$$Q_{inf.,tot} = Q_{inf.,g} + Q_{inf.,d}$$

$$= 14.9 + 17.3$$

$$= 32.25 \text{ W}$$

**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:

$$Q_{vent} = \dot{m} \times C_{p_{air}} \times (T_o - T_{in}) \quad (2.6)$$

Where:

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

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

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

= 3.5×7×10 = 245 L/s = 0.245 $m^3$/s.

$v_o$= 0.791 $m^3$/kg.

$\dot{m}$ = 0.309kg/s.

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

$Q_{vent.}$ = 0.309×1.005 × (24- 4.7) = 6 W.

**The total heat loss from the sample room is**

$Q_{tot} = Q_{w,tot} + Q_c + Q_g + Q_d + Q_{inf.,tot} + Q_{vn}$

= 524.21 + 461.7 + 469 + 93 + 32.25 + 6

= 1586.16 W

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

$Q_{tot}$ = 1586.16 × 1.15 = 1824.084 W.

Heating Load Summary is listed in the following table:

**Table 2.6: Heating load for each floor in the building**

| Floor | Q(kW) |
|---|---|
| Ground | 67.75 |
| First | 68.68 |
| Secon | 64.32 |
| Third | 64.32 |
| Fourth | 76.65 |

# CHAPTER THREE

# COOLING LOAD CALCULATION

## 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

The total cooling load of a structure involves:

1. Sensible heat gain through walls, floors and roof.
2. Sensible heat gain through windows.
3. Sensible heat and latent heat gain from ventilation.
4. Sensible and latent heat due occupancy.
5. Sensible heat gain from the equipment.

### 3.2.1 Cooling load calculations:

**Total cooling load calculations for the sample room:**

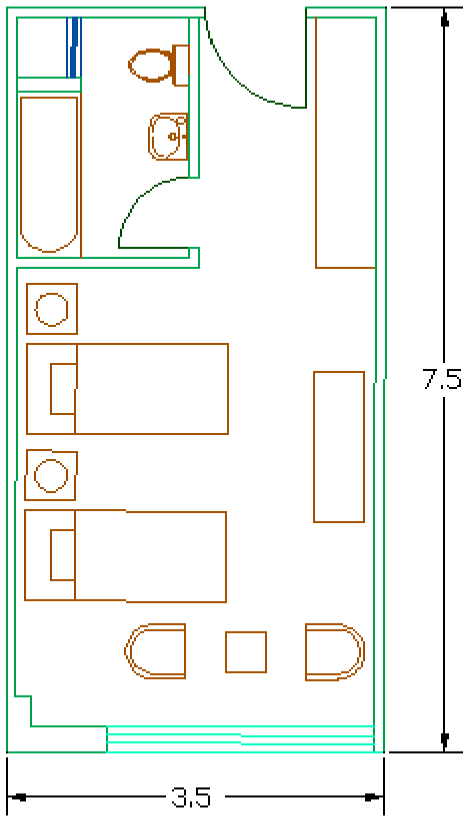


**Figure 3.1: Sample room**

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 is calculated from the following equation:

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

Where:

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

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

Where:

CLTD: cooling load temperature difference, ˚C , from Table (A-3)

LM: latitude correction factor, from Table (A-25)

k: color adjustment factor .

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

f: attic or roof fan factor.

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

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

Where:

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

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

$T_{max}$ = 35 ˚C and $T_{min}$ = 13.8 ˚C are obtained from Palestinian Code.

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

$T_{o,m}$ = 24.8 ˚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.

$$(CLTD)_{corr.} = (14 + 0.5)\ 0.83 + (25.5 - 24) + (24.8 - 29.4)\ 1$$

$$= 8.935˚C$$

$$Q_{Roof} = (U_1 A_1 + U_2 A_2)\ (CLTD)_{corr} \quad (3.4)$$

$$Q_{Roof} = (0.834 \times 4.9 + 19.6 \times 1.012)\ (8.935)$$

$$= 213.74 \text{ W}$$

**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.

$A_E = 5.7\ m^2$

$(CLTD)_{corr., E} = (15+0)\ 0.83 + (25.5-24) + (24.8-29.4) \times 1$

$= 9.35\ ^\circ C$

$\dot{Q}_{Wall} = \dot{Q}_E = 2.94 \times 5.7 \times 9.35$

$= 156.68\ W \quad = 0.2204\ kW$

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

Solar radiation which falls on glass has three components 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:

$$Q_{Glass} = Q_{tr.} + Q_{conv.} \tag{3.5}$$

Where:

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

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

SHG: 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 : which Represent the effect of the internal walls, floor, and furniture on the instantaneous cooling load, and 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:

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

SHG in $W/m^2$ … from Table (A-12)

$A = 7.6\ m^2$

SHG = 691 W/m m

SC = 0.57… reflective double from Table A (2.14)

CLF = 0.31 at 14:00 o'clock … from Table A (2.16)

$Q_{tr.\ N} = 7.6 \times 691 \times 0.57 \times 0.31$

$= 927.95$ W

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

Where:

U: Over all heat transfer coefficient of glass (W/m².K).

A: Out windows Area of heat conduction. (m²).

$(CLTD)_{corr.}$: 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

$Q_{conv.\,N}$ = 170.24 W

$Q_{Glass}$ = 927.95 + 170.24

= 1098.19 W

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

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

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

Where:

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

A: floor area = 24.5 m$^2$

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

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

$Q_{Lt.}$ = 30 × 24.5 × 0.82

= 602.7 W

= 0.708 kW

**Heat gain due to infiltration ($Q_f$):**

As the same way in heating load

$$Q_{inf,g}= \frac{1250}{3600} Vf\,(T_i\text{-}T_o) \quad (3.9)$$

Where:

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

$$Vf = K\times L[0.613(S_1\times S_2\times V_0)^2]^{2/3} \quad (3.10)$$

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.

$V$: 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

$V_0$=1.4(m/s) from Palestinian code

And the window is sliding , then:

L = [ (1.5× 2) + (2×1)]

= 5 m

Therefore;

$\dot{V}f$ = (0.43) (5) [0.613( 1 × 0.94 × 1.4)$^2$ ] $^{2/3}$

= 2.23 m$^3$/h

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

= $\frac{1250}{3600}$ (2.23( )30 – 24)

= 4.6

Through door

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

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

L = [ (2× 0.9) + (2×2)] = 5.8 m

Therefore;

$\dot{V}f$ = (0.43) (5.8) [0.613( 1 × 0.94 × 1.4)$^2$ ]$^{2/3}$

= 2.59 m$^3$/h

$Q_{inf,d}$= $\frac{1250}{3600}\dot{V}f$ ($T_i$ - $T_o$)

= $\frac{1250}{3600}$ ( 2.59 )(30 +24)

= 16.1W

$Q_{inf.,tot}$ =$Q_{inf.,g}$+ $Q_{inf.,d}$

= 4.6 + 16.1

= 20.7 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(2.18)

No. of people = 2

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

$Q_{sensible} = 70 \times 2 \times 0.84$

$= 117.6$ W

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

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

$Q_{latent} = 44 \times 2$

$= 88$W

$Q_{oc.} = 117.6 + 88$

$= 205.6$ 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:

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

Where:

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

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

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

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

$A_{room} = 24.5\ m^2$

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

rate of ventilation air = 24.5 × 10

= 245 L/s

= 0.245 $m^3/s$

$v_o = 0.879 m^3/kg$

$\dot{m}$ = 0.245/0.879

= 0.278 kg/s

$Q_{vn.}$ = 0.278 × 1.005 × (30 - 24)

= 1.67 W

**The total heat loss from Sample Room is:**

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

= 4299.28 W

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

$Q_{Tot}$ = 4299.28*1.15

= 4944.17 W

Cooling Load Summary is listed in the following table:

**Table 3.1: Cooling load for each floor in the building**

| Floor | Q(kW) |
|---|---|
| Ground | 105.36 |
| First | 108.7 |
| Secon | 103.4 |
| Third | 103.4 |
| Fourth | 143.5 |

# CHAPTER FOUR

# PLUMBING SYSTEM

---

**4.1 Introductions**

**4.2 Water system**

**4.3 Pipe size calculations**

**4.4 Water tank volume**

**4.5 pump selection**

**4.6 Sanitary Drainage System**

**4.7 Calculating the volume of tanks for the sanitation 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 uses, 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, fire fighting, bathing, and irrigation.

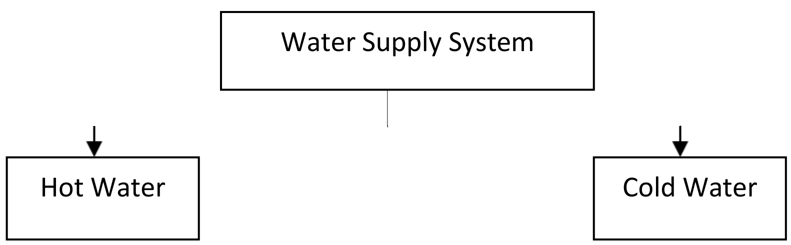


**Figure 4.1: Water supply system**

### 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 | Clothes washer | Lavatory | Water closet | bathtub | Bidet |
|---|---|---|---|---|---|
| Ground floor | 6.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| First floor | 0.0 | 3.0 | 2.0 | 3.0 | 1.0 |
| Second floor | 0.0 | 3.0 | 2.0 | 3.0 | 1.0 |
| Third floor | 0.0 | 3.0 | 2.0 | 3.0 | 1.0 |
| Forth floor | 0.0 | 3.0 | 2.0 | 3.0 | 1.0 |
| Total | 6.0 | 12.0 | 8.0 | 12.0 | 4.0 |

The figure 4.2 shows the first riser diagram .

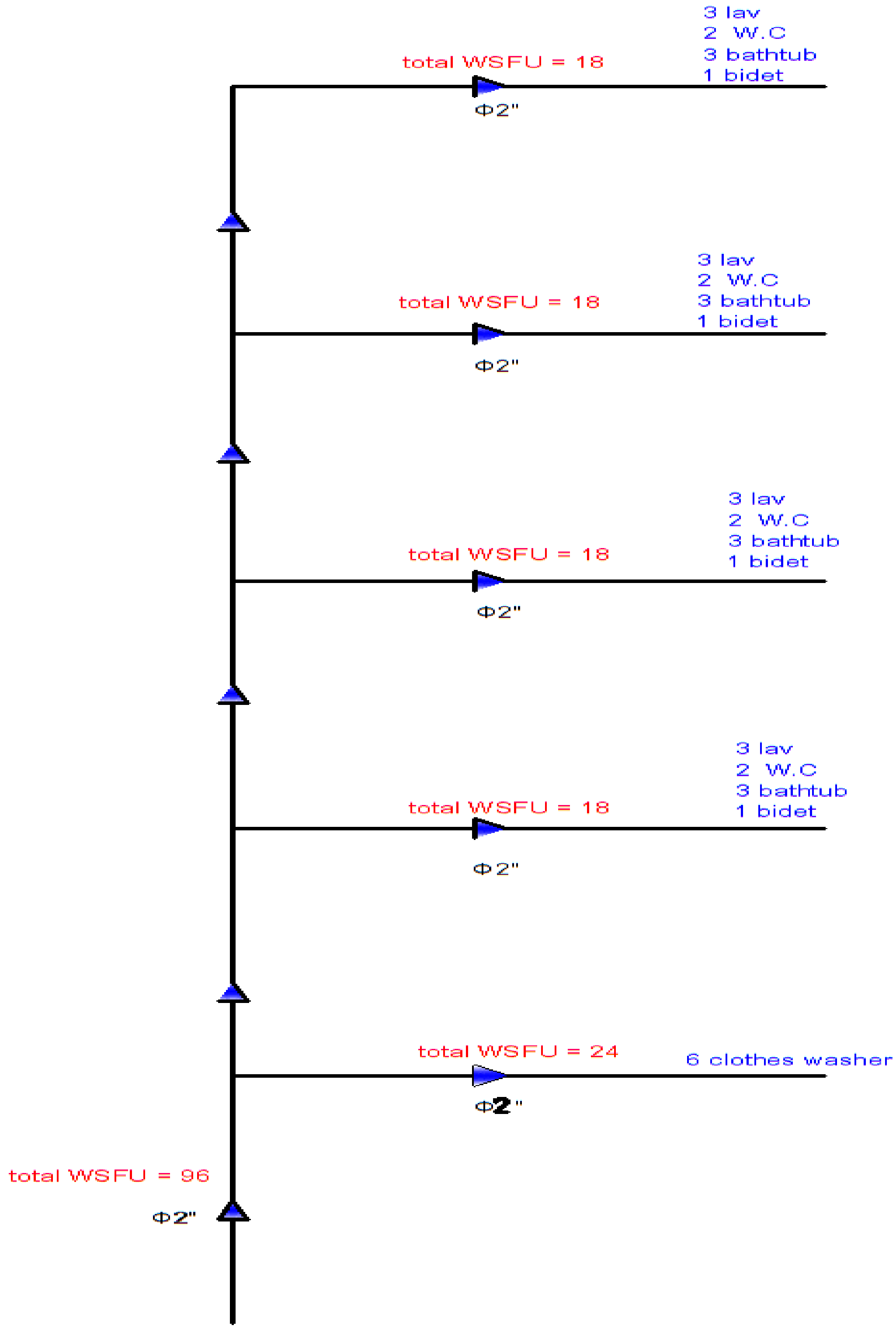


**Figure 4.2: First riser diagram**

**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 |
|---|---|---|---|---|---|---|---|
| Clothes washer | 6.0 | 4.0 | 24.0 | 24.0 | 0.0 | 24.0 | 0.0 |
| Lavatory | 12.0 | 1.0 | 12.0 | $1 \times \frac{3}{4} = 0.75$ | $1 \times \frac{3}{4} = 0.75$ | 9.0 | 9.0 |
| Water closet | 8.0 | 3.0 | 24.0 | 24.0 | 0.0 | 24.0 | 0.0 |
| bathtub | 12.0 | 2.0 | 24.0 | $2 \times \frac{3}{4} = 1.5$ | $2 \times \frac{3}{4} = 1.5$ | 18.0 | 18.0 |
| Bidet | 4.0 | 3.0 | 12.0 | 12.0 | 0.0 | 12.0 | 0.0 |
| Total WSFU | - | - | 96.0 | - | - | 87.0 | 27.0 |

**WSFU at the fifth riser**

Tables (4.3, 4.4) below show the total numbers of fixture units and the total water supply fixture unit (WSFU) for the fifth riser.

**Table 4.3: Fixture unit's number of the fifth riser in each floor**

| Fixture type Floor | Lavatory (private) | Lavatory (general) | Water closet (private) | Water closet (general) | bathtub | bidet |
|---|---|---|---|---|---|---|
| Ground floor | 0 | 3 | 0 | 5 | 0 | 2 |
| First floor | 4 | 0 | 4 | 0 | 4 | 0 |
| Second floor | 4 | 0 | 4 | 0 | 4 | 0 |
| Third | 4 | 0 | 4 | 0 | 4 | 0 |
| Forth floor | 4 | 0 | 4 | 0 | 4 | 0 |
| Total | 16 | 3 | 16 | 5 | 16 | 2 |

Figure 4.3 shows the fifth riser diagram.

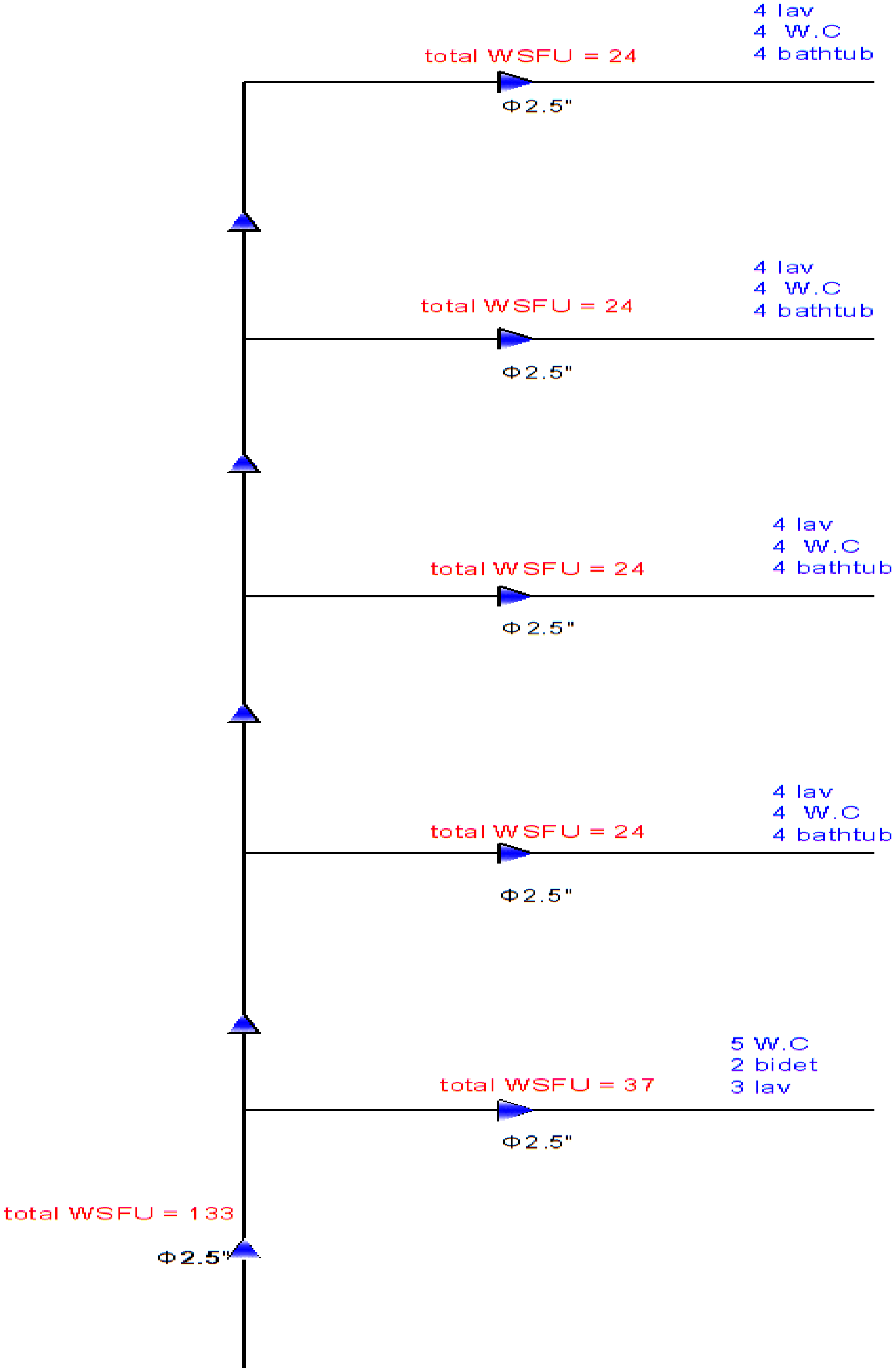


**Figure 4.3: Fifth riser diagram**

**Table 4.4: Total WSFU of the fifth riser**

| Fixture Type | No .OF FU | WSFU | Total WSFU | Cold WSFU | Hot WSFU | Total Cold | Total Hot |
|---|---|---|---|---|---|---|---|
| Lavatory (private) | 16 | 1 | 16 | $1 \times \frac{3}{4} = 0.75$ | $1 \times \frac{3}{4} = 0.75$ | 12 | 12 |
| Lavatory (general) | 3 | 2 | 6 | $2 \times \frac{3}{4} = 1.5$ | $2 \times \frac{3}{4} = 1.5$ | 4.5 | 4.5 |
| Water closet (general) | 5 | 5 | 25 | 25 | 0 | 25 | 0 |
| Water closet (private) | 16 | 3 | 48 | 48 | 0 | 48 | 0 |
| bathtub | 16 | 2 | 32 | $2 \times \frac{3}{4} = 1.5$ | $2 \times \frac{3}{4} = 1.5$ | 24 | 24 |
| bidet | 2 | 3 | 6 | 6 | 0 | 0.0 | 0.0 |
| Total WSFU | - | - | 133 | - | - | 119.5 | 40.5 |

**Table 4.5: Total WSFU of each cold water riser**

| Riser | Total WSFU |
|---|---|
| 1st riser section | 87 |
| 2nd riser section | 63 |
| 3rd riser section | 84 |
| 4th riser section | 42 |
| 5th riser section | 119.5 |
| 6th riser section | 92.5 |
| 7th riser section | 75 |
| Total | 563 |

**Table 4.6: Total WSFU of each hot water riser**

| Riser | Total WSFU |
|---|---|
| 1$^{st}$riser section | 27 |
| 2$^{nd}$riser section | 27 |
| 3$^{rd}$ riser section | 36 |
| 4$^{th}$ riser section | 18 |
| 5$^{th}$ riser section | 40.5 |
| 6$^{th}$ riser section | 31.5 |
| 7$^{th}$ riser section | 39 |
| Total | 219 |

## 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 indicated that 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 of four floors and basement (floor to floor height is 3.8 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 18 m.

