$t_{wb} [28^0C]$ : The wet bulb temperature of environment.

$dt [3^0C] = t_0 - t_{wb} \geq 3^0C$. Vậy ta có $t_0 = t_{wb} + 3^0C = 28 + 3 = 31^0C$

**Conclusion:** In this category we choose water as a refrigerant and use a cooling tower to cool the coolant.

**III. CALCULATE THE HEAT**

1. Calculation of cooling system for load1 & load2

1.1 Introduction to cooling towers

A cooling tower is a heat exchanger used to cool circulating water for condensers by evaporating part of the water in direct contact with the ambient air.

**To classify**

The cooling tower have two type: Circle type and shaft type, shaft type consist of: Many of modul can assemble to have large capacity. For average system usually use Cylinder cooling tower.

The cooling tower is made by composit plastic, slight and convenient assembly. In the shaft plastic have function make water retention, increasing the area and contact time. Hot water is transfer from above to under, in the process spray, Spray pipe rotate around axis and puff on many shaft plastic. The air is exhausted from under to above and heat exchange with water. Fan at position above of cooling tower. The under of tower have many grill plate use to stop garbage and can remove to clean the bottom of cooling tower. The body is assembled from many plate, assembly position create thews to hard body. For small capacity, the bottle of Tower is produced one plate.

**Pipe work of the cooling tower include:**

Water pipe in and out cooling tower: Input pipe, output pipe, drain pipe, overflow pipe and make up pipe.
1.2 Choose a solution for the cooling system

Option 1:

Operational principles

Coolant is pumped to the equipment load1 and load2. The tower contains structure, vertical cylindrical, is divided into two sections contain hot water and cold water, the tower contains this at the same time is the heat exchanger to help reduce the hot water temperature before putting up the cooling tower. Water after being cooled in cooling tower to achieve the required temperature of 31°C will return to the tower contains continue the process of cooling for the device to work. So we must determine the temperature heated up after cooling for load1 and load2. According to the law of thermal equilibrium, we have the formula:

\[ M_1 \cdot C_1 \cdot T_1 + M_2 \cdot C_2 \cdot T_2 = \Sigma M_0 \cdot C_0 \cdot T_0 \]

\[ \Leftrightarrow M_1 \cdot T_1 + M_2 \cdot T_2 = M_0 \cdot T_0 \]

In which:

- \( C_0 \) [\( J/kg.K \)] The specific heat of water
- \( T_0 \) [\( ^\circ C \)] Water temperature of the main pipe goes on the buffer tank
- \( C_1 \) [\( J/kg.K \)] The specific heat of water.
- \( T_1 \) [\( 41.8 \, ^\circ C \)] Water temperature out of the equipment load2.
- \( C_2 \) [\( J/kg.K \)] The specific heat of water.
- \( T_2 \) [\( 39 \, ^\circ C \)] Water temperature out of the equipment load 1.
- \( M_0 \) \[ \frac{205x 100}{3600} \left( \frac{kg}{s} \right) \] The water mass of the main pipe goes on the buffer tank.
The mass of water out of the equipment load 2.

The mass of water out of the equipment load 2.

We have:

\[ M_1 x T_1 + M_2 x T_2 = M_0 x T_0 = 147 \times \frac{1000}{3600} \times (41.8+273) + 58 \times \frac{1000}{3600} \times (39+273) = 205 \times \frac{1000}{3600} \times T_0 \]

\[ \Rightarrow T_0 \approx (273 + 41) \times K \approx 41^0 C \]

So water temperature go to heat exchanger tank is: \( T_0 = 41^0 \)

Because of the heat exchange inside the tower (heat exchanger tank), we must calculate the water flow before entering the cooling tower. The water temperature out of the heat exchanger tank is: \( T_1 = 36^0 C \)

According to the law of thermal equilibrium, we have the formula:

\[ M_0 x C_0 x T_0 + M_2 x C_2 x T_2 = \Sigma M_1 x C_1 x T_1 \]

\[ \Rightarrow M_0 x T_0 + M_2 x T_2 = M_1 x T_1 \]

In which:

- \( C_0 [\text{ (J/kg.K)}] \) The specific heat of water.
- \( T_0 [\text{ (41 °C)}] \) Water temperature go into the heat exchanger tank.
- \( C_1 [\text{ (J/kg.K)}] \) The specific heat of water.
- \( T_1 [\text{ (36 °C)}] \) The water temperature go to cooling tower.
- \( C_2 [\text{ (J/kg.K)}] \) The specific heat of water.
- \( T_2 [\text{ (31 °C)}] \) The Water temperature out of the cooling tower.

\[ M_0 \left[ 205 \times \frac{1000}{3600} \left( \frac{kg}{s} \right) \right] \] The mass of water go into the heat exchanger tank.

\[ M_1 \left[ \left( \frac{kg}{s} \right) \right] \] khối lượng nước đi vào tháp giải nhiệt. The mass of water go into the cooling tower.

\[ M_2 \left[ 205 \times \frac{1000}{3600} \left( \frac{kg}{s} \right) \right] \] The mass of water out of the cooling tower.

We have:

\[ M_0 x T_0 + M_2 x T_2 = M_1 x T_1 \]

\[ \Leftrightarrow M_0 x (41 + 273) + M_2 x (31 + 273) = (M_0 + M_2) x (36 + 273) \]

\[ \Leftrightarrow M_0 = M_2 \]
The mass of water going into the cooling tower is:

\[ M_1 = M_0 + M_2 = 205 \times \frac{1000}{3600} + 205 \times 410 \times \frac{1000}{3600} \left( \frac{kg}{s} \right) = 410 \ (m^3/h) \]

So we have:

Water flow rate out of the heat exchanger tank is:

\[ G_1 = 410 \frac{m^3}{h} = 113.8889 \ (l/s) \]

Use the graph to select the cooling tower's capacity is:

\[ Q_{CT} = 800RT. \]

So we choose cooling tower : \( Q_{CT} = 800RT. (\text{see index 1.1; 1.2}) \)

**Option 2:**

Operating principles:

Coolant is pumped to the device load 1 load 2, in this process, heat exchange is performed, the water will heat up. After out of these devices, water is return the tank. The buffer tank have functions to stabilize the coolant before it is transfer on the cooling tower. Water after being cooled in cooling tower to achieve the required temperature of 31°C will return to the buffer tank to continue the process of cooling for the device to work. So we have to determine the hot water temperature after cooling for load1 and load2.

Because the buffer tank no heat exchange function, the water out of the equipment will go to the cooling tower with constant flow. \((G= 205 \ m^3/h)\).

Use the graph to select the cooling tower’s capacity is:
\[ Q_{CT} = 500RT \ (see \ index\ 1.1, \ 1.2) \]

**Conclusion:** We chose option 2 due to the have low investment cost.

**We have:**

Water flow rate go into cooling tower: \( G = 205m^3/h = 56.9444 \ (l/s) \)
Wet bulb temperature (at the location is Ho Chi Minh city) : \( T_{wb} = 28 \ (\degree C) \)
Water temperature to the cooling tower is : \( T_V = 41 \ (\degree C) \)
Water temperature out of the cooling tower is : \( T_r = 31 \ (\degree C) \)

**Based on parameters we choose cooling tower:**

Model : UT 28-718 (based on wet bulb temperature at TP.HCM is 28\(^\circ\)C (see index 1.3)

Fan motor capacity (quality : 2) : 11kW/3Pha/50Hz
Air flow rate : 44.5 \( m^3/s \)
Shipping weights : 3510 (kg)
Operating weights : 6035 (kg)
Inside Pipe (quality : 2) : 200 (mm)
Outside pipe (quality : 2) : 200 (mm)
Overflow pipe : 50 (mm)
Height : 4333 (mm)
Width : 2388 (mm)
Length : 6401 (mm)

1.3 Calculate the size pipe

Separate parts of the cold system are connected by pipeworks. Requirements for piping calculation and selection are sufficiently durable, pipe section required to meet technical and economic requirements. Pipes usually used in refrigeration systems are usually steel pipes, copper tubes.

We use the formula \( G = \frac{d_i^2 \times \pi}{4} \cdot \omega \)

\[
=> d_i = \sqrt{\frac{G \times \omega}{\pi \cdot \omega}}
\]

In which:
\( d_i : [(mm)] \) The inside diameter of the pipework

\( G : [205(m^3)] \) The water flow rate going through the pipe

\( \omega : [2(m^2/s)] \) The velocity of the water going in the tube

Main pipe size at head pump :

\[
d_i = \sqrt{\frac{G \times 4}{\pi x \omega}} = \sqrt{\frac{205 \times 4}{\pi \times 2 \times 3600}} = 190.399\ (mm)\text{ we choose DN200.}
\]

(see index 1.5)

We create a spreadsheet using the same formula as above.

<table>
<thead>
<tr>
<th>STT</th>
<th>Calculation Requirements</th>
<th>Actual Parameters</th>
<th>Pipe position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>velocity ((m/s))</td>
<td>Inside diameter ((mm))</td>
<td>velocity ((m/s))</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>190.399</td>
<td>1.764</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>161.78</td>
<td>2.2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>101.28</td>
<td>1.75</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>190.399</td>
<td>1.764</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>190.399</td>
<td>1.764</td>
</tr>
</tbody>
</table>

The size pipeto supply water at the MV4 valve use to ensure the water temperature when it go in the cooling tower is 41°C. When the water in the cooling tower is hotter than the design temperature, we will select superheat is 3°C.