The figure (4.4) shows the static head of the building

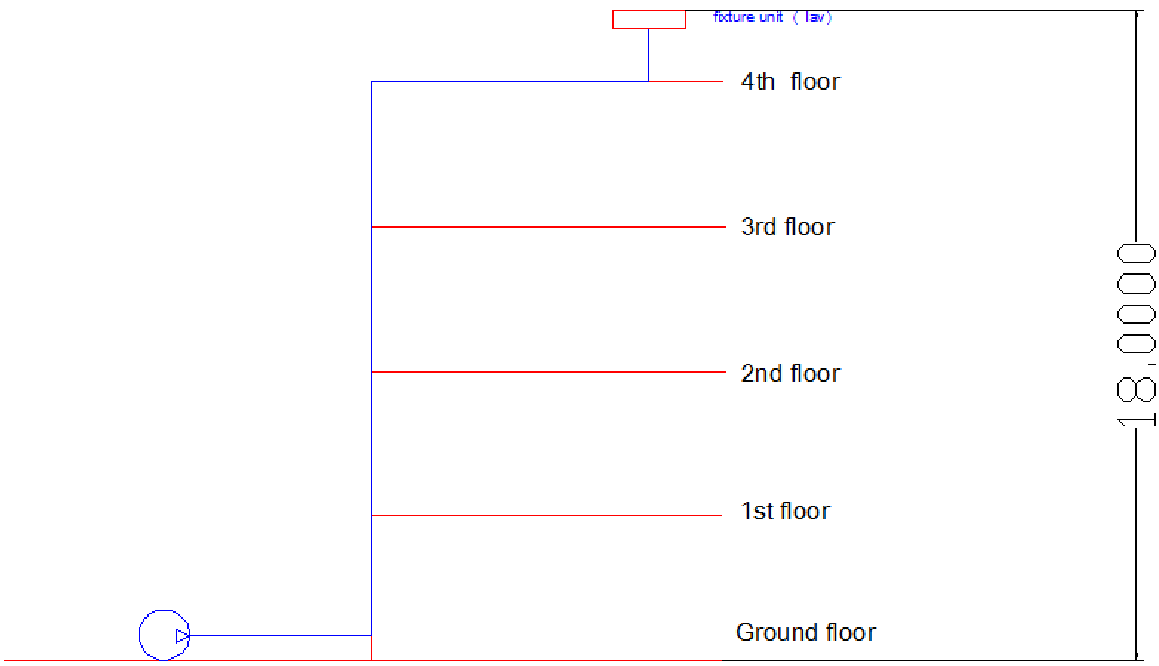


**Figure 4.4: Static head of the building**

$$\text{Static pressure} = 18 \times \frac{0.433}{0.33} = 23.6 \text{ psi} \qquad (4.2)$$

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 – 23.6 – 8.0 = 18.4 psi

The estimated water meter loss is 5.0 psi, so:

Friction head= Pipe friction – Water meter loss

= 18.4 – 5.0 =13.4psi (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 68 meter.

$$TEL = \frac{Total\ length\ (m) \times 1.5}{0.33} = 68 \times 1.5 / 0.304 = 335.3\ ft \quad (4.5)$$

$$\text{Uniform design friction loss} = \frac{13.4 \times 100}{335.3} = 3.96 \frac{psi}{100ft} \quad (4.6)$$

**Table 4.7: Properties of cold water riser**

| No. of Riser | Total WSFU | Total gpm | Diameter (inch) | Velocity (fps) |
|---|---|---|---|---|
| **First riser** | 87 | 41 | 2 | 4 |
| **Second** | 63 | 33 | 2 | 3 |
| **Third** | 84 | 40 | 2 | 4 |
| **Fourth** | 42 | 25 | 1.5 | 4 |
| **Fifth** | 119.5 | 49 | 2.5 | 3.4 |
| **Sixth** | 92.5 | 43 | 2 | 4 |
| **Seventh** | 75 | 36 | 2 | 3.7 |

**Table 4.8: Properties of hot water riser**

| No. of Riser | Total WSFU | Total gpm | Diameter (inch) | Velocity (fps) |
|---|---|---|---|---|
| **First riser** | 27 | 18 | 1.25 | 4 |
| **Second** | 27 | 18 | 1.25 | 4 |
| **Third** | 36 | 24 | 1.5 | 4 |
| **Fourth** | 18 | 13 | 1.25 | 3.2 |
| **Fifth** | 40.5 | 25 | 1.5 | 4 |
| **Sixth** | 31.5 | 20 | 1.25 | 4 |
| **Seventh** | 39 | 25 | 1.5 | 4 |

## 4.4 Water tank volume

Water tank volume can be determined by multiplying the amount of gpm by 3 as a factor to ensure the availability of water source.

Then, 149.5 gpm are the total demand for the building and two risers.

So: 149.5×3 = 448.5 gpm.

Converting 448.5 gpm the result is 85 cubic meters that will the underground tank volume for water building demand.

## 4.5 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 563 WSFU equal 136 Gpm from all the cold water risers equals 30.88 $m^3$/hour.

Total flow rate = 30.88 $m^3$/hour.

**Head estimation**

Height of the building = 21m convert to psi equals 29.8 psi

then convert from psi to bar : 29.8 psi = 2.05 bar

Adding 1 bar for fittings losses the value is almost 3.05 bar

Head = 3.05 bar

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

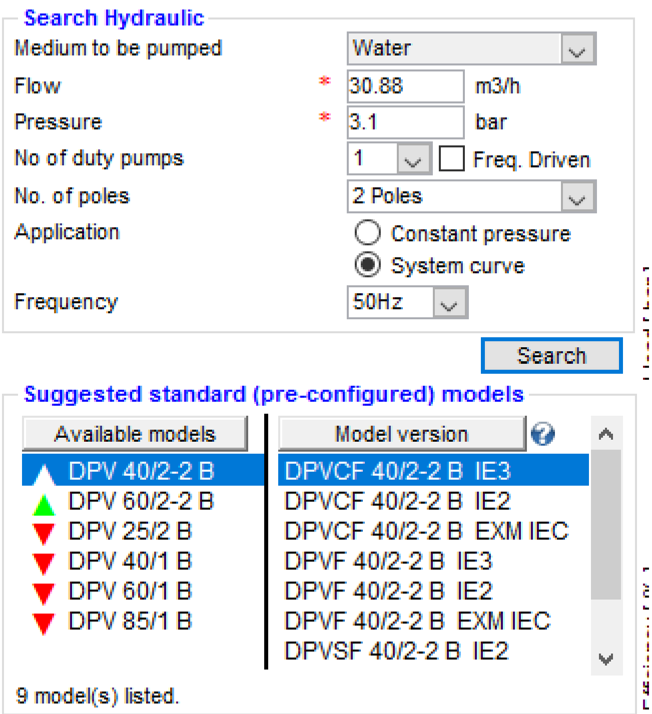


**Figure 4.5: Cold pump data**

The pump model selected “DPV40/2-2B”

The characteristic curves of this pump as follow:

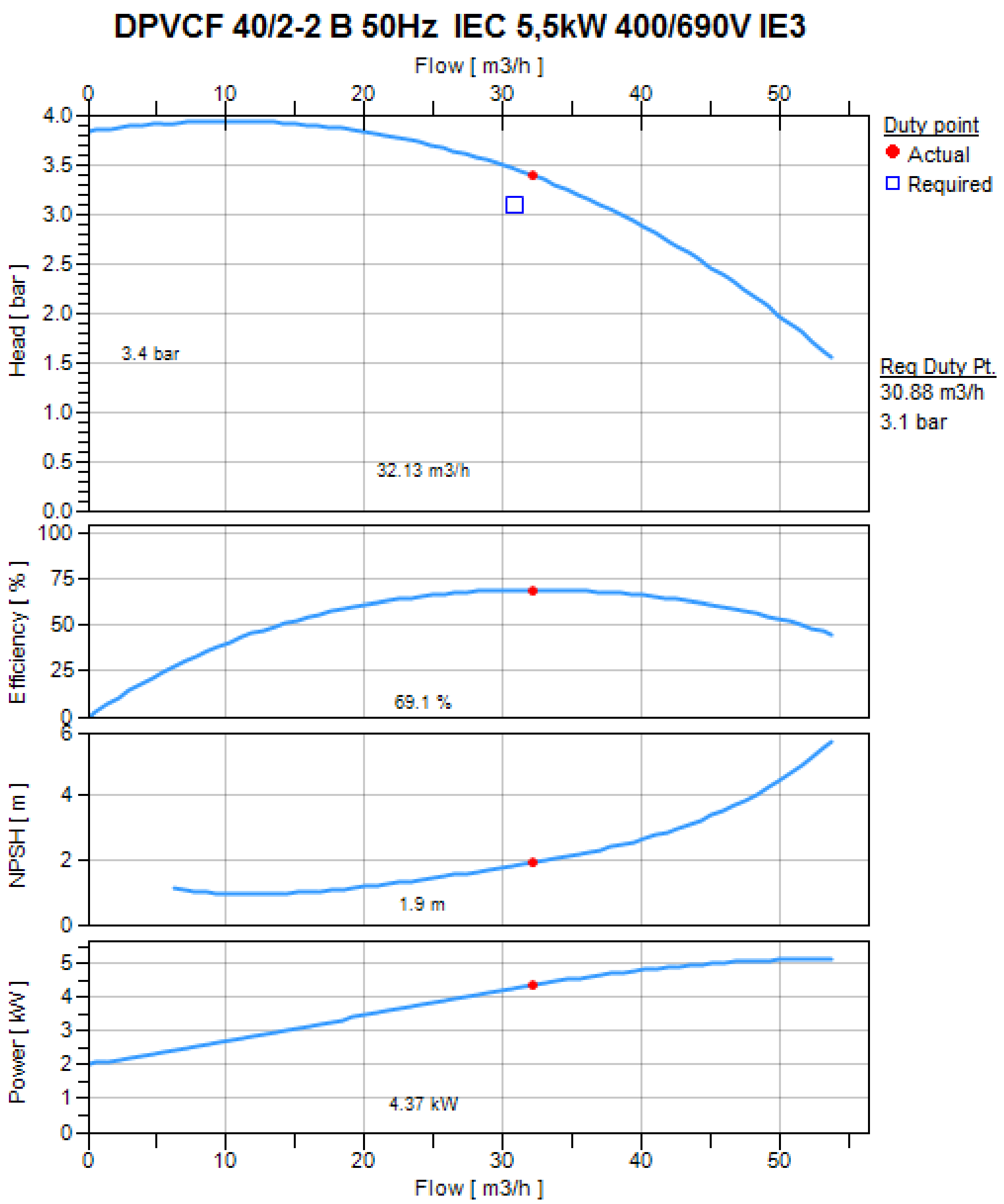


**Figure 4.6: Cold pump characteristic curves**

2) Hot water pump

By converting WSFU to GPM to $m^3$/hour, the 219 WSFU equal 68 Gpm from all the cold water risers equals 15.45 $m^3$/hour.

Total flow rate = 15.45 $m^3$/hour.

Head = 3.05 bar.

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

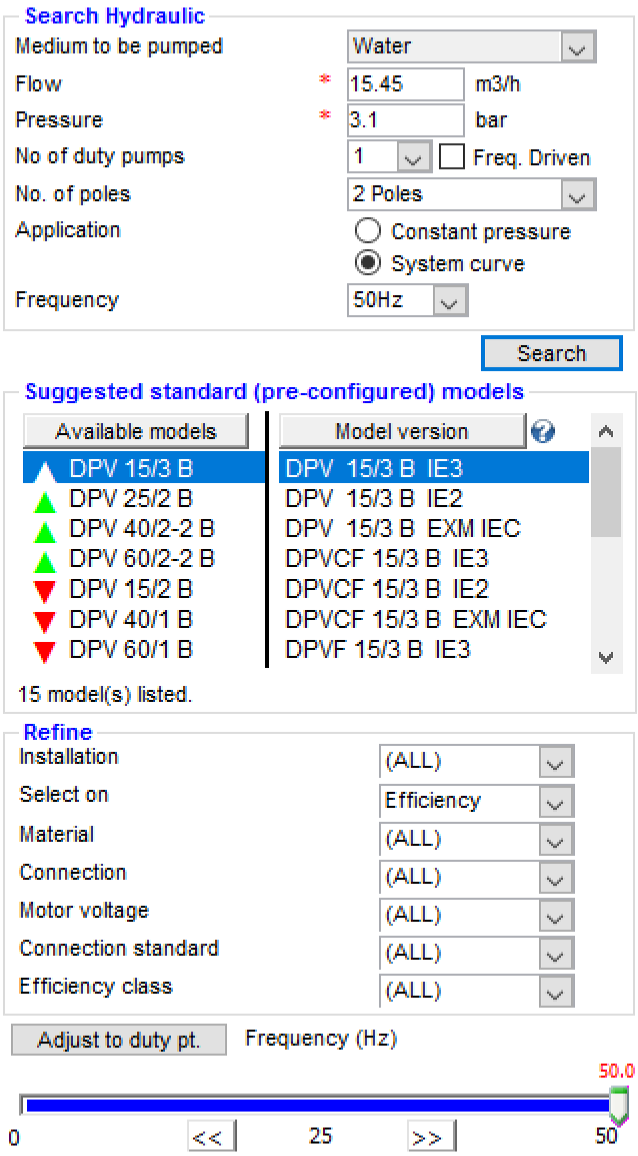


**Figure 4.7: Hot pump data**

The pump model selected “DPV40/2-2B”

The characteristic curves of this pump as follow:

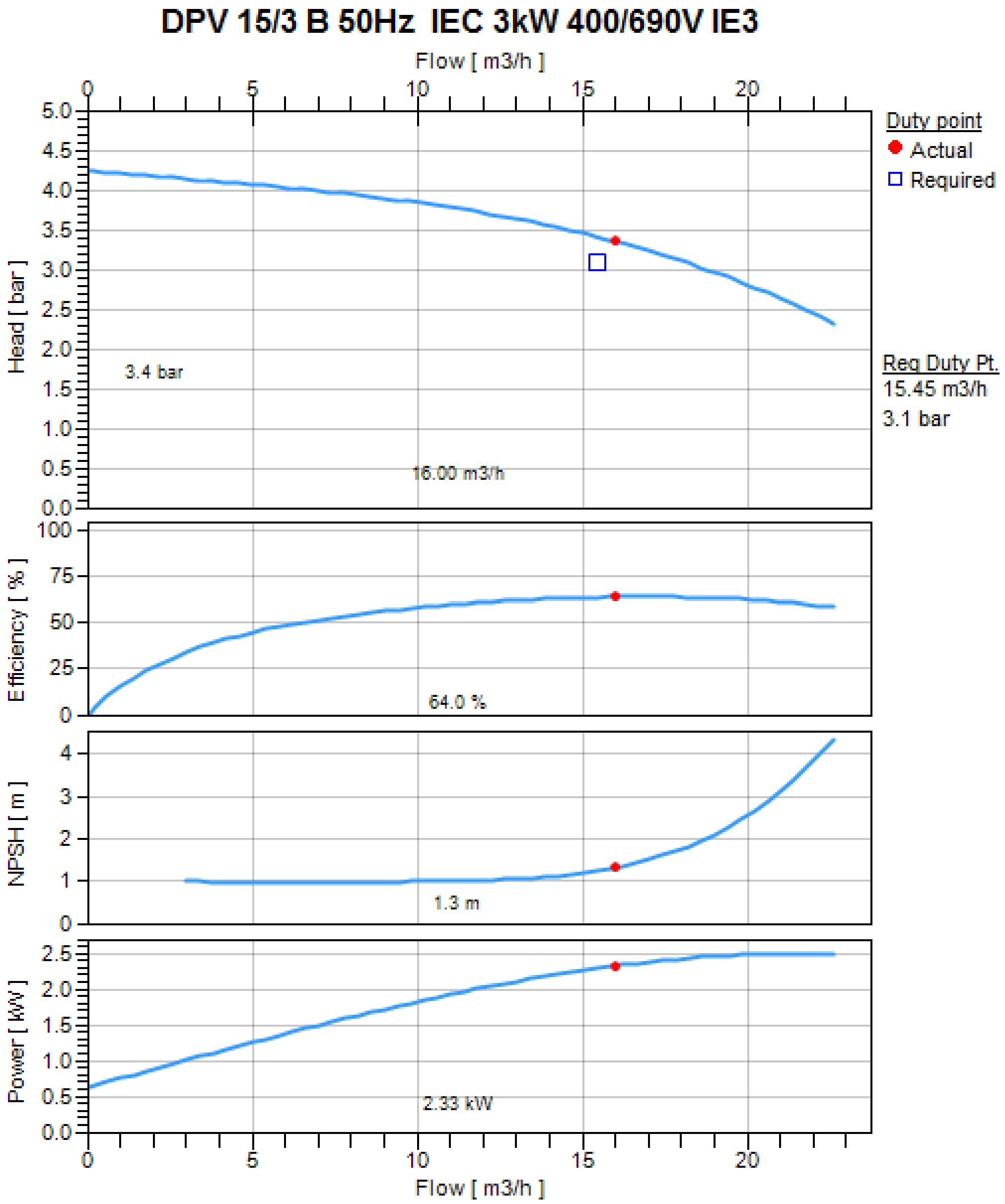


**Figure 4.8: Hot pump characteristic curves**

## 4.6 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
- Storm drainage

**Drainage system components**

The main components of drainage system are:

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

**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 ((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 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 (A-23)
2) Calculation of the number of DFU for each stack
3) Choosing the branch pipe diameter by using Table (A-18)
4) Choosing the stack pipe diameter by 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:

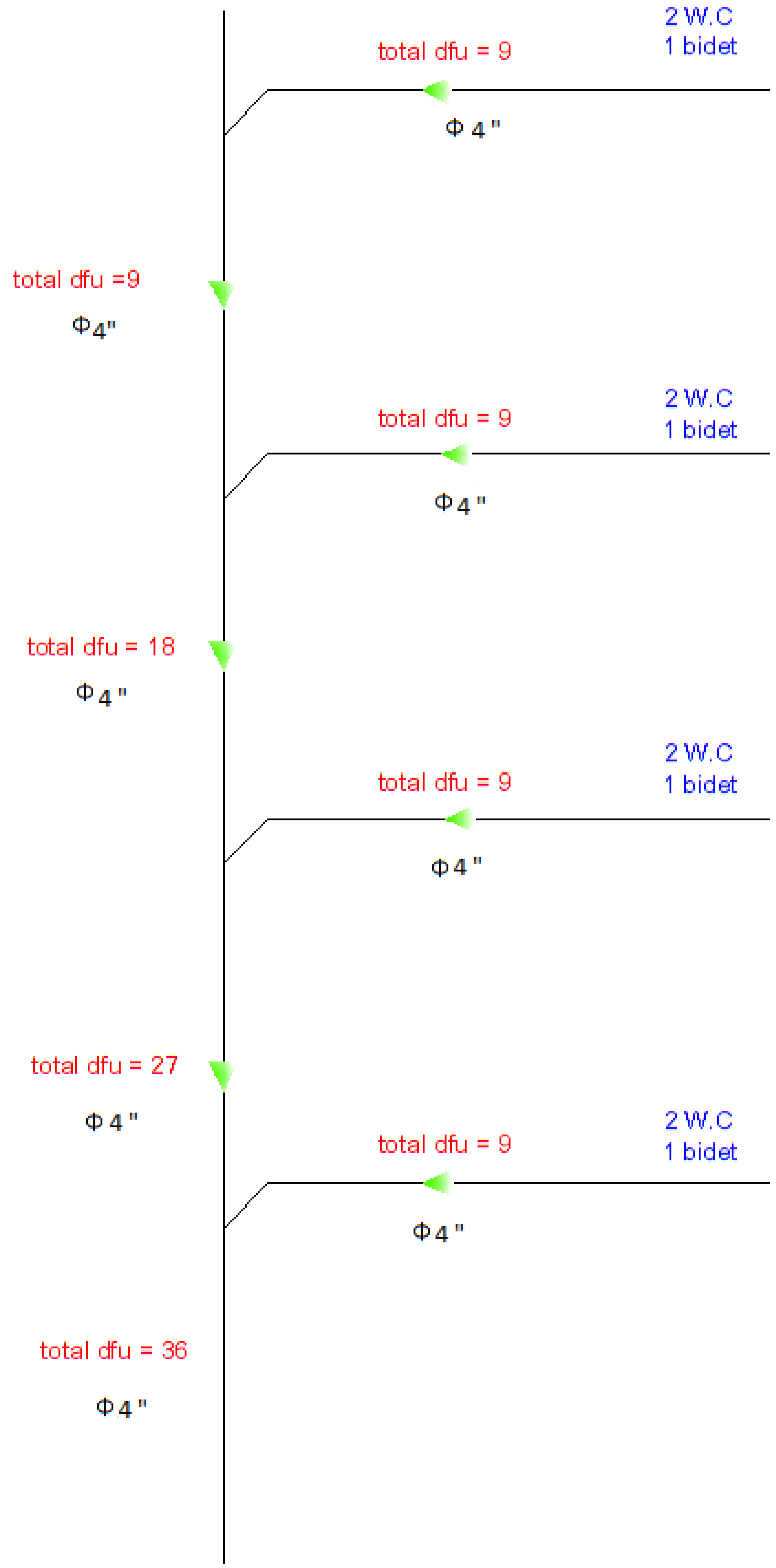


**Figure 4.9: Sample of black water stack 1**

**Table 4.9: Sizing of black water stack 1**

| Stack 1 | Total dfu value | Diameter (inch) |
|---|---|---|
| From Fourth floor (branch) | 9 | 4 |
| From Fourth to third floor (stack) | 9 | 4 |
| From third floor (branch) | 9 | 4 |
| From third floor to second floor (stack) | 18 | 4 |
| From second floor (branch) | 9 | 4 |
| From second floor to first floor (stack) | 27 | 4 |
| From first floor (branch) | 9 | 4 |
| From first floor to building drain (stack) | 36 | 4 |

**Table 4.10: Sizing of black water stacks and building drain**

| #of stack | Total Dfu | Diameter (in) | Diameter of building drain | Slope % | Velocity ft/s |
|---|---|---|---|---|---|
| Stack 1 | 36 | 4 | 4 | ¼ | 2.73 |
| Stack 2 | 32 | 4 | 4 | ¼ | 2.73 |
| Stack 3 | 32 | 4 | 4 | ¼ | 2.73 |
| Stack 4 | 32 | 4 | 4 | ¼ | 2.73 |
| Stack 5 | 32 | 4 | 4 | ¼ | 2.73 |
| Stack 6 | 32 | 4 | 4 | ¼ | 2.73 |
| Stack 7 | 32 | 4 | 4 | ¼ | 2.73 |
| Stack 8 | 16 | 4 | 4 | ¼ | 2.73 |
| Stack 9 | 16 | 4 | 4 | ¼ | 2.73 |
| Stack 10 | 32 | 4 | 4 | ¼ | 2.73 |
| Stack 11 | 32 | 4 | 4 | ¼ | 2.73 |
| Stack 12 | 16 | 4 | 4 | ¼ | 2.73 |
| Stack 13 | 16 | 4 | 4 | ¼ | 2.73 |

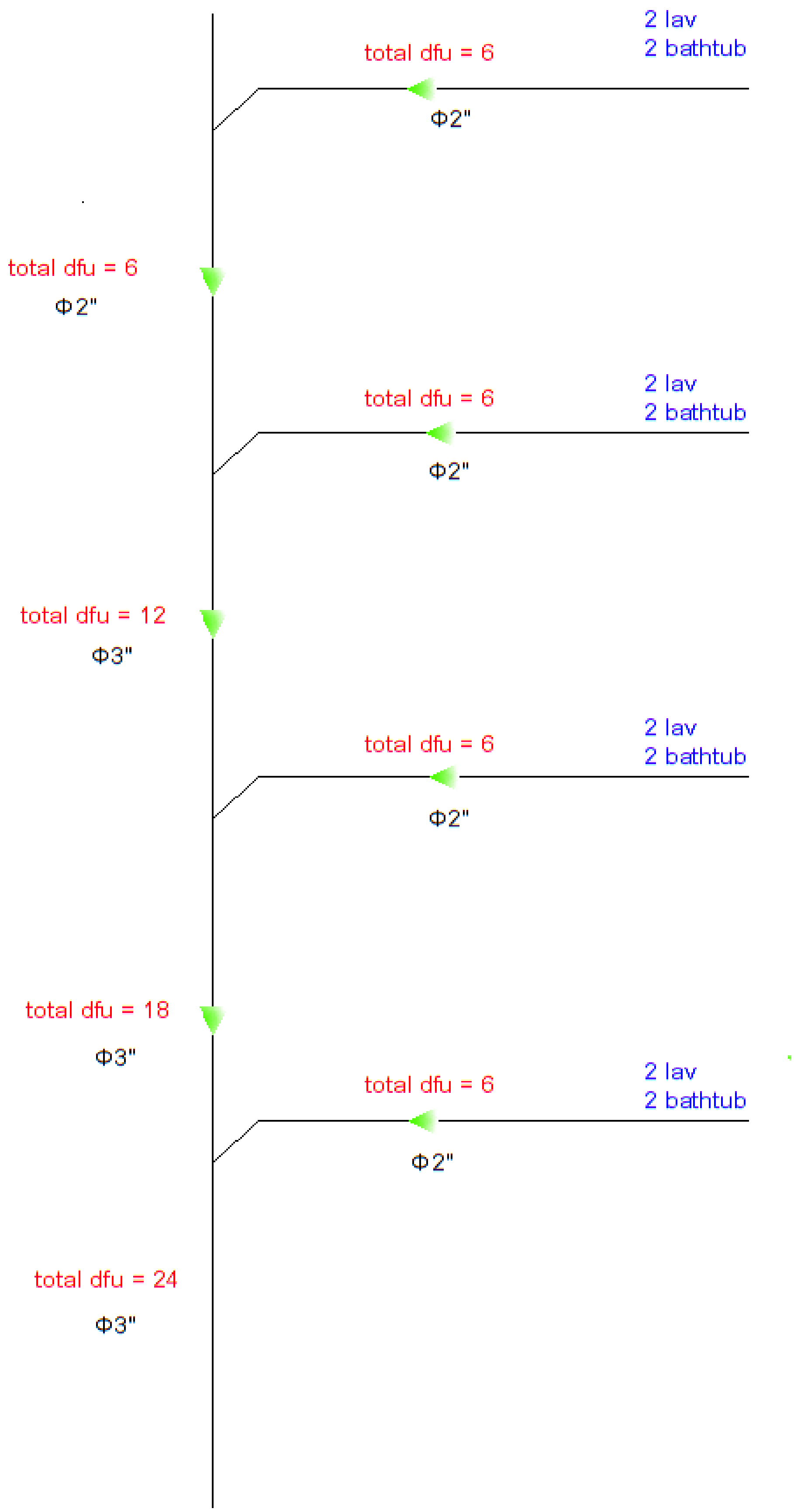


**Figure 4.10: Sample of gray water stack 1**

**Table 4.11: Sizing of gray water stack 1**

| Stack 2 | Total dfu value | Diameter (inch) |
|---|---|---|
| From Fourth floor (branch) | 6 | 2 |
| From Fourth to third floor (stack) | 6 | 2 |
| From third floor (branch) | 6 | 2 |
| From third floor to second floor (stack) | 12 | 3 |
| From second floor (branch) | 6 | 2 |
| From second floor to first floor (stack) | 18 | 3 |
| From first floor (branch) | 6 | 2 |
| From first floor to building drain (stack) | 24 | 3 |

**Table 4.12: Sizing of gray water stacks and building drain**

| #of stack | Total Dfu | Diameter (in) | Diameter of building drain | Slope % | Velocity ft/s |
|---|---|---|---|---|---|
| Stack 1 | 24 | 3 | 4 | ½ | 3.86 |
| Stack 2 | 24 | 3 | 4 | ½ | 3.86 |
| Stack 3 | 24 | 3 | 4 | ½ | 3.86 |
| Stack 4 | 24 | 3 | 4 | ½ | 3.86 |
| Stack 5 | 24 | 3 | 4 | ½ | 3.86 |
| Stack 6 | 24 | 3 | 4 | ½ | 3.86 |
| Stack 7 | 24 | 3 | 4 | ½ | 3.86 |
| Stack 8 | 12 | 3 | 4 | ½ | 3.86 |
| Stack 9 | 12 | 3 | 4 | ½ | 3.86 |
| Stack 10 | 24 | 3 | 4 | ½ | 3.86 |
| Stack 11 | 24 | 3 | 4 | ½ | 3.86 |
| Stack 12 | 12 | 3 | 4 | ½ | 3.86 |
| Stack 13 | 12 | 3 | 4 | ½ | 3.86 |

## 4.7 Calculating the volume of tanks for the sanitation system

Number of bedrooms in each floor = 18 bedrooms.

Number of bedrooms in the building = 72 bedrooms.

Note: each bedroom has 2 persons, so number of persons in the building = 144 person.

Estimated usage per person per day for grey water is:

**Table 4.13: Grey water usage breakdown**

| Water use | Volume (L) | Description |
|---|---|---|
| **Bathing** | 20 | --- |
| **Hand washing** | 6 | 1.5 L per wash<br>About 4 times a day |

Based on these estimated usages for 144 people using the facility, the volumetric flow rate for grey water is:

**Table 4.14: Grey water volumetric flow rates**

| Volumetric flow rates (Q) | Grey water | Total (L/day) | Total (L/hour) |
|---|---|---|---|
| **Per person** | 26 | 26 | 1.08 |
| **Total into system** | 3744 | 3744 | 155.52 |

Similarly, the estimated usage per person per day for black water is:

**Table 4.15: Black water usage breakdown**

| Type | Volume (L) |
|---|---|
| **Urine (per person per day)** | 1.1 |
| **Feces (per person per day)** | 0.2 |
| **Water ( per flush)** | 4.28 |

Because the facility will only been opened during the day, calculations are based on an estimation of 2 flushes per person per day.

The following volumetric flow rates for black water below is for an estimation of 144 people using the facility

**Table 4.16: Black water volumetric flow rates**

| Volumetric flow rates (Q) | Black water | Total (L/day) | Total (L/hour) |
|---|---|---|---|
| **Per person** | 9.86 | 9.86 | 0.41 |
| **Total into system** | 1419.84 | 1419.84 | 59.04 |

According to several studies, the hydraulic retention time (HRT) of ten hours is accurate and can be used to calculate the volume of the two tanks needed.

$$V = Q \times HRT \qquad (4.7)$$

For grey water:

V = 155.52 L/hour × 10 hour = 1555.2 L = 1.552 $m^3$.

For black water:

V = 59.04 L/hour × 10 hour = 590.4 L = 0.5904 $m^3$.

In order to account for any changes in population or an increase in usage, a safety factor will be used.

The original volume calculations are the minimum volume needed to handle the specified flow rates. For these purposes, a minimum of a 45% safety factor will be used. The volume of the tank will be calculated:

For grey water: 1.552 $m^3$ + (1.552 × 0.45) = 2.2504 $m^3$. For

black water: 0.5904 $m^3$ + (0.5904×0.45) = 0.8560 $m^3$.

# 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 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.

## 5.2 Types of firefighting 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' 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:

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


| TYPE | Class A | Class B | Class C | Class D | Electrical | Class F | Comments |
|---|---|---|---|---|---|---|---|
| | Combustible materials (e.g. paper & wood) | Flammable liquids (e.g. paint & petrol) | Flammable gases (e.g. butane & methane) | Flammable metals (e.g. lithium & potassium) | Elecrical equipment (e.g. computers & generators) | Deep fat fryers (e.g. chip pans) | |
| WATER | O | X | X | X | X | X | Do not use on liquid or electric |
| FOAM | O | O | X | X | X | X | Not suited to domestic use |
| DRY POWDER | O | O | O | O | O | X | Can be safely up to 1000 volts |
| $CO_2$ | X | O | X | X | O | X | Safe on both high and low voltage |
| WET CHEMICAL | O | X | X | X | X | O | Use on extremely high temperatures |

**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 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 5.3: 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.

## 5.4 Fire 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).

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 the second, and 250 for the third.

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

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

**Pressure head calculation:**

$$H_{Pump} = H_{St.} + H_{Res.} + H_f \quad (5.1)$$

$H_{Pump}$= 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.

$H_{St.}$= 21 m = 2.1 bar. So:

$H_{Pump}$= 4.5 + 2.1 + 1 = 7.6 bar.

**5.6 Pump selection**

Total flow rate 500 GPM equal to 113.5 $m^3$/h and amount of head 7.6 bars.

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

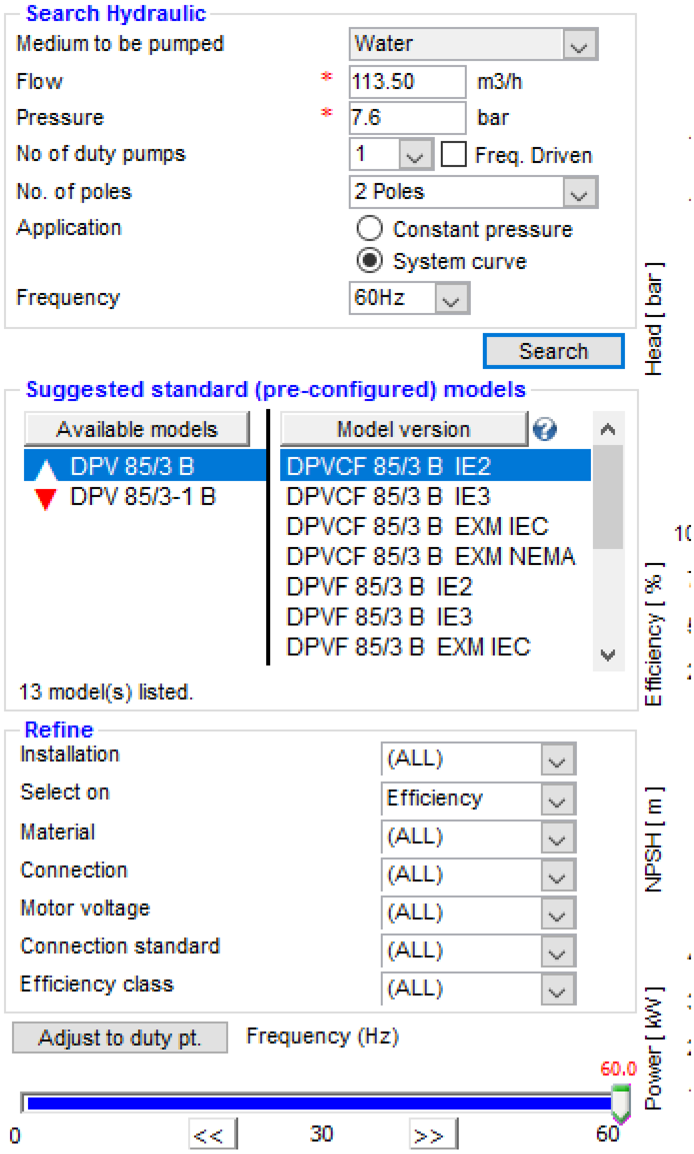


**Figure 5.9: Pump details**

The pump model selected "DPV85/3 B"

The characteristic curves of this pump as follow:

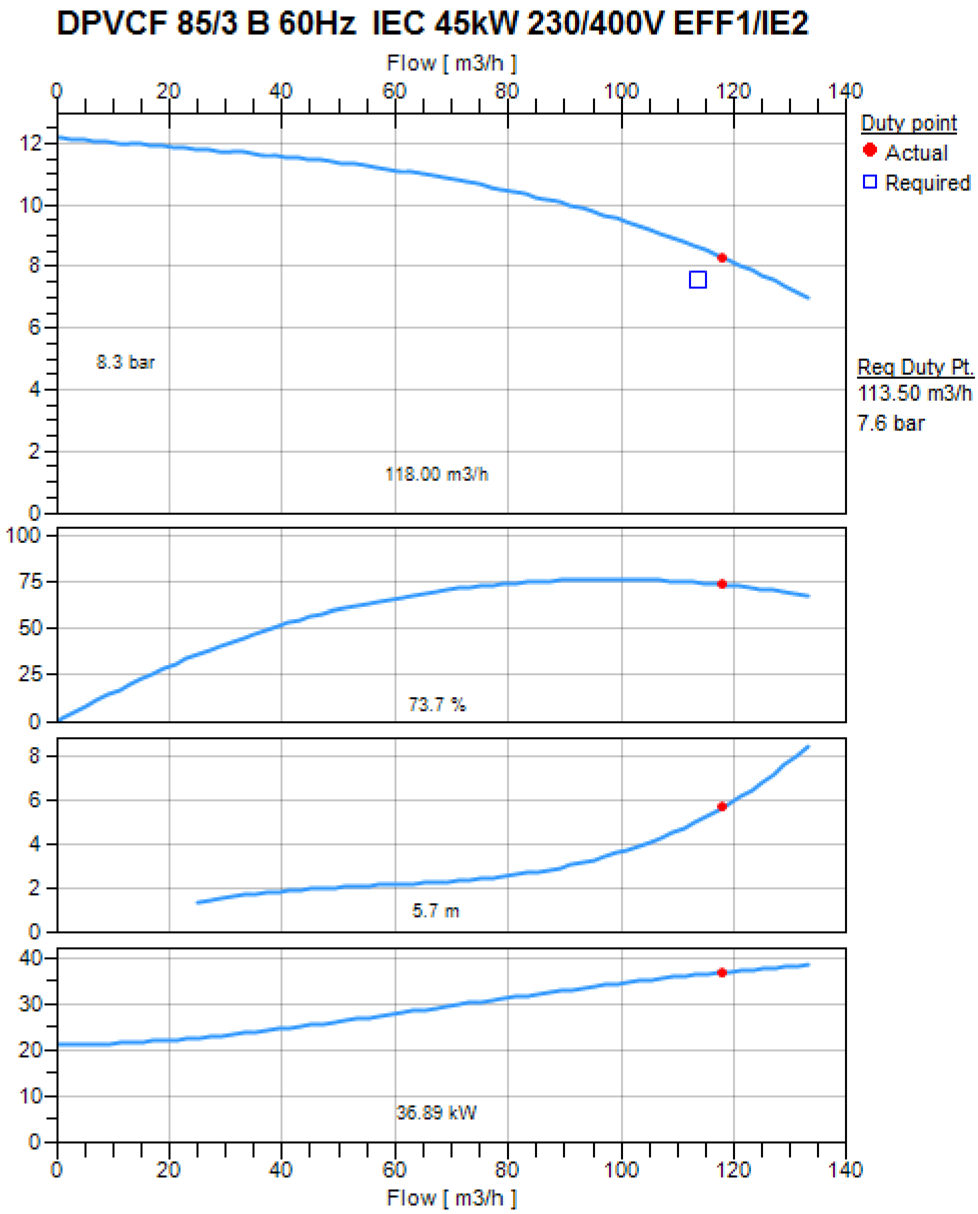


**Figure 5.10: Pump characteristic**

# CHAPTER SIX

# Swimming pool

**6.1 introduction**

Swimming pools consider as one of the most places that attract human to reduce the daily work pressure, and daily troubles.