Pipe size have MV4 valve: \( d_i = 202.74\ mm\ DN = 200 \) (see index 1.5)
1.4 Calculate select pump.
1.4.1 Select the cooling water pump to the work equipment.

We will select a pump running and one backup pump (pump 100% water flow)
Ta có: We have

- Pressure: \(4 \text{ bar} = 41 \text{ m}_H^2\text{O}\)
- Flow rate: \(205 \text{ m}^3/\text{h}\)

*From the above parameters, we choose the pump according to the catalog: (See index 1.6)*

- Brand: Grundfos
- Model: 100-400/375 EUP A1-F-B-E-BAQE
- Type: Centrifugal
- Flow rate: \(210 \text{ m}^3/\text{h}\)
- Pressure: \(4.215 \text{ bar}\)
- Frequency: \(50\text{Hz}\).
- Pump Inlet: DN125
- Pump Outlet: DN100
- Motor power: \(37 \text{ kW/3Pha/50Hz}\)

**Check calculations pump:**

➢ *Capacity on the shaft of the pump:*

\[
N = \frac{\gamma \times Q \times H}{102 \times \eta} \quad \text{(See index 1.10)}
\]

- \(N\): [(\(\text{kw}\))] Capacity on the shaft of the pump
- \(H\): [41(\(\text{m}_H^2\text{O}\))] The pressure of pump
- \(Q\): [\(\frac{205}{3600}\) (\(\text{m}^3/\text{s}\))] Flow Rate of the pump
- \(\eta\): 0.749 Efficient of pump (*See index 1.6*)
- \(\gamma\): [1000(\(\text{Kg/ m}^3\))] Density of liquid

\[
N = \frac{1000 \times 205 \times 41}{102 \times 0.749} = 30.56(\text{ kW})
\]

➢ *Motor power of pump*

\[
P = k \times \frac{N}{\eta_m \times \eta_{tr}}
\]

- \(P\): (\(\text{kw}\)) Motor power of pump
- \(N\): [(\(\text{kw}\))] Capacity on the shaft of the pump
- \(\eta_m\): Efficient of pump
η_{tr} : Efficient of pump (direct drive by hard coupling) The efficiency of the pump is 1 (because it is a direct drive by a liquid coupling).

γ \times 1000 (Kg / m^3) \] Density of liquid

k : [1.15] safe factor (See index 1.10)

\[ N_{dc} = k \times \frac{N}{\eta_m \times \eta_{tr}} = 1.15 \times \frac{30.56}{0.921 \times 1} = 38.16 (kw) \]

A.1.4.2 Select pump coolant to cooling tower

We will select a pump running and one backup pump (pump 100% water flow)

We have parameters pump:

- Flow rate : 205 m^3/h
- Pressure

The pressure pump is calculated as follows

- Determine the kinematic viscosity of water at temperature 41°C (see index 1.4)

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>40</th>
<th>41</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>V \times 10^{-6}</td>
<td>0.6579</td>
<td>X</td>
<td>0.5531</td>
</tr>
</tbody>
</table>

Using a method of interpolation we have:

\[ \frac{41-40}{50-40} = \frac{X-0.6579}{0.531-0.6579} \]

\[ X = 0.64742 \times 10^{-6} (m^2/s) \]

- Determine the resistance Reynolds (Re):

\[ Re = \frac{\omega \times d_i}{v} \]

Re : Coefficient of resistance

- \( \omega : [1.764 (m/s)] \) Velocity in pipes
- \( d_i : [0.20274 (mm)] \) The inside diameter of the water pipe
- \( v : [0.64742 \times 10^{-6}] \) Kinematic viscosity at temperature 41°C

\[ Re = \frac{\omega \times d_i}{v} = \frac{1.764 \times 0.20274}{0.64742 \times 10^{-6}} = 552397.76 \]
**Coefficient of friction** $f$:

Determine $f$ based on $F_{DASH}$

When $f = F_{DASH}$ ($F_{DASH} > 0.018$)

$$f = 0.85 \times F_{DASH} + 0.0028 \ (F_{DASH} \leq 0.018)$$

We have:

$$F_{DASH} = 0.11 \times \left( \frac{\varepsilon}{d} + \frac{68}{Re} \right)^{0.25}$$

$f$ : Coefficient of resistance on the pipe

$F_{DASH}$ : Factor to determine $f$.