Swimming pools in general must have appropriate design for all ages and different level of swimming skills, also it must have a clean ,good water quality.

**6.2 swimming pool components**

**1- Skimmer :** machine that separates a liquid from particles floating on it or from another liquid.

Fig 6.1 swimming pool skimmer

**2- main drain :** are usually located on the lowest point in the pool, Most of the dirt and debris that sinks exits the pool through these drains, he drains are almost always covered with grates or antivortex covers (a cover that diverts the flow of water to prevent a dangerous vortex from forming).

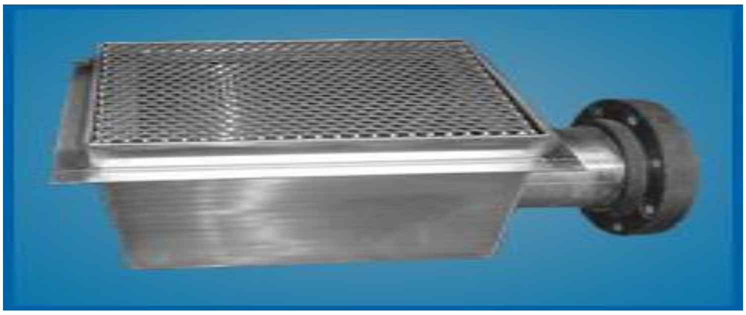

Fig 6.2 swimming pool main drain

**3- Pump** : pulls water from one or more suction ports (i.e., skimmer & main drain), and then pushes it through the filter & heater**.**


Fig 6.3 swimming pool pump

**4- Return inlet :** Pool water returns are places in the pool where water comes back in from the circulation system**.**

Fig 6.4 swimming pool return inlet

**5- Filter :** Pool water comes from the circulation pump into the filter where small debris particles are removed**.**

Fig 6.5 swimming pool filters

**6- Suction inlet :** used primarily as a suction port for vacuuming the pool

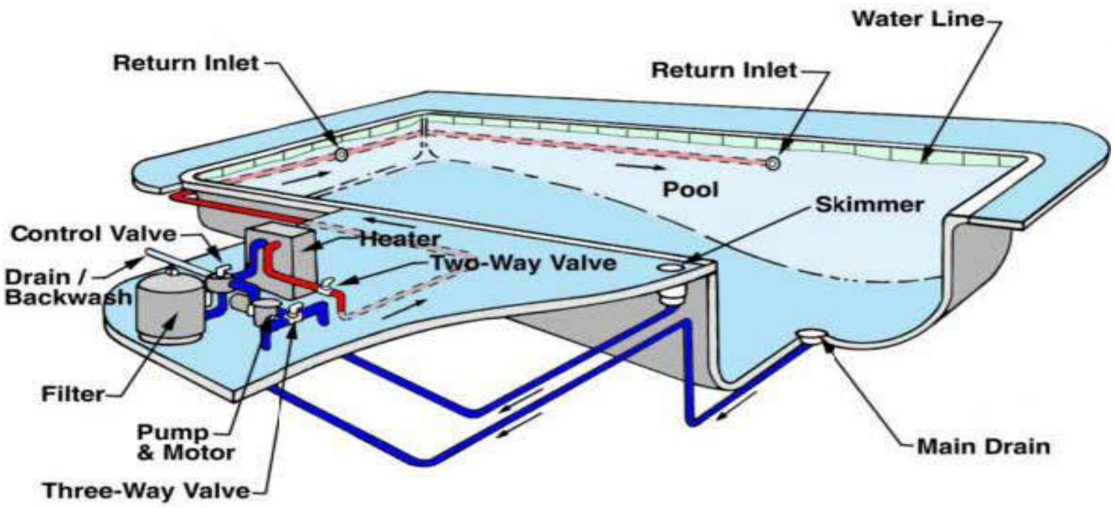


Fig 6.6 general swimming pool components

### 6.3 Pool Capacity Calculations

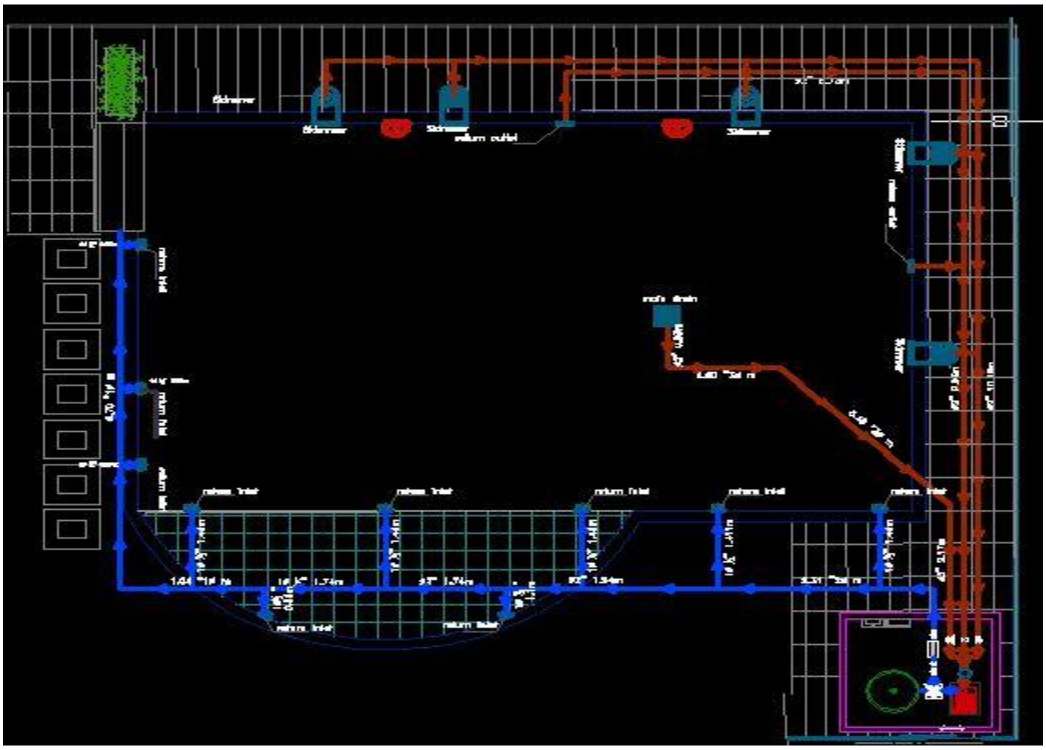

Fig 6.7 swimming pool top view

Average depth = (Shallow end depth + deep end depth)/2 **[6.1]**

= (3 + 1)/2 = 2 $m$.

Volume of water = area * average depth **[6.2]**

= (144)*2 = 288 $m^3$.

Turn Over Time**:**

In Hebron the turn over time is 5 hr in hotel pools.

## 6.4 Filter Sizing and Selection

Filter flow rate = Total Water Circulation rate ($m^3$/hr)

$$= \left[\frac{Pool\ water\ volume\ (m^3)}{Pool\ turn\ over\ period\ (hr)}\right] \quad \textbf{[6.3]}$$

= 288/5

= 57.6 ($m^3$/hr)

For a filtration velocity of 20 $m/hr$, the efficiency is 100%.

For a filtration velocity of 30$m/hr$, the efficiency is 70%.

For a filtration velocity of 40 $m/hr$, the efficiency is 50%.

The filter efficiency between 70-100%, so a 25 $m/hr$ filtration velocity.

Filter surface area = $\left[\frac{Filtration\ flow\ rate}{Filtration\ velocity}\right]$ **[6.4]**

= 57.6/25

= 2.3 $m^2$

**6.5 Skimmers and main drain selection**

● Number of skimmers =(50% X Total flow rate)/capacity of each skimmer

= pool surface area / 25 **[6.5]**

= 144/25

= 6 skimmers are required .

Flow rate of each skimmer = (50% × flow rate)/number of skimmers **[6.6]**

= (50% × 57.6) / 6

= 4.8 $m^3/hr$ = 21.2 gpm.

Flow rate of main drain = 50% × flow rate **[6.7]**

= 50% × 57.6

= 28.8 $m^3/hr$ = 126.8 gpm.

Number of main drains = (flow rate × 50%)/ flow rate of main drain **[6.8]**

= (57.6 × 50%)/28.8

= 1 main drain required.

**6.6 Selection of return inlets:**

Number of required return inlets = $\left[\frac{Filtration\ flow\ rate}{Flow\ rate\ of\ each\ inlet}\right]$ **[6.9]**

= pool perimeter / 5

= 50/6

= 9 return inlets.

$Flow\ rate\ of\ each\ return\ inlet$ = $\left[\frac{Filtration\ flow\ rate}{\text{Number of required return inlets}}\right]$ **[6.10]**

= 57.6/9

= 6.4 $m^3/hr$

= 28.2 gpm.

**6.7 swimming pool control room components:**

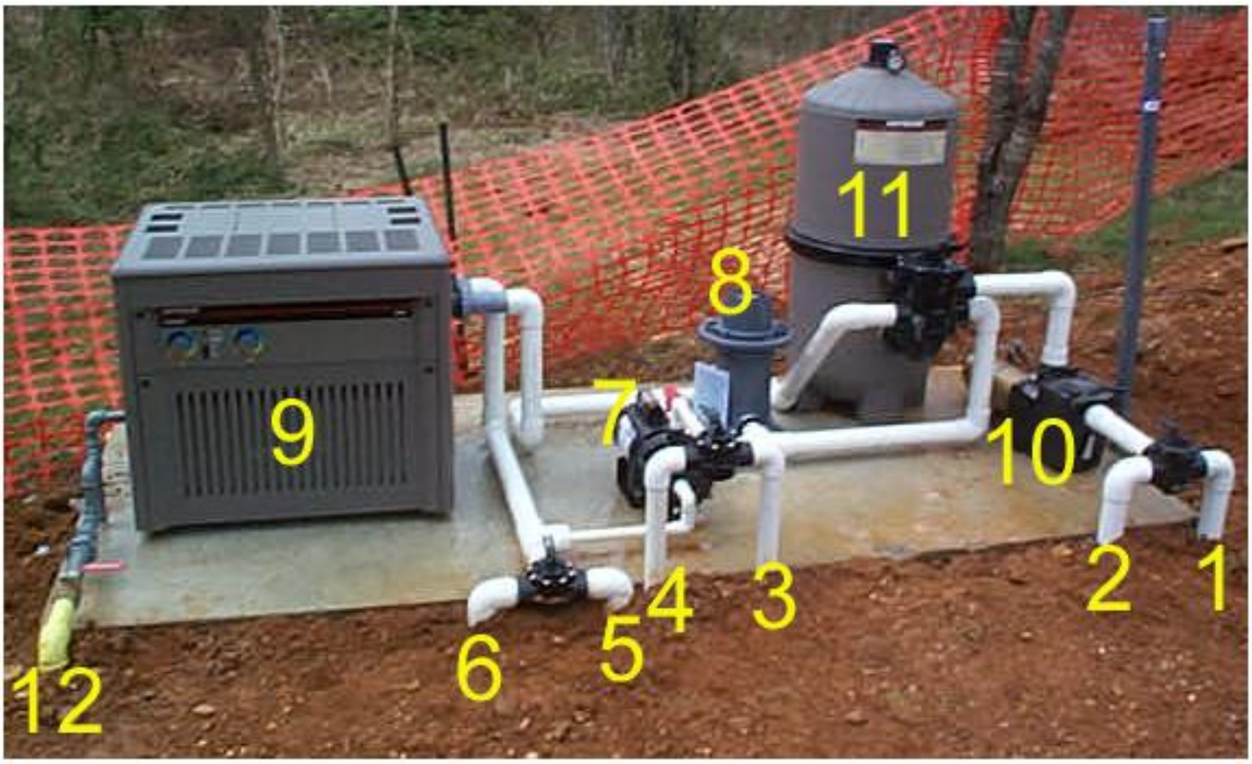

Fig 6.8 swimming pool control room main components

1. Swimming Pool Skimmer Line
2. Swimming Pool Main Drain Line
3. Swimming Pool Slide Line
4. Automatic Pool Cleaner Line
5. Swimming Pool Return Line
6. Swimming Pool Return Line
7. Automatic Pool Cleaner Motor
8. Auto Sanitizer
9. Swimming Pool Heater
10. Swimming Pool Pump
11. D.E. Pool Filter
12. Pool Heater Gas Supply Line

## REFREGRATORS

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### 6.1 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 [ $W/m^2.\ ^\circ C$ ] .

$$U = \frac{1}{\frac{1}{hin} + \sum \frac{\Delta X}{K} + \frac{1}{hout}} \quad (6.1)$$

$h_{in}$ : 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 $^oC$ .

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

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

### 6.1.1 The Overall heat transfer coefficient

1. External Wall:

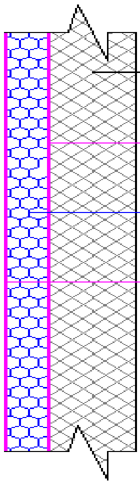



**Figure 1:External wall details**

**Table 1:variable of heat transfer coefficient**

| 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 .

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

$= 0.58/m^2.^{o}C$ .

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

$= 30 – 5 = 25\ ^{o}C$ .

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

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

2. Internal Wall-1:

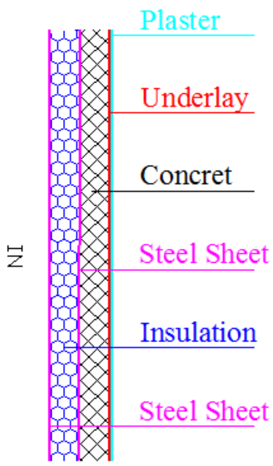



**Figure 2:internal wall details**

**Table 2: variable of heat transfer coefficient**

| Material | K (W/m.°C) | 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 .

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

$= 0.43\ W/m^2.^{o}C$.

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

$= 28.3 – 5 = 23.3\ ^{o}C$ .

$A = A_{Internal\ Wall} – A_{Door}$

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

$= 5.6\ m^2$ .

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

3. Internal Wall-2 :
4. The same propriety of Internal Wall-2 but the aria is deferens

$A = A_{\text{Internal Wall}}$
$= (4 * 3.8) = 15.2\ m^2$ .
$Q_{\text{Internal Wall-1}} = 0.43 * 23.3 * 15.2 = 152W = 0.152\ kW$ .

5. Internal Wall-3 :

The same propriety of Internal Wall-2 but the aria is deferens
$A = A_{\text{Internal Wall-3}}$
$= (2 * 3.8$
$= 7.6\ m^2$ .
$Q_{\text{Internal Wall-3}} = 0.43 * 23.3 * 7.6 = 76W = 0.076\ kW$ .

1. Internal Wall-4 :

Consists of :

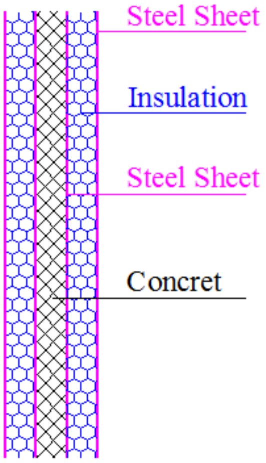



**Figure 3:internal wall -2**

**Table 3: variable of heat transfer coefficient**

| 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 .

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

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

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

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

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

$= (4 * 3.8)$

$= 15.2\ m^2.$

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

2. Ground:

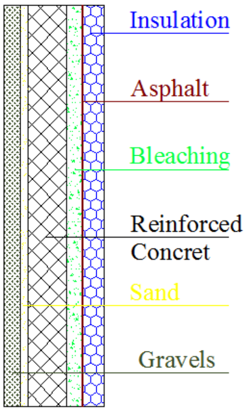



**Figure 4:ground details**

**Table 4: variable of heat transfer coefficient**

| Material | K (W/m.°C) | 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.

3. Ceiling:

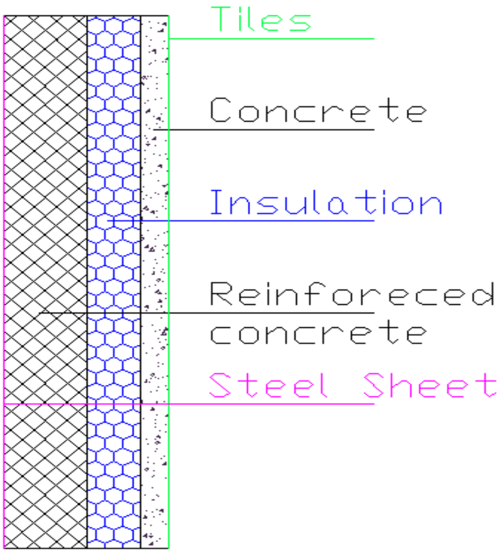



**Figure 5:ceiling details**

**Table 5:variable of heat transfer coefficient**

| 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 $m^2$.

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

4. Door:

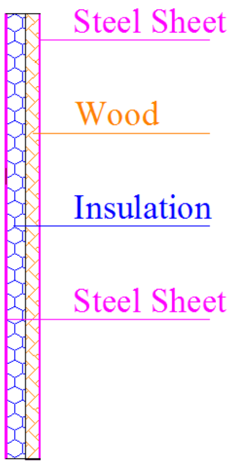



**Figure 6:door details**

**Table 6: variable of heat transfer coefficient**

| 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 .

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

$= 0.631\ W/m^2.^oC$ .

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

$= 28.3 - 5 = 23.3\ ^oC$ .

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

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

### 6.1.2 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.

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

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

$= 0.022+0.038 + 0.076 +0.114 = 0.448$.

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

$Q_1 = 0.448 + 0.055 + 0.038 + .050 = 0.6$ kW.
$Q_{Solar} = 0$
$Q_{Envelope} = 0 + 0.6 = 0.6$kW .

**$Q_{Product}$ Calculation:**
$Q_{Product} = Q_2^{*} + Q_2^{**} + Q_{Packaging}$. (6.4)
$Q_2^{*} = m^{o}\ cp\ \Delta T$.
When:
$m^{o} = (m_{Product}\ /\ \text{Time Cooling})$
Time Cooling: Working Time Per a Day .
$\Delta T = \Delta T_{sur} = 30\ ^{o}C$ .

**Table 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 $^oC$ .
$Q_{Packaging}$ = ( 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.$^oC$ @ $T_{out}$ = 30 $^oC$ & R.H = 56 % .
$h_{in}$ = 17 J/kg.$^oC$ @ $T_{in}$ = 5$^oC$ & R.H =85 % .
$m^o = \rho_{Air} * v^o$
$\rho_{Air}$: 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 .

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

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

**$Q_{Service}$ 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 = 2.5 kW .
$Q_{Total}$ =2.5*F.S = 2.5*1.5 = 3.75 Kw

**<u>From Cool pack:</u>**

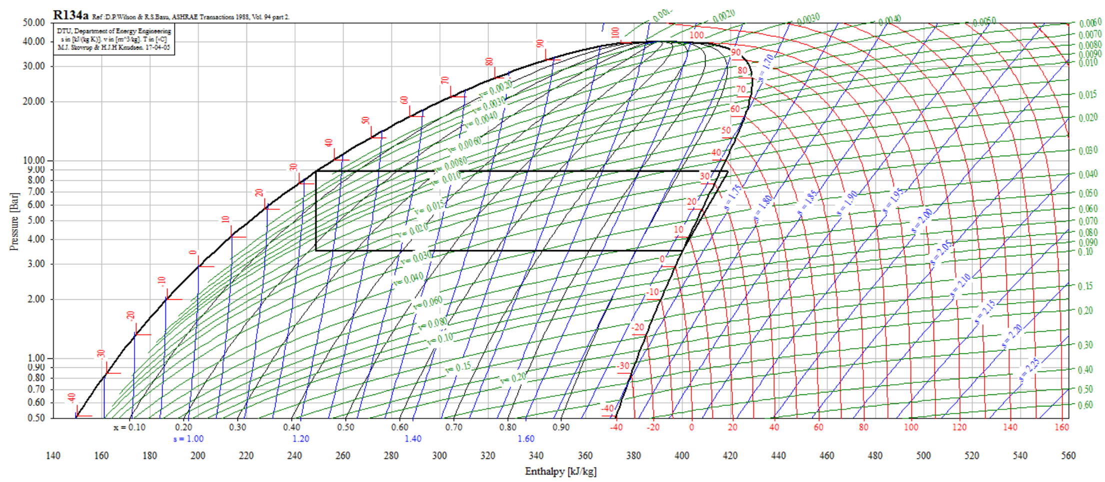
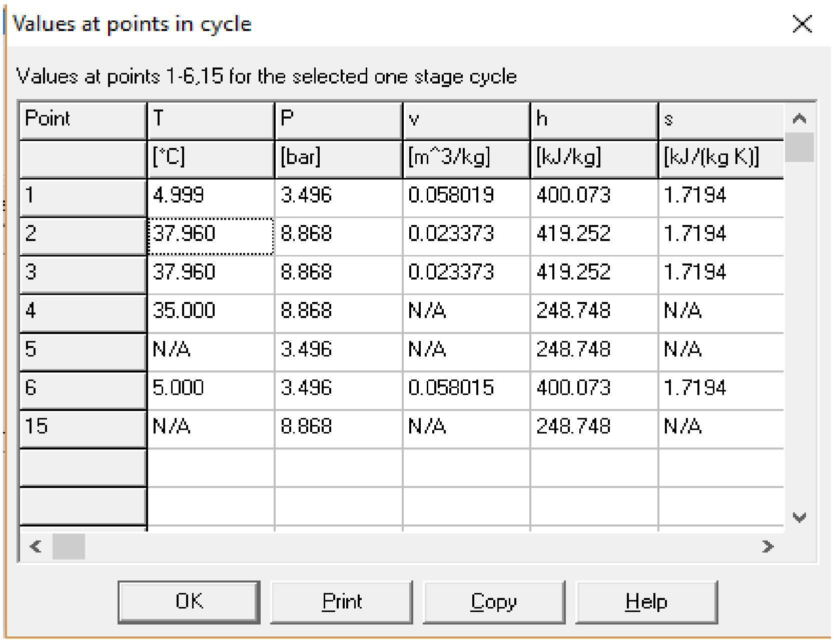



**Figure 7 The cycle in the PH diagram**

**Table 8: the value 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 .

$P = m^o \, w_c$

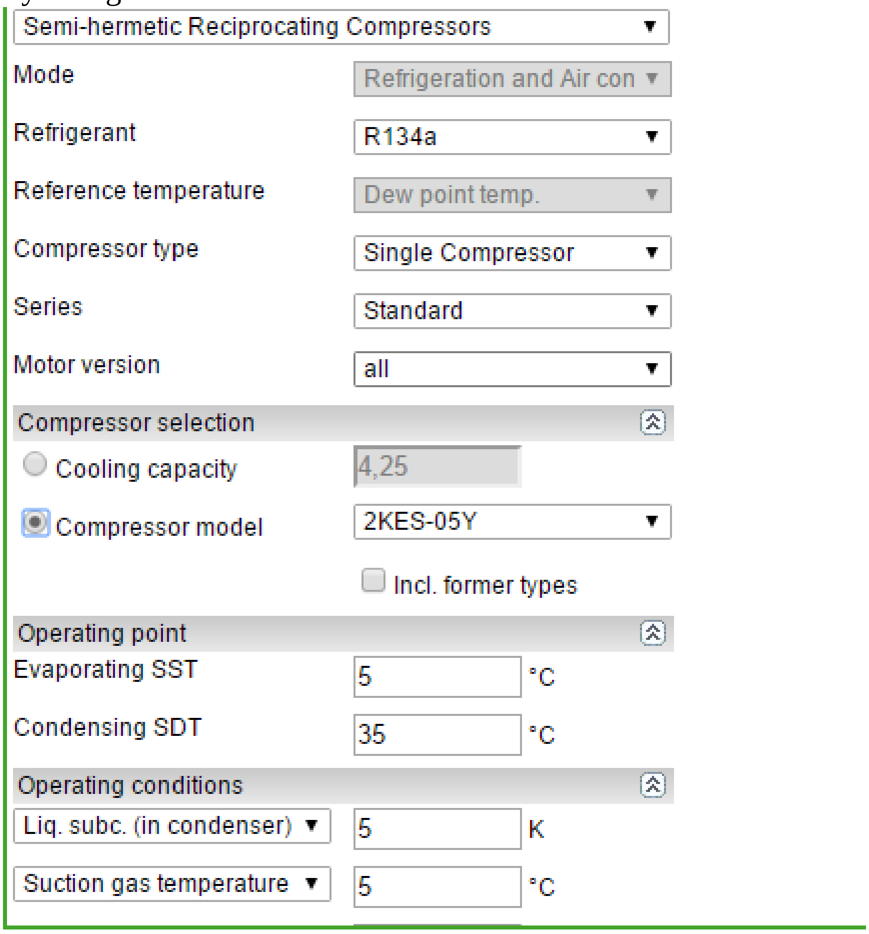
$=0.02476 * 19.179$

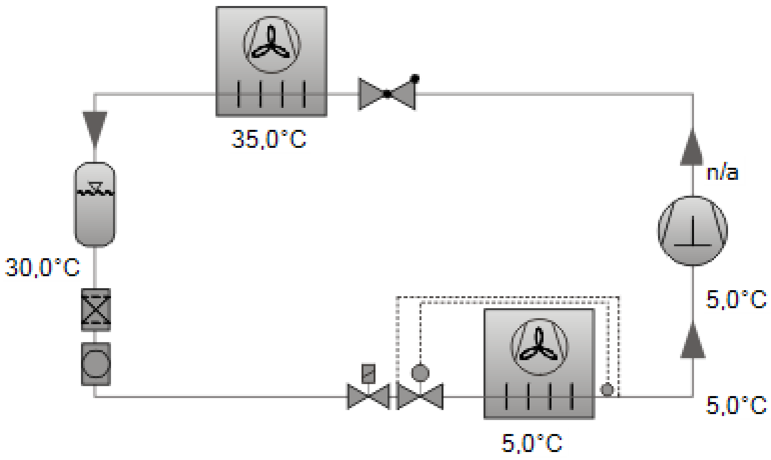
$= 0.474$ kW $= 0.62$ hp {hp : horsepower } .

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

### 6.1.3 Compressor selection

By Using BITZER-Software



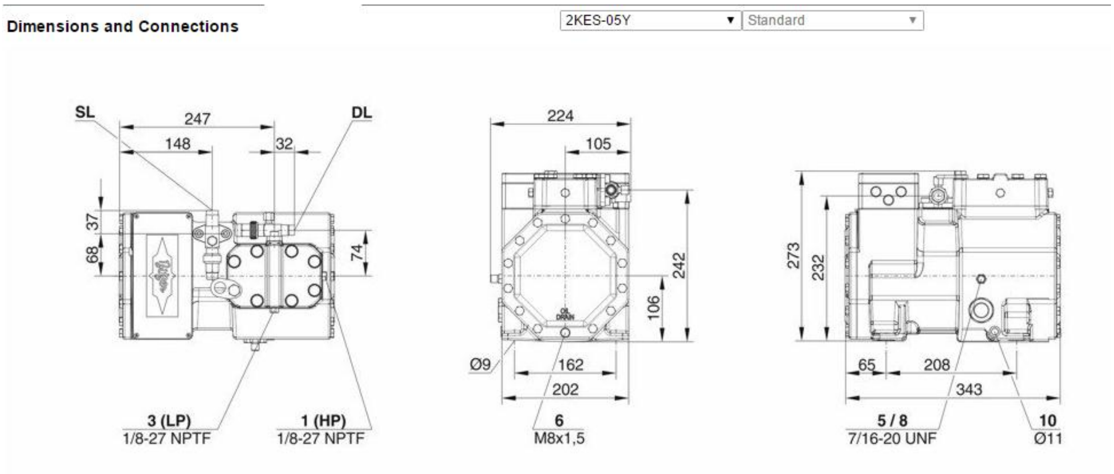
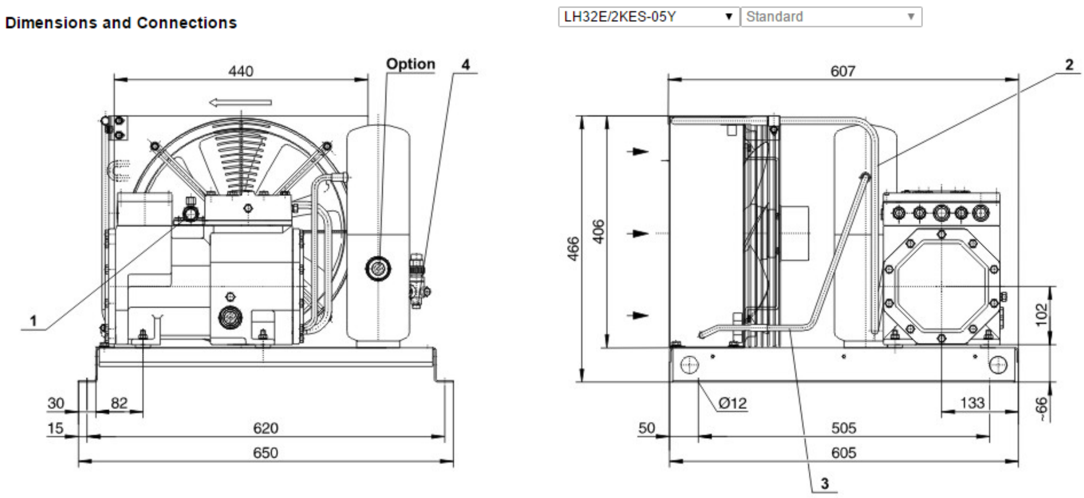


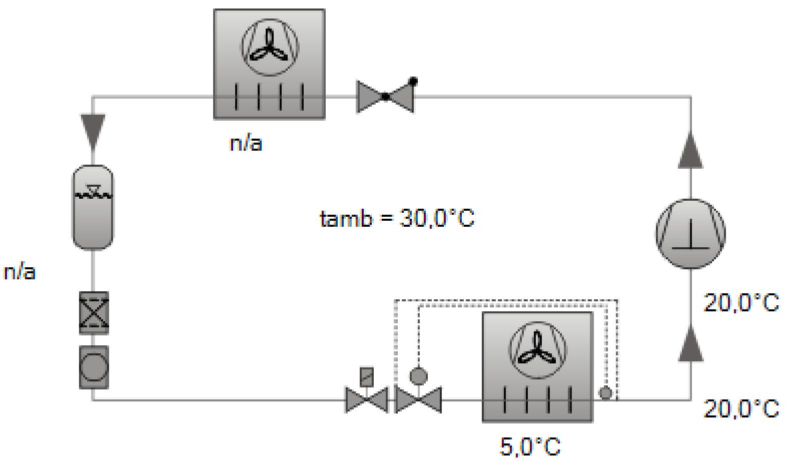

**Figure 8:compressor data sheet**

For more about data sheet go to appendix B

**6.1.4 Condensers selection:**

By Using BITZER-Software



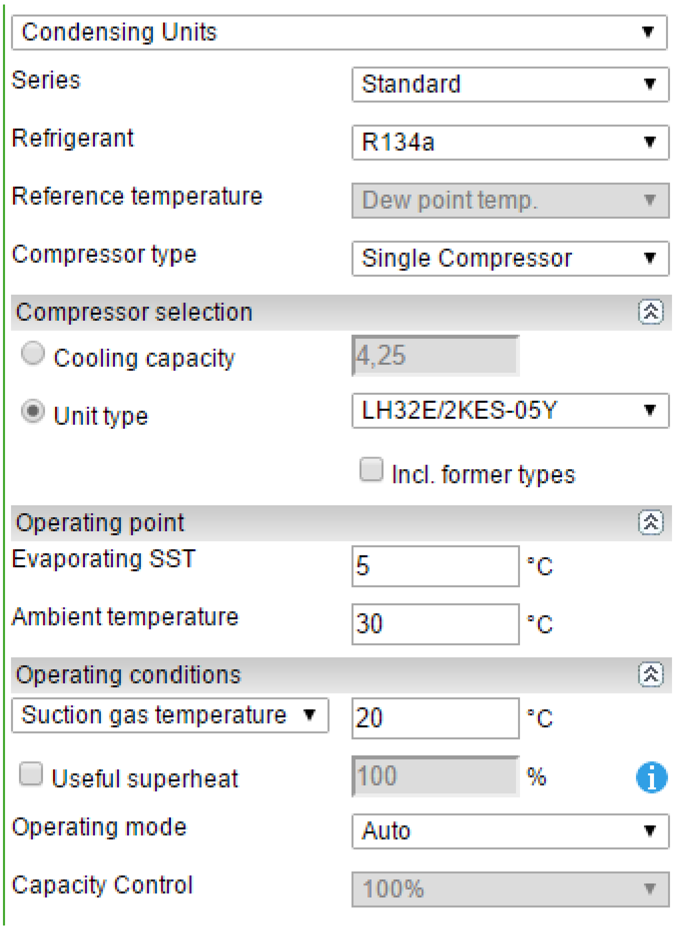



**Figure 9:condenser data sheet**

## 6.2 Cooling Load Calculation for freezer

### 6.2.1 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 [ $W/m^2 . ^\circ C$ ]

$$U = \frac{1}{\frac{1}{hin} + \sum \frac{\Delta X}{K} + \frac{1}{hout}}$$

$h_{in}$ : 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.$^o$C] .
$\Delta$X: is the Thickness of the material in [m] .
A: Surface area in [m$^2$] .
A=Length * Width.
$\Delta$T: The difference in temperature [$^o$C] .

1. Internal Wall-1 :

$\Delta T = T_{Room} - T_{in}$
$= 28 – -18 = 46\ ^oC$ .
$A = A_{Internal\ Wall} – A_{Door}$
$= (2 * 3.8) -(2 * 1)$
$= 5.6\ m^2$ .
$Q_{Internal\ Wall-1} = 0.038 * 46 * 5.6 = 0.015\ kW$ .

2. Internal Wall-2 :

$\Delta T = T_{Room} - T_{in}$
$= 24 – -18 = 42\ ^oC$ .
$A = A_{Internal\ Wall-2}$
$= (4 * 3.8)$
$= 15.2\ m^2$ .
$Q_{Internal\ Wall-2} = 0.152 * 42 * 15.2 = 97W = 0.97\ kW$.

3-Internal Wall-3 :

$\Delta T = T_{Room} - T_{in}$
$= 24 – -18 = 42\ ^oC$ .
$A = A_{Internal\ Wall-2}$
$= (2 * 3.8)$
$= 7.6\ m^2$ .
$Q_{Internal\ Wall-2} = 0.076 * 42 * 7.6 = 64W = 0.064\ kW$

4-Internal Wall-4 :

$\Delta T = T_{Room} - T_{in}$
$= 5 – -18 = 23\ ^oC$ .
$A = A_{Internal\ Wall-2}$
$= (4 * 3.8)$
$= 15.2\ m^2$ .
$Q_{Internal\ Wall-2} = 0.114 * 23 * 15.2 = 88W = 0.088\ kW$

1. Ground:

$\Delta T = T_{ground} – Tin$
$=24- -18 = 42\ ^oC$ .
$A = (2 * 4)$
$= 8\ m^2$ .
$Q_{ground} = 0.399 * 42 * 8 = 0.134\ kW$ .

2. Ceiling:

$\Delta T = 28 - T_{in}$
$= 24– -18=42\ ^oC$ .

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

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

3. Door:

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

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

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

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

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 .

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

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

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

$Q_{Product}$ Calculation :

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

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

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

Time Cooling: Working Time Per a Day.

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

**Table 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

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

$m_{Material} = m * N$ .

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 = 4.3 kW .
$Q_{Total}$ =4.3*F.S = 4.3*1.5 = 6.5KW

**From Cool pack:**

**Table 10: The cycle in the PH diagram**

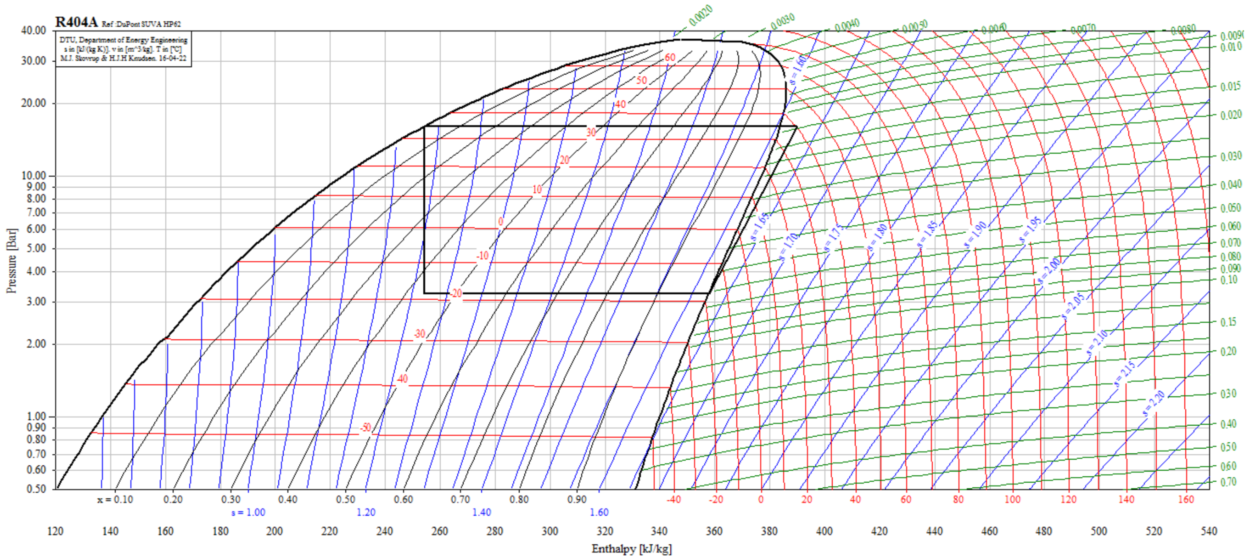



Table 11 the value from PH diagram

| 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 = 2.7 hp { hp : horsepower [electric] } .

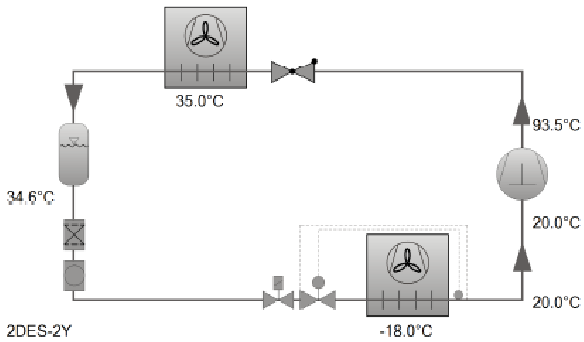
Coefficient of performance (cop) = $q_e$ / w = 103.14/32.102 = 3.212

### 6.2.2 compressor selection
**By Using BITZER-Software**

For more about data sheet go to appendix B

**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 |

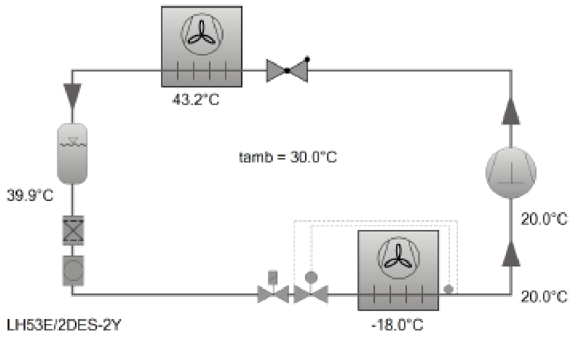
**Figure 10:compressor data sheet**

### 6.2.3 Condensers 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 11:condenser data sheet**

For more about data sheet go to appendix B

To see all Refrigeration systems go to drawings from (M16).

# References

[1] Palestinian code.

[2] J. A. D. W. A.Beckman, Solar Engineering of Thermal Processes, John Wiley & Sons, 2006.

[3] M. A. A. M. Ashamed, Heating and Air Conditioning for Residential Buildings, National Library Department, Jordan, 2007.

[4] J. F. Krieger, Handbook of Heating, Ventilation, and Air Conditioning, Boca Raton, CRC.Press LLC, Florida, 2001.

[5] B. Stein, Building Technology Mechanical and Electrical Systems, John Wiley & sons, Canada, 1997.

[7] Internet.

# Appendix

## A-1: Description of wall construction groups

**TABLE 9-5** Description of wall construction groups.

| Group No. | Description Of Construction | $U_{ov.}$ $W/m^2 \cdot °C$ |
|---|---|---|
| | **101.6 mm Face Brick + (Brick)** | |
| C | Air space + 101.6 mm face brick | 2.033 |
| D | 101.6 mm common brick | 2.356 |
| C | 25.4 mm insulation or air space + 101.6 mm common brick | 0.987-1.709 |
| B | 50.6 mm insulation + 101.6 mm common brick | 0.630 |
| B | 203.2 mm common brick | 1.714 |
| A | Insulation or air space + 203.2 mm common brick | 0.874-1.379 |
| | **101.6 mm Face Brick + (H.W. Concrete)** | |
| C | Air space + 50.8 mm concrete | 1.987 |
| B | 50.8 mm insulation + 101.6 mm concrete | 0.658 |
| A | Air space or insulation + 203.2 mm or more concrete | 0.625-0.636 |
| | **101.6 mm Face Brick + (L.W. or H.W Concrete Block)** | |
| E | 101.6 mm block | 1.811 |
| D | Air space or insulation + 101.60 mm block | 0.868-1.397 |
| D | 203.2 mm block | 1.555 |
| C | Air space or 25.4 mm insulation + 152.4 mm or 203.2 mm block | 1.255-1.561 |
| B | 50.8 insulation + 203.2 mm block | 0.545-0.607 |
| | **101.6 mm Face Brick + (Clay Tile)** | |
| D | 101.6 mm tile | 2.163 |
| D | Air space + 101.6 mm tile | 1.595 |
| C | Insulation + 101.6 mm tile | 0.959 |
| C | 203.2 mm tile | 1.561 |
| B | Air space or 25.4 mm insulation + 203.2 mm tile | 0.806-1.255 |
| A | 50.8 mm insulation + 203.2 mm tile | 0.551 |
| | **L.W. Concrete Wall + (Finish)** | |
| E | 101.5 mm concrete | 3.321 |
| D | 101.6 mm concrete + 25.4 mm or 50.8 mm insulation | 1.136 - 0.675 |
| C | 50.8 mm insulation+101.6 mm concrete | 0.675 |
| C | 203.2 mm concrete | 2.782 |
| B | 203.2 mm concrete + 25.4 mm or 50.8 mm insulation | 1.061 - 0.653 |
| A | 203.2 mm concrete + 50.8 mm insulation | 0.653 |
| B | 304.8 mm concrete | 2.390 |
| A | 304.8 mm concrete + insulation | 0.642 |
| | **L.W. and H.W. Concrete Block + (Finish)** | |
| F | 101.6 mm block + air space/insulation | 0.914-1.493 |
| E | 50.8 mm insulation + 101.6 mm block | 0.596-0.647 |
| E | 203.2 mm block | 1.669-2.282 |
| D | 203.2 mm block + air space/insulation | 0.846-0.982 |
| | **Clay Tile + (Finish)** | |
| F | 101.6 mm tile | 2.379 |
| F | 101.6 mm tile +air space | 1.720 |
| F | 101.6 mm tile + 25.4 mm insulation | 0.993 |
| D | 80.8 mm insulation + 10.4 mm tile | 0.825 |
| C | 203.3 mm tile + air space/25.4 mm insulation | 0.857-1.312 |
| B | 50.8 mm insulation + 203.2 mm tile | 0.562 |
| | **Metal Curtain Wall** | |
| G | With/without air space + 25.4 mm/58 to 76.2 mm insulation | 0.516-1.306 |
| | **Frame Wall** | |
| G | 24.4 mm to 76.2 mm insulation | 1.010 - 0.459 |

**A-2: Approximate CLTD values for light, medium, and heavy weight construction walls**

TABLE 9-6 Approximate CLTD values for light, medium, and heavy weight construction walls, °C.

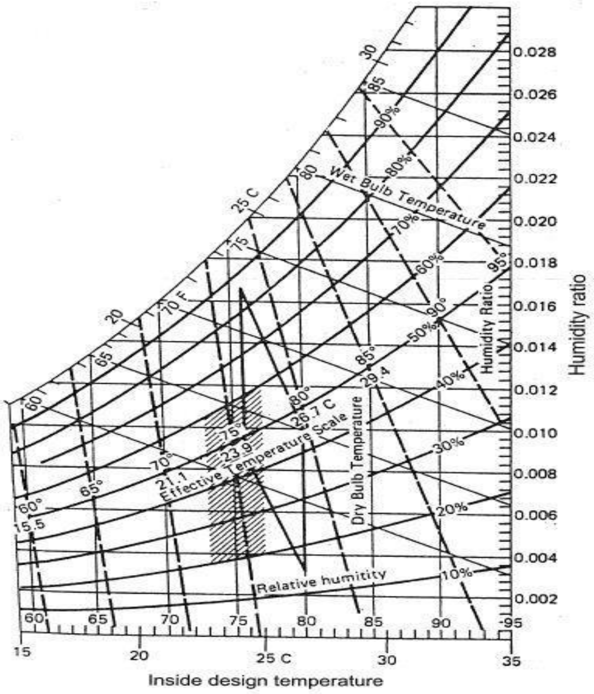
| Solar Time | Wall construction | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Light | | | | Medium | | | | Heavy | | | |
| | N | E | S | W | N | E | S | W | N | E | S | W |
| 8:00 | — | 16 | — | — | — | — | — | — | — | — | — | — |
| 9:00 | — | 20 | — | — | — | 6 | — | — | — | — | — | — |
| 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 |

**A-3: Approximate CLTD values for sunlit roofs**

TABLE 9-3 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 |

## A-4: Inside design temperature




## A-5: cooling load factor (CLF), for lights

Table (A-8) 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 |

[3] Adapted from Stoecker and Jones, 1982, "*Refrigeration and Air Conditioning*", 2[nd] ed., MacGraw Hill. (Fixture X = not vented recessed lights and Fixture Y = vented or free-hanging light.)

[4] Adapted from Jones, 1979 "*Air Conditioning applications and Design*", Edward Arnold.

**A-6: Cooling load factor due to occupants (CLF), for sensible gain**

Table (A-6-2) 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 |

**A-7: Cooling load temperature differences (CLTD) for convection heat gain for glass windows**

Table (A-7) 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 |

## A-8: Cooling load factor (CLF) for glass windows without interior shading

Table (A-5-1) Cooling load factors (CLF) for glass windows without interior shading, north latitudes.

| Glass Facing | Building Construction | Solar Time, h | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| | L | 0.17 | 0.14 | 0.11 | 0.09 | 0.08 | 0.33 | 0.24 | 0.48 | 0.56 | 0.61 | 0.71 | 0.76 | 0.80 | 0.82 | 0.82 | 0.79 | 0.75 |
| N | M | 0.23 | 0.20 | 0.18 | 0.16 | 0.14 | 0.34 | 0.14 | 0.46 | 0.53 | 0.59 | 0.65 | 0.70 | 0.73 | 0.75 | 0.76 | 0.74 | 0.75 |
| Shaded | H | 0.25 | 0.23 | 0.21 | 0.20 | 0.19 | 0.38 | 0.45 | 0.49 | 0.55 | 0.60 | 0.65 | 0.69 | 0.72 | 0.72 | 0.72 | 0.70 | 0.70 |
| | L | 0.06 | 0.05 | 0.04 | 0.03 | 0.03 | 0.26 | 0.43 | 0.47 | 0.44 | 0.41 | 0.40 | 0.39 | 0.39 | 0.38 | 0.36 | 0.33 | 0.30 |
| NNE | M | 0.09 | 0.08 | 0.07 | 0.06 | 0.06 | 0.24 | 0.38 | 0.42 | 0.39 | 0.37 | 0.37 | 0.36 | 0.36 | 0.36 | 0.34 | 0.33 | 0.30 |
| | H | 0.11 | 0.10 | 0.09 | 0.09 | 0.08 | 0.26 | 0.39 | 0.42 | 0.39 | 0.36 | 0.35 | 0.34 | 0.34 | 0.33 | 0.32 | 0.31 | 0.28 |
| | L | 0.04 | 0.04 | 0.03 | 0.02 | 0.02 | 0.23 | 0.41 | 0.51 | 0.51 | 0.45 | 0.39 | 0.36 | 0.33 | 0.31 | 0.28 | 0.26 | 0.23 |
| NE | M | 0.07 | 0.06 | 0.06 | 0.05 | 0.04 | 0.21 | 0.36 | 0.44 | 0.45 | 0.40 | 0.36 | 0.33 | 0.31 | 0.30 | 0.28 | 0.26 | 0.24 |
| | H | 0.09 | 0.08 | 0.08 | 0.07 | 0.07 | 0.23 | 0.37 | 0.44 | 0.44 | 0.39 | 0.34 | 0.31 | 0.29 | 0.27 | 0.26 | 0.24 | 0.22 |
| | L | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.21 | 0.40 | 0.52 | 0.57 | 0.53 | 0.45 | 0.39 | 0.34 | 0.31 | 0.28 | 0.25 | 0.22 |
| ENE | M | 0.07 | 0.06 | 0.05 | 0.05 | 0.04 | 0.20 | 0.35 | 0.45 | 0.49 | 0.47 | 0.41 | 0.36 | 0.33 | 0.30 | 0.28 | 0.26 | 0.23 |
| | H | 0.09 | 0.09 | 0.08 | 0.07 | 0.07 | 0.22 | 0.36 | 0.46 | 0.49 | 0.45 | 0.38 | 0.31 | 0.30 | 0.27 | 0.25 | 0.23 | 0.21 |
| | L | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | 0.19 | 0.37 | 0.51 | 0.57 | 0.57 | 0.50 | 0.42 | 0.37 | 0.32 | 0.29 | 0.25 | 0.22 |
| E | M | 0.07 | 0.06 | 0.06 | 0.05 | 0.05 | 0.18 | 0.33 | 0.44 | 0.50 | 0.51 | 0.46 | 0.39 | 0.35 | 0.31 | 0.29 | 0.26 | 0.23 |
| | H | 0.09 | 0.09 | 0.08 | 0.08 | 0.07 | 0.20 | 0.34 | 0.45 | 0.49 | 0.49 | 0.43 | 0.39 | 0.32 | 0.29 | 0.26 | 0.24 | 0.22 |
| | L | 0.05 | 0.04 | 0.03 | 0.03 | 0.02 | 0.17 | 0.34 | 0.49 | 0.58 | 0.61 | 0.57 | 0.48 | 0.41 | 0.36 | 0.32 | 0.28 | 0.24 |
| ESE | M | 0.08 | 0.07 | 0.06 | 0.05 | 0.05 | 0.16 | 0.31 | 0.43 | 0.51 | 0.54 | 0.51 | 0.44 | 0.39 | 0.35 | 0.32 | 0.29 | 0.26 |
| | H | 0.10 | 0.09 | 0.09 | 0.08 | 0.08 | 0.19 | 0.32 | 0.43 | 0.50 | 0.52 | 0.49 | 0.41 | 0.36 | 0.32 | 0.29 | 0.26 | 0.24 |
| | L | 0.05 | 0.04 | 0.04 | 0.03 | 0.03 | 0.13 | 0.28 | 0.43 | 0.55 | 0.62 | 0.63 | 0.57 | 0.48 | 0.42 | 0.37 | 0.33 | 0.28 |
| SE | M | 0.09 | 0.08 | 0.07 | 0.06 | 0.05 | 0.14 | 0.26 | 0.38 | 0.48 | 0.54 | 0.56 | 0.51 | 0.45 | 0.40 | 0.36 | 0.33 | 0.29 |
| | H | 0.11 | 0.10 | 0.10 | 0.09 | 0.08 | 0.17 | 0.28 | 0.40 | 0.49 | 0.53 | 0.53 | 0.48 | 0.41 | 0.36 | 0.33 | 0.30 | 0.27 |
| | L | 0.07 | 0.05 | 0.04 | 0.04 | 0.03 | 0.06 | 0.15 | 0.29 | 0.43 | 0.55 | 0.63 | 0.64 | 0.60 | 0.25 | 0.45 | 0.40 | 0.35 |
| SSE | M | 0.11 | 0.09 | 0.08 | 0.07 | 0.06 | 0.08 | 0.16 | 0.26 | 0.38 | 0.58 | 0.55 | 0.57 | 0.54 | 0.48 | 0.43 | 0.39 | 0.35 |
| | H | 0.12 | 0.11 | 0.11 | 0.10 | 0.09 | 0.12 | 0.19 | 0.29 | 0.40 | 0.49 | 0.54 | 0.55 | 0.51 | 0.44 | 0.39 | 0.35 | 0.31 |
| | L | 0.08 | 0.07 | 0.05 | 0.04 | 0.04 | 0.06 | 0.09 | 0.14 | 0.22 | 0.34 | 0.48 | 0.59 | 0.65 | 0.65 | 0.59 | 0.50 | 0.43 |
| S | M | 0.12 | 0.11 | 0.09 | 0.08 | 0.07 | 0.08 | 0.11 | 0.14 | 0.21 | 0.31 | 0.42 | 0.52 | 0.57 | 0.58 | 0.53 | 0.47 | 0.41 |
| | H | 0.13 | 0.12 | 0.12 | 0.11 | 0.10 | 0.11 | 0.14 | 0.17 | 0.24 | 0.33 | 0.43 | 0.51 | 0.56 | 0.55 | 0.50 | 0.43 | 0.37 |
| | L | 0.10 | 0.08 | 0.07 | 0.06 | 0.05 | 0.06 | 0.09 | 0.11 | 0.15 | 0.19 | 0.27 | 0.39 | 0.52 | 0.62 | 0.67 | 0.65 | 0.58 |
| SSW | M | 0.14 | 0.12 | 0.11 | 0.09 | 0.08 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.25 | 0.35 | 0.46 | 0.55 | 0.59 | 0.59 | 0.53 |
| | H | 0.15 | 0.14 | 0.13 | 0.12 | 0.11 | 0.12 | 0.14 | 0.16 | 0.18 | 0.21 | 0.27 | 0.37 | 0.46 | 0.53 | 0.57 | 0.55 | 0.49 |
| | L | 0.12 | 0.10 | 0.08 | 0.06 | 0.05 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 | 0.24 | 0.36 | 0.49 | 0.60 | 0.66 | 0.66 |
| SW | M | 0.15 | 0.14 | 0.12 | 0.10 | 0.09 | 0.09 | 0.10 | 0.12 | 0.13 | 0.15 | 0.17 | 0.23 | 0.33 | 0.44 | 0.53 | 0.58 | 0.59 |
| | H | 0.15 | 0.14 | 0.13 | 0.12 | 0.11 | 0.12 | 0.13 | 0.14 | 0.16 | 0.17 | 0.19 | 0.25 | 0.34 | 0.44 | 0.52 | 0.56 | 0.56 |
| | L | 0.12 | 0.10 | 0.08 | 0.07 | 0.05 | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 | 0.13 | 0.17 | 0.26 | 0.40 | 0.52 | 0.62 | 0.66 |
| WSW | M | 0.15 | 0.13 | 0.12 | 0.10 | 0.09 | 0.09 | 0.10 | 0.11 | 0.12 | 0.13 | 0.14 | 0.17 | 0.24 | 0.35 | 0.46 | 0.54 | 0.58 |
| | H | 0.15 | 0.14 | 0.13 | 0.12 | 0.11 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.16 | 0.19 | 0.26 | 0.36 | 0.46 | 0.53 | 0.56 |
| | L | 0.12 | 0.10 | 0.08 | 0.06 | 0.05 | 0.06 | 0.07 | 0.08 | 0.10 | 0.11 | 0.12 | 0.14 | 0.20 | 0.32 | 0.45 | 0.57 | 0.64 |

**A-9: cooling load factors for glass windows with interior shading**

Table (A-5-2) 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 |

**A-10: Shading coefficient for glass with interior shading**

Table (A-4-2) Shading coefficient (SC) for glass windows with interior shading.

| Type of Glass | Nominal Thickness, mm | Type of Interior Shading | | | | |
|---|---|---|---|---|---|---|
| | | Venetian Blinds | | Roller Shade | | |
| | | | | Opaque | | Translucent |
| | | Medium | Light | Dark | White | 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 | — | — |

## A-11: Shading coefficient for glass windows without interior shading

Table (A-4-1) Shading coefficient (SC) for glass windows without interior shading.[1]

| Type of Glass | Nominal Thickness, mm | Solar Trans. | Shading Coefficient, $W/m^2 \cdot K$ | |
|---|---|---|---|---|
| | | | $h_o = 22.7$ | $h_o = 17.0$ |
| **Single Glass** | | | | |
| Clear | 3 | 0.84 | 1.00 | 1.00 |
| | 6 | 0.78 | 0.94 | 0.95 |
| | 10 | 0.72 | 0.90 | 0.92 |
| | 12 | 0.67 | 0.87 | 0.88 |
| Heat absorbing | 3 | 0.64 | 0.83 | 0.85 |
| | 6 | 0.46 | 0.69 | 0.73 |
| | 10 | 0.33 | 0.60 | 0.64 |
| | 12 | 0.42 | 0.53 | 0.58 |
| **Double Glass** | | | | |
| Regular | 3 | — | 0.90 | — |
| Plate | 6 | — | 0.83 | — |
| Reflective | 6 | — | 0.20-0.40 | — |
| **Insulating Glass** | | | | |
| Clear | 3 | 0.71 | 0.88 | 0.88 |
| | 6 | 0.61 | 0.81 | 0.82 |
| Heat absorbing* | 6 | 0.36 | 0.55 | 0.58 |

## A-12: Solar heat gain factor for sunlit glass

Table (A-3) Solar heat gain factor (SHG) for sunlit glass, $W/m^2$, 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 |

**A-13: Values of infiltration air coefficient for windows**

**TABLE 6–2** Values of infiltration air coefficient K.(2) for windows.

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

**A-14: Infiltration rates due to door opening**

**TABLE 6–5** Infiltration rates due to door opening, $m^3$ per passage.[4]

| № of Passage per Hour | Doors in One Wall Only | | | Doors in more than One Wall | | |
|---|---|---|---|---|---|---|
| | Single Swing | Vestibule Swinging Doors | Revolving Doors | Single Swing | Vestibule Swinging Doors | Revolving Doors |
| 300 | 4.757 | 3.540 | 1.359 | 3.115 | 2.350 | 0.850 |
| 500 | 4.757 | 3.540 | 1.303 | 3.115 | 2.350 | 0.821 |
| 700 | 4.757 | 3.540 | 1.218 | 3.115 | 2.322 | 0.765 |
| 900 | 4.757 | 3.540 | 1.104 | 3.087 | 2.322 | 0.708 |
| 1,100 | 4.757 | 3.540 | 0.935 | 3.087 | 2.322 | 0.651 |
| 1,200 | 4.757 | 3.540 | 0.850 | 3.058 | 2.322 | 0.595 |
| 1,300 | 4.757 | 3.540 | 0.793 | 3.058 | 2.322 | 0.538 |
| 1,400 | 4.757 | 3.540 | 0.708 | 3.058 | 2.294 | 0.510 |
| 1,500 | 4.757 | 3.540 | 0.651 | 3.058 | 2.294 | 0.481 |
| 1,600 | 4.729 | 3.540 | 0.595 | 3.058 | 2.294 | 0.453 |
| 1,700 | 4.616 | 3.511 | 0.538 | 3.030 | 2.294 | 0.425 |
| 1,800 | 4.502 | 3.455 | 0.510 | 2.973 | 2.265 | 0.396 |
| 1,900 | 4.418 | 3.398 | 0.481 | 2.945 | 2.265 | 0.368 |
| 2,000 | 4.304 | 3.341 | 0.453 | 3.832 | 2.237 | 0.340 |

## A-15: Table for estimating demand

Table (P-1): 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 |
| 10000 | 790 | 10000 | 790 |

## A-16: fixture units

| 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:

## A-17: Approximate discharge rates and velocities in sloping drains flowing half full

Table (P-3) 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.

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## A-18: Horizontal fixture branches and stacks

Table (P-3) Horizontal Fixture Branches and Stacks

| Diameter of Pipe, in. | Maximum Number of Fixture Units That May Be Connected to | | | |
|---|---|---|---|---|
| | 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 |
| 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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**A-19: Values of the factor S1**

TABLE 6–3 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 |

**A-20: Values of the factor S2**

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

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

## A-21: Instantaneous heat gain from occupants

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

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

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

## A-22: Minimum pressure required by typical plumbing fixtures

Table 9.1 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 |
| Garden hose | |
| ⅝-in. sill cock | 15 |
| ¾-in. sill cock | 30 |
| Drinking fountain | 15 |

*Source.* EPA Manual of Individual Water Supply System, 1975 and manufacturers' data.

Table 9.2 Recommended Flow Rates for Typical Plumbing Fixtures

| *Fixture Type* | *Flow, gpm* |
|---|---|
| Lavatory | 3 |
| Sink | 4.5 |
| Bathtub | 6 |
| Laundry tray | 5 |
| Shower | 3–10 |
| Water closets | |
| tank type | 3 |
| flush valve* | 15–40 |
| Urinal flush valve | 15 |
| Garden hose | |
| ⅝-in. sill cock | 3⅓ |
| ¾-in. sill cock | 5 |
| Drinking fountain | ¾ |

*Source.* Data extracted from various sources.
*Wide range of flows; depends on flow pressure.

Table 9.5 Demand at Individual Water Outlets

| *Type of Outlet* | *Demand, gpm* |
|---|---|
| Ordinary lavatory faucet | 2.0 |
| Self-closing lavatory faucet | 2.5 |
| Sink faucet, ⅜ or ½ in. | 4.5 |
| Sink faucet, ¾ in. | 6.0 |
| Bath faucet, ½ in. | 5.0 |
| Shower head, ½ in. | 5.0 |
| Laundry faucet, ½ in. | 5.0 |
| Ballcock in water closet flush tank | 3.0 |
| 1-in. flush valve (25-psi flow pressure) | 35.0 |
| 1-in. flush valve (15-psi flow pressure) | 27.0 |
| ¾-in. flush valve (15-psi flow pressure) | 15.0 |
| Drinking fountain jet | 0.75 |
| Dishwashing machine (domestic) | 4.0 |
| Laundry machine (8 or 16 lb) | 4.0 |
| Aspirator (operating room or laboratory) | 2.5 |
| Hose bibb or sill cock (½ in.) | 5.0 |

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Table 9.4 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 |

*Water Supply Fixture Units
*Source.* Reproduced with permission from The National Standard Plumbing Code, published by The Na-

## A-23: Drainage fixture unit values for various plumping fixtures



**Table 10.2 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 | ½ |
| 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 10.3 Minimum Size of Nonintegral Traps**

| *Plumbing Fixture* | *Trap Size, in.* |
|---|---|
| Bathtub (with or without overhead shower) | 1½ |
| Bidet | 1¼ |
| Clothes washing machine standpipe | 2 |
| Combination sink and wash (laundry) tray | 1½ |
| Combination sink and wash (laundry) tray with food waste grinder unit[a] | 1½ |
| Combination kitchen sink, domestic, dishwasher, and food waste grinder | 1½ |
| Dental unit or cuspidor | 1¼ |
| Dental lavatory | 1¼ |
| Drinking fountain | 1¼ |
| Dishwasher, commercial | 2 |
| Dishwasher, domestic (nonintegral trap) | 1½ |
| Floor drain | 2 |
| Food waste grinder, commercial | 2 |
| Food waster grinder, domestic | 1½ |
| Kitchen sink, domestic, with food waste grinder unit | 1½ |
| Kitchen sink, domestic | 1½ |
| Kitchen sink, domestic, with dishwasher | 1½ |
| Lavatory, common | 1¼ |
| Lavatory (barber shop, beauty parlor or surgeon's) | 1½ |
| Lavatory, multiple type (wash fountain or wash sink) | 1½ |
| Laundry tray (1 or 2 compartments) | 1½ |
| Shower stall or drain | 2 |
| Sink (surgeon's) | 1½ |
| Sink flushing rim type (flush valve supplied) | 3 |
| Sink (service type with floor outlet trap standard) | 3 |
| Sink (service trap with P trap) | 2 |
| Sink, commercial (pot, scullery, or similar type) | 2 |
| Sink, commercial (with food grinder unit) | 2 |

[a]Separate trap required for wash tray and separate trap required for sink compartment with food waste grinder unit.

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## A-24: Horizontal fixture branches and stacks, building drains and sewers



Table 10.4 Horizontal Fixture Branches and Stacks

| Diameter of Pipe, in. | Maximum Number of Fixture Units That May Be Connected to: 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 |
|---|---|---|---|---|
| 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 10.5 Building Drains and Sewers[a]

| Diameter of Pipe, in. | Maximum Number of Fixture Units That May Be Connected to Any Portion of the Building Drain or the Building Sewer — Slope per Foot: 1/16 in. | 1/8 in. | 1/4 in. | 1/2 in. |
|---|---|---|---|---|
| 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.

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## A-25: Latitude- month correction factor LM

Table (A-2) Latitude-Month correction factor LM, as applied to walls and horizontal roofs, north latitudes.

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

**A-26: mechanical ventilation**

**TABLE A(2.20) Minimum outside air requirements for mechanical ventilation**

| 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 | — |

**A-27: inside & outside film resistance**

Table A(2.2) Inside film resistance, $R_i$.

| Element | Heat Direction | Material Type | $R_i$ $m^2 \cdot °C/W$ |
|---|---|---|---|
| **Walls** | Horizontal | Construction materials | 0.12 |
| | | Metals | 0.31 |
| **Ceilings and floors** | Upward | Construction materials | 0.10 |
| | | Metals | 0.21 |
| | Downward | Construction materials | 0.15 |

Table A(2.3) Outside film resistance, $R_o$.

| Wind Speed | | Less than 0.5 m/s | 0.5 - 5.0 m/s | More than 5.0 m/s |
|---|---|---|---|---|
| Element | Material Type | Outside Resistance $R_o$, $m^2 \cdot °C/W$ | | |
| **Walls** | Construction materials | 0.08 | 0.06 | 0.03 |
| | Metals | 0.10 | 0.07 | 0.03 |
| **Ceilings** | Construction materials | 0.07 | 0.04 | 0.02 |
| | Metals | 0.09 | 0.05 | 0.02 |
| **Exposed floors** | Construction materials | 0.09 | — | — |

**A-28: overall heat coefficient for windows**

TABLE A(2.4) Overall Heat Transfer Coefficient for Windows, W/m²·°C

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

**A-29: overall heat coefficient for wood and metals door**

TABLE A(2.5) 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 | — | — |

**Palestinian code**

جدول رقم (3/ 1): القيم التصميمية الخارجية للمناطق المناخية المختلفة

| القيم التصميمية الخارجية | | المنطقة المناخية* | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | الضفة الغربية | | | | | قطاع غزة | |
| | | الأولى | الثانية | الثالثة | الرابعة | الخامسة | الثالثة | السادسة |
| درجة الحرارة (C˚) | شتاءً | 7 | 7 | 5 | 4 | 8 | 5 | 9 |
| | صيفاً | 39 | 39 | 32 | 30 | 34 | 32 | 31 |
| الرطوبة النسبية (%) | شتاءً: أدنى | 60 | 60 | 60 | 62 | 63 | 60 | 62 |
| | أقصى | 70 | 70 | 72 | 72 | 78 | 72 | 69 |
| | صيفاً: أدنى | 43 | 43 | 49 | 44 | 55 | 49 | 65 |
| | أقصى | 54 | 54 | 67 | 57 | 66 | 67 | 77 |
| سرعة الرياح (m/s) | | 1 | 1 | 1.5 | 1.4 | 1.1 | 1.5 | 2.8 |
| شدة الاشعاع الشمسي ($W/m^2$) | | تعتبر قيم شدة الاشعاع القصوى للاتجاهات المختلفة في الجدولين (3/ 18) و (3/ 19) قيماً تصميمية لكافة المناطق المناخية | | | | | | |
| درجة يوم تسخين (C.day˚) | | لا تتوفر معلومات عن هذه القيم حالياً | | | | | | |
| درجة يوم تبريد (C.day˚) | | | | | | | | |

* المناطق المناخية للأراضي الفلسطينية مبينة في الملحق (هـ)

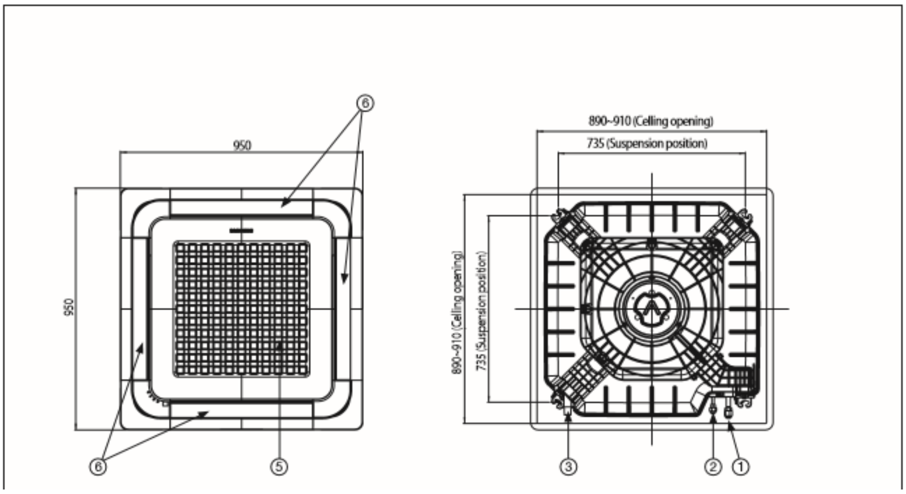
جدول رقم (1/ 10) معدل سرعة الرياح للمحطات المناخية في الضفة الغربية.

| المحطة | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| القدس | 16.3 | 18.0 | 18.4 | 18.5 | 18.0 | 19.4 | 20.4 | 18.6 | 17.0 | 13.0 | 14.1 | 16.0 |
| نابلس | 8.7 | 9.5 | 10.0 | 10.2 | 10.7 | 12.0 | 12.4 | 11.7 | 10.3 | 7.7 | 7.8 | 7.7 |
| جنين | 7.5 | 7.9 | 7.9 | 7.9 | 9.0 | 9.4 | 9.7 | 8.6 | 7.2 | 5.4 | 6.1 | 7.5 |
| طولكرم | 4.3 | 4.1 | 3.8 | 3.4 | 3.3 | 2.9 | 2.9 | 2.7 | 2.6 | 2.9 | 3.8 | 4.0 |
| أريحا | 8.9 | 10.4 | 13.1 | 16.2 | 15.8 | 15.3 | 16.0 | 14.8 | 12.5 | 9.4 | 7.9 | 7.6 |
| الخليل | 12.4 | 12.8 | 12.6 | 11.5 | 9.3 | 9.3 | 9.2 | 8.7 | 8.1 | 8.0 | 8.8 | 10.1 |
| العروب | 8.6 | 10.1 | 10.8 | 9.7 | 6.5 | 5.1 | 5.1 | 5.4 | 5.1 | 5.8 | 5.8 | 7.9 |
| الفارعة | 4.6 | 6.5 | 6.1 | 3.6 | 3.3 | 3.6 | 6.8 | 6.5 | 5.0 | 2.5 | 2.5 | 2.1 |

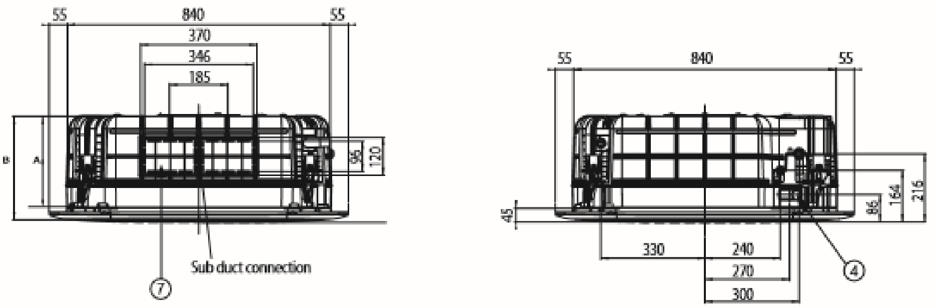
catalogue of VRF:
4 -way cassette in door unit and dimensional drawing:


4-4 . Dimensional drawing

Unit:mm




Indoor units




| No. | Name | Description | | | |
|---|---|---|---|---|---|
| | | 4.5/5.6kW | 7.1/9.0kW | 11.2kW | 12.8/14.0kW |
| ① | Liquid pipe connection | Ø6.35 Flare | Ø9.52 Flare | | |
| ② | Gas pipe connection | Ø12.70 Flare | Ø15.88 Flare | | |
| ③ | Drain pipe connection | ID25 Hose (OD 32, ID 25) | | | |
| ④ | Conduit for power supply & communication wiring | - | | | |
| ⑤ | Air inlet grille | - | | | |
| ⑥ | Air outlet louver | - | | | |
| ⑦ | Fresh air intake | - | | | |
| ⑧ | Drainage testing hole | - | | | |

| | | Description | | | |
|---|---|---|---|---|---|
| | | 4.5/5.6kW | 7.1/9.0kW | 11.2kW | 12.8/14.0kW |
| A | mm | 204 | | 246 | 288 |
| B | mm | 253 | | 295 | 337 |

1) Technical specifications

| Model | | | | ND0454HXEA | ND0564HXEA | ND0714HXEA | ND0904HXEA | ND1124HXEA | ND1284HXEA | ND1404HXEA |
|---|---|---|---|---|---|---|---|---|---|---|
| Power Supply | | | Ø, #, V, Hz | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 |
| Mode *1) | | | - | HP / HR | HP / HR | HP / HR | HP / HR | HP / HR | HP / HR | HP / HR |
| | Capacity (Nominal) | Cooling *2) | kW | 4.5 | 5.6 | 7.1 | 9.0 | 11.2 | 12.8 | 14.0 |
| | | | Btu/h | 15,400 | 19,100 | 24,200 | 30,700 | 38,200 | 43,700 | 47,800 |
| | | Heating *3) | kW | 5.0 | 6.3 | 8.0 | 10.0 | 12.5 | 13.8 | 16.0 |
| | | | Btu/h | 17,100 | 21,500 | 27,300 | 34,100 | 42,700 | 47,100 | 54,600 |
| Power | Power Input (Nominal) | Cooling *2) | W | 40 | 40 | 45 | 50 | 50 | 65 | 80 |
| | | Heating *3) | | 40 | 40 | 45 | 50 | 50 | 65 | 80 |
| | Current Input (Nominal) | Cooling *2) | A | 0.19 | 0.19 | 0.21 | 0.23 | 0.23 | 0.30 | 0.36 |
| | | Heating *3) | | 0.19 | 0.19 | 0.21 | 0.23 | 0.23 | 0.30 | 0.36 |
| Fan | Motor | Type | - | Turbo Fan / BLDC | Turbo Fan / BLDC | Turbo Fan / BLDC | Turbo Fan / BLDC | Turbo Fan / BLDC | Turbo Fan / BLDC | Turbo Fan / BLDC |
| | | Output | W | | | | | | | |
| | | Number of unit | EA | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Air Flow Rate | H/M/L (UL) | CMM | 14.5 | 15.0 | 17.0 | 19.5 | 26.0 | 28.0 | 30.0 |
| | | | CFM | 510 / 480 / 440 | 530 / 490 / 460 | 600 / 550 / 510 | 690 / 640 / 580 | 920 / 850 / 780 | 990 / 920 / 810 | 1060 / 990 / 920 |
| | External Pressure | Min / Std / Max | mmAq | - | - | - | - | - | - | - |
| | | | Pa | - | - | - | - | - | - | - |
| | | | WG | - | - | - | - | - | - | - |
| Option Code | | | - | 01407F-156097-232D2D-30000B | 01407F-1560A7-23383B-30000B | 01407F-1460D8-234747-30000B | 01407F-156209-235A5A-30000B | 01407F-15621B-237070-30000B | 01407F-15622D-23B0B9-30000B | 01407F-15624F-23BC8C-30000B |
| Piping Connections | Liquid Pipe | | Ø, mm | 6.35 | 6.35 | 9.52 | 9.52 | 9.52 | 9.52 | 9.52 |
| | | | Ø, inch | 1/4 | 1/4 | 3/8 | 3/8 | 3/8 | 3/8 | 3/8 |
| | Gas Pipe | | Ø, mm | 12.7 | 12.7 | 15.88 | 15.88 | 15.88 | 15.88 | 15.88 |
| | | | Ø, inch | 1/2 | 1/2 | 5/8 | 5/8 | 5/8 | 5/8 | 5/8 |
| | Drain Pipe | | Ø, mm | ID25 Hose (OD 32, ID 25) | ID25 Hose (OD 32, ID 25) | ID25 Hose (OD 32, ID 25) | ID25 Hose (OD 32, ID 25) | ID25 Hose (OD 32, ID 25) | ID25 Hose (OD 32, ID 25) | ID25 Hose (OD 32, ID 25) |
| Field Wiring | Power Source Wire | Below 20m / over 20m | $mm^2$ | 1.5 / 2.5 | 1.5 / 2.5 | 1.5 / 2.5 | 1.5 / 2.5 | 1.5 / 2.5 | 1.5 / 2.5 | 1.5 / 2.5 |
| | Transmission Cable | | $mm^2$ | 0.75 / 1.5 | 0.75 / 1.5 | 0.75 / 1.5 | 0.75 / 1.5 | 0.75 / 1.5 | 0.75 / 1.5 | 0.75 / 1.5 |
| Refrigerant | Type | | - | R410A | R410A | R410A | R410A | R410A | R410A | R410A |
| | Control Method | | - | EEV | EEV | EEV | EEV | EEV | EEV | EEV |
| Sound | Sound Pressure | High / Low *4) | dBA | 34/29 | 34/30 | 36/30 | 39/32 | 39/32 | 41/35 | 45/38 |
| Dimensions | Net Weight | | kg | 15.1 | 15.1 | 15.1 | 15.1 | 17 | 18.7 | 18.7 |
| | Shipping Weight | | kg | 19.1 | 19.1 | 19.1 | 19.1 | 20.5 | 22.8 | 22.8 |
| | Net Dimensions (WxHxD) | | mm | 840 x 204 x 840 | 840 x 204 x 840 | 840 x 204 x 840 | 840 x 204 x 840 | 840 x 246 x 840 | 840 x 288 x 840 | 840 x 288 x 840 |
| | Shipping Dimensions | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

Wall mounted in door unit and dimensional drawing:

# 10 Neo Forte & Neo-Forte E

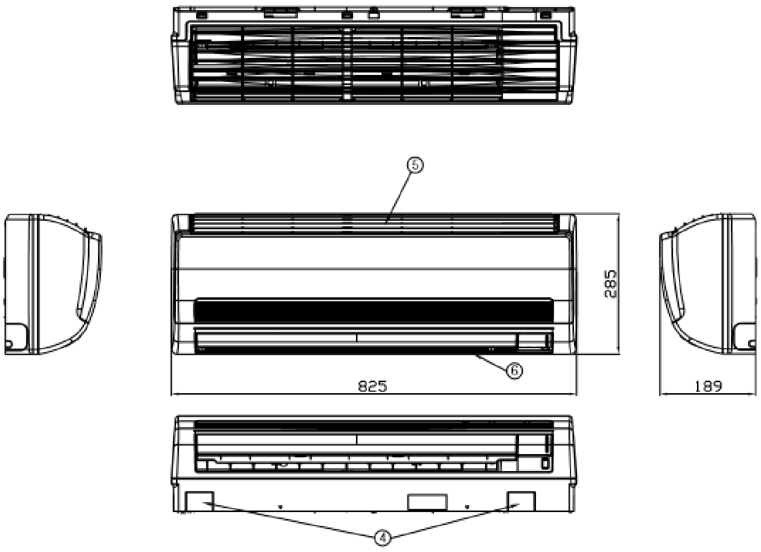
(AVXWNH✶✶✶E✶/ND✶✶✶QHXE✶)

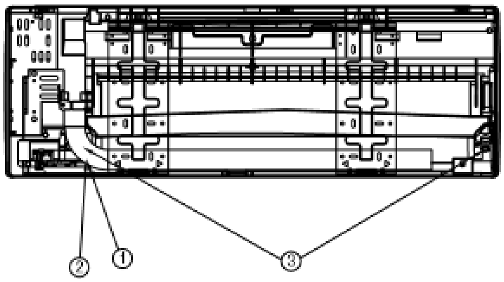


## 10-4. Dimensional drawing

1) AVXWNH022/028/036E✳, ND022/028/036QHXE✳

Unit:mm






| No. | Name | Description | | |
|---|---|---|---|---|
| | | 2.2kW | 2.8kW | 3.6kW |
| ① | Liquid pipe connection | Ø6.35 Flare | | |
| ② | Gas pipe connection | Ø12.70 Flare | | |
| ③ | Drain pipe connection | ID18 Hose | | |
| ④ | Conduit for power supply & communication wiring | - | | |
| ⑤ | Air inlet grille | - | | |
| ⑥ | Air outlet louver | - | | |

## 1) Technical specifications



| Model | | | | AVXWNH022E*, ND022QHXE* | AVXWNH028E*, ND028QHXE* | AVXWNH036E*, ND036QHXE* | ND045QHXE* | AVXWNH056E*, ND056QHXE* | AVXWNH071E*, ND071QHXE* |
|---|---|---|---|---|---|---|---|---|---|
| Power Supply | | | Ø, #, V, Hz | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 | 1, 2, 220~240, 50 |
| Mode *1) | | | - | HP / HR | HP / HR | HP / HR | HP / HR | HP / HR | HP / HR |
| | Capacity (Nominal) | Cooling *2) | kW | 2.2 | 2.8 | 3.6 | 4.5 | 5.6 | 6.8 |
| | | | Btu/h | 7,500 | 9,600 | 12,300 | 15,300 | 19,100 | 23,200 |
| | | Heating *3) | kW | 2.5 | 3.2 | 4.0 | 5.0 | 6.3 | 7.0 |
| | | | Btu/h | 8,500 | 10,900 | 13,600 | 17,000 | 21,500 | 23,900 |
| Power | Power Input (Nominal) | Cooling *2) | W | 25 | 25 | 30 | 40 | 45 | 50 |
| | | Heating *3) | | 25 | 25 | 30 | 40 | 45 | 50 |
| | Current Input (Nominal) | Cooling *2) | A | 0.16 | 0.16 | 0.18 | 0.18 | 0.27 | 0.30 |
| | | Heating *3) | | 0.16 | 0.16 | 0.18 | 0.18 | 0.27 | 0.30 |
| Fan | Motor | Type | - | Crossflow Fan / SSR | Crossflow Fan / SSR | Crossflow Fan / SSR | Crossflow Fan / SSR | Crossflow Fan / SSR | Crossflow Fan / SSR |
| | | Output | W | 23 | 23 | 23 | 40 | 40 | 40 |
| | | Number of unit | EA | 1 | 1 | 1 | 1 | 1 | 1 |
| | Air Flow Rate | H/M/L (UL) | CMM | 7.8 / 6.8 / 5.8 | 8.2 / 7.2 / 6.2 | 9.3 / 8.3 / 7.3 | 11.7 / 10.2 / 8.7 | 12 / 10.5 / 9 | 14 / 12.5 / 11 |
| | | | CFM | 280 / 240 / 200 | 290 / 250 / 220 | 330 / 290 / 260 | 410 / 360 / 310 | 420 / 370 / 320 | 490 / 440 / 390 |
| | External Pressure | Min / Std / Max | mmAq | - | - | - | - | - | - |
| | | | Pa | - | - | - | - | - | - |
| | | | WG | - | - | - | - | - | - |
| Option Code | | | - | 027602-1120FA-200000-300000 | 027602-1320FA-200000-300000 | 027602-15224d-200000-300000 | 026602-18223F-200000-300000 | 026602-1A226F-200000-300000 | 026602-1C228F-200000-300000 |
| Piping Connections | Liquid Pipe | | Ø, mm | 6.35 | 6.35 | 6.35 | 6.35 | 6.35 | 9.52 |
| | | | Ø, inch | 1/4 | 1/4 | 1/4 | 1/4 | 1/4 | 3/8 |
| | Gas Pipe | | Ø, mm | 12.7 | 12.7 | 12.7 | 12.7 | 12.7 | 15.88 |
| | | | Ø, inch | 1/2 | 1/2 | 1/2 | 1/2 | 1/2 | 5/8 |
| | Drain Pipe | | Ø, mm | ID18 Hose (OD, ID) | ID18 Hose (OD, ID) | ID18 Hose (OD, ID) | ID18 Hose (OD, ID) | ID18 Hose (OD, ID) | ID18 Hose (OD, ID) |
| Field Wiring | Power Source Wire | Below 20m / over 20m | $mm^2$ | 1.5 / 2.5 | 1.5 / 2.5 | 1.5 / 2.5 | 1.5 / 2.5 | 1.5 / 2.5 | 1.5 / 2.5 |
| | Transmission Cable | | $mm^2$ | 0.75 / 1.5 | 0.75 / 1.5 | 0.75 / 1.5 | 0.75 / 1.5 | 0.75 / 1.5 | 0.75 / 1.5 |
| Refrigerant | Type | | - | R410A | R410A | R410A | R410A | R410A | R410A |
| | Control Method | | - | EEV (External) EEV (Internal) | EEV (External) EEV (Internal) | EEV (External) EEV (Internal) | EEV (Internal) | EEV (External) EEV (Internal) | EEV (External) EEV (Internal) |
| Sound | Sound Pressure | High / Low *4) | dBA | 32 / 23, 35 / 26 | 32 / 23, 35 / 26 | 36 / 23, 39 / 26 | 39 / 33 | 40 / 30, 42 / 33 | 41 / 30, 44 / 33 |
| Dimensions | Net Weight | | kg | 8 | 8 | 8 | 13 | 13 | 13 |
| | Shipping Weight | | kg | 9 | 9 | 9 | 16 | 16 | 16 |
| | Net Dimensions (WxHxD) | | mm | 825 x 285 x 189 | 825 x 285 x 189 | 825 x 285 x 189 | 1,065 x 298 x 218 | 1,065 x 298 x 218 | 1,065 x 298 x 218 |
| | Shipping Dimensions (WxHxD) | | mm | 900 x 349 x 252 | 900 x 349 x 252 | 900 x 349 x 252 | 1,137 x 377 x 299 | 1,137 x 377 x 299 | 1,137 x 377 x 299 |
| | Panel model | | - | - | - | - | | - | - |
| | Panel Net Weight | | kg | - | - | - | | - | - |

Out door unit :

## 1) Compact (Single)

| Type | | | |  |  |  |  |
|---|---|---|---|---|---|---|---|
| Model Name | | | | RD080HHXGA | RD100HHXGA | RD120HHXGA | RD140HHXGA |
| | | | | 8 | 10 | 12 | 14 |
| Power Supply | | | Ø, #, V, Hz | 3, 4, 380~415, 50 | 3, 4, 380~415, 50 | 3, 4, 380~415, 50 | 3, 4, 380~415, 50 |
| Mode | | | - | Heat Pump | Heat Pump | Heat Pump | Heat Pump |
| Performance | HP | | HP | 8 | 10 | 12 | 14 |
| | Capacity (Nominal) | Cooling [1] | kW | 22.4 | 28.0 | 33.6 | 39.2 |
| | | | Btu/h | 76,400 | 95,500 | 114,600 | 133,800 |
| | | Heating [2] | kW | 25.2 | 31.5 | 37.8 | 44.1 |
| | | | Btu/h | 86,000 | 107,500 | 129,000 | 150,500 |
| Power | Power Input (Nominal) | Cooling [1] | kW | 5.20 | 7.04 | 9.20 | 10.10 |
| | | Heating [2] | | 5.46 | 6.89 | 8.50 | 9.65 |
| | Current Input (Nominal) | Cooling [1] | A | 8.80 | 13.00 | 20.00 | 20.90 |
| | | Heating [2] | | 11.40 | 12.70 | 18.40 | 19.40 |
| | Max. Current Input | | | 18.40 | 21.50 | 28.40 | 29.40 |
| | Circuit Breaker (MCCB+ELB / ELCB) | | A | 30 | 30 | 40 | 40 |
| COP | Nominal Cooling | | - | 4.31 | 3.98 | 3.65 | 3.88 |
| | Nominal Heating | | - | 4.62 | 4.57 | 4.45 | 4.57 |
| FAN | Air Flow Rate | | CMM | 173 | 173 | 210 | 226 |
| Piping Connections | Liquid Pipe | | Ø, mm | 9.52 | 9.52 | 12.70 | 12.70 |
| | Gas Pipe | | Ø, mm | 19.05 | 22.23 | 25.40 | 25.40 |
| | Discharge Gas Pipe | | Ø, mm | - | - | - | - |
| | Oil Equalizing Pipe | | Ø, mm | - | - | - | - |
| | Installation Limitation | Max. Length | m | 200 | 200 | 200 | 200 |
| | | Max. Height | m | 50 (40)* | 50 (40)* | 50 (40)* | 50 (40)* |
| Field Wiring | Power cable | | mm² | CV 1.5 | CV 2.5 | CV 4 | CV 4 |
| | Communication cable | | mm² | 0.75~1.5 | 0.75~1.5 | 0.75~1.5 | 0.75~1.5 |
| Refrigerant | Type | | - | R-410A | R-410A | R-410A | R-410A |
| | Factory Charging | | kg | 5.0 | 5.0 | 5.0 | 7.0 |
| Sound [5] | Sound Pressure | | dB(A) | 57 | 58 | 60 | 60 |
| External Dimension | Net Weight | | kg | 237 | 237 | 240 | 280 |
| | Shipping Weight | | kg | 253 | 253 | 256 | 301 |
| | Net Dimensions (WxHxD) | | mm | 880 x 1695 x 765 | 880 x 1695 x 765 | 880 x 1695 x 765 | 1295 x 1695 x 765 |
| | Shipping Dimensions (WxHxD) | | mm | 948 x 1912 x 832 | 948 x 1912 x 832 | 948 x 1912 x 832 | 1363 x 1912 x 832 |
| Operating Temp. Range | Cooling | | °C | -5 ~ 48 | -5 ~ 48 | -5 ~ 48 | -5 ~ 48 |
| | Heating | | °C | -20 ~ 24 | -20 ~ 24 | -20 ~ 24 | -20 ~ 24 |

| Type | | | |  |  |  |
|---|---|---|---|---|---|---|
| Model Name | | | | RD160HHXGA | RD180HHXGA | RD200HHXGA |
| | | | | 16 | 18 | 20 |
| Power Supply | | | Ø, #, V, Hz | 3, 4, 380~415, 50 | 3, 4, 380~415, 50 | 3, 4, 380~415, 50 |
| Mode | | | - | Heat Pump | Heat Pump | Heat Pump |
| Performance | HP | | HP | 16 | 18 | 20 |
| | Capacity (Nominal) | Cooling [1] | kW | 44.8 | 50.4 | 56.0 |
| | | | Btu/h | 152,900 | 172,000 | 191,100 |
| | | Heating [2] | kW | 50.4 | 56.7 | 63.0 |
| | | | Btu/h | 172,000 | 193,500 | 215,000 |
| Power | Power Input (Nominal) | Cooling [1] | kW | 12.00 | 15.70 | 17.00 |
| | | Heating [2] | | 11.30 | 12.90 | 14.50 |
| | Current Input (Nominal) | Cooling [1] | A | 22.00 | 31.30 | 32.80 |
| | | Heating [2] | | 27.20 | 26.70 | 29.10 |
| | Max. Current Input | | | 38.30 | 42.5 | 44.1 |
| | Circuit Breaker (MCCB+ELB / ELCB) | | A | 50 | 60 | 60 |

| | | | | | | |
|---|---|---|---|---|---|---|
| COP | Nominal Cooling | | - | 3.73 | 3.21 | 3.29 |
| | Nominal Heating | | - | 4.46 | 4.40 | 4.34 |
| FAN | Air Flow Rate | | CMM | 250 | 270 | 275 |
| Piping Connections | Liquid Pipe | | Ø, mm | 12.70 | 15.88 | 15.88 |
| | Gas Pipe | | Ø, mm | 28.58 | 28.58 | 28.58 |
| | Discharge Gas Pipe | | Ø, mm | - | - | - |
| | Oil Equalizing Pipe | | Ø, mm | - | - | - |
| | Installation Limitation | Max. Length | m | 200 | 200 | 200 |
| | | Max. Height | m | 50 (40)* | 50 (40)* | 50 (40)* |
| Field Wiring | Power cable | | $mm^2$ | CV 6 | CV 6 | CV 10 |
| | Communication cable | | $mm^2$ | 0.75~1.5 | 0.75~1.5 | 0.75~1.5 |
| Refrigerant | Type | | - | R-410A | R-410A | R-410A |
| | Factory Charging | | kg | 7.0 | 8.5 | 8.5 |
| Sound [5)] | Sound Pressure | | dB(A) | 60 | 60 | 61 |
| External Dimension | Net Weight | | kg | 329 | 340 | 349 |
| | Shipping Weight | | kg | 350 | 361 | 370 |
| | Net Dimensions (WxHxD) | | mm | 1295 x 1695 x 765 | 1295 x 1695 x 765 | 1295 x 1695 x 765 |
| | Shipping Dimensions (WxHxD) | | mm | 1363 x 1912 x 832 | 1363 x 1912 x 832 | 1363 x 1912 x 832 |