$\varepsilon$ : [0.15(mm)] Roughness of galvanize pipe
d : [202.74(mm)]. The inside diameter of the pipe

$Re$ : [552397.76]Coefficient of resistance

$$F_{DASH} = 0.11 \times \left( \frac{\varepsilon}{d} + \frac{68}{Re} \right)^{0.25} = 0.11 \times \left( \frac{0.15}{202.74} + \frac{68}{552397.76} \right)^{0.25} = 0.0189$$

$$f = F_{DASH} = 0.0189$$

**Determine the resistance to friction of the pipe**

Figure 1.1: The suction height of the pump from suction head to tank.
Figure 1.2: The total length of the horizontal of the suction pump.

Figure 1.3: The height of head discharge pump.
**Figure 1.4: The total length horizontally of the pipedischarge the pump.**

- **Figure 1.4: The total length horizontally of the pipedischarge the pump.**

Total length of the suction pipe : 16.4 m (See figure 1.1 and figure 1.2)
Height of suction pipe : 6.9 m (See figure 1.1)
Height of discharge pipe : 11.5 m (See figure 1.3)
Total length of the discharge pipe : 62 m (See figure 1.3 and figure 1.4)

- **Determination of resistant factor of valves and fittings at suction pipe (see index 1.11)**

- Butterfly valve DN200 : $\zeta = 2 \times 1 = 2$
- Strainervalve : $\zeta = 2 \times 1 = 2$
- Reducer : $\zeta = 0.25 \times 1 = 0.25$
- Tee : $\zeta = 0.4 \times 1 = 0.4$
- Elbow 90 : $\zeta = 0.6 \times 4 = 2.4$
We calculate the total suction pressure of the pump.

Pressure loss of water through the pipe and locally is:

\[ H_{\text{loss}} = f \frac{1}{d} \frac{\omega^2}{2 \cdot g} + k \frac{\omega^2}{2 \cdot g} \]

In which:

- \( f \): Coefficient of resistance on the pipe
- \( d \): [202.74 (mm)] The inside diameter of the pipe
- \( \omega \): [1.764 (m/s)] The velocity of the water flow
- \( g \): [9.81 (m²/s)] Gravitational acceleration
- \( l \): [(m)] Total length of suction pipe.
- \( k \): Coefficient of friction

\[ H_{\text{loss}} = f \frac{1}{d} \frac{\omega^2}{2 \cdot g} + k \frac{\omega^2}{2 \cdot g} = 0.0189 \frac{16.4}{0.20274} \frac{1.764^2}{2 \cdot 9.81} \]

\[ = 0.0189 \times 0.20274 \times \frac{1.764^2}{2 \cdot 9.81} + (2.4+2+2+0.25+0.4) \times \frac{1.764^2}{2 \cdot 9.81} = 1.36 (m_{H2O}) \]

Determine the pressure of water at temperature 41°C

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>40</th>
<th>41</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho ) [Pa]</td>
<td>7381.1</td>
<td>X</td>
<td>9589.7</td>
</tr>
</tbody>
</table>

Using a method of interpolation we have:

\[
\frac{41-40}{45-40} = \frac{X-7381.1}{9589.7-7381.1}
\]

\[ X = 7822.82 \text{ [Pa]} \]

Total pressure at the suction pipe is:

\[ H_s = h_s + \frac{P_a - P_v}{\rho \times g} - H_{\text{loss}} \]

\[ H_s : [(m_{H2O})] \text{ Total pressure at the suction pipe} \]

\[ h_s : [6.9 (m_{H2O})] \text{ Height of suction pipe} \]

\( P_a : [101325(Pa)] \text{ Environment Pressure} \]

\( P_v : [7822.82(Pa)] \text{ Vapor pressure of water} \]

\( H_{\text{loss}} : \text{ Pressure loss of water through the pipe and locally} \]

\[ H_s = h_s + \frac{P_a - P_v}{\rho \times g} - H_{\text{loss}} \]

\[ \Leftrightarrow H_s = 6.9 + \frac{101325 - 7822.82}{992.2 \times 9.81} - 1.36 = 15.15 m_{H2O} \]

Determination of resistant factor of valves and fittings at the discharge pipe (See index 1.11)
Butterfly valve DN200 : \( \zeta = 2 \times 1 = 2 \).

Check valve : \( \zeta = 2 \times 1 = 2 \).

Reducer : \( \zeta = 0.25 \times 1 = 0.25 \)

Tee : \( \zeta = 0.4 \times 1 = 0.4 \)

Elbow 90 : \( \zeta = 0.6 \times 4 = 2.4 \)

- **We calculate the total discharge pressure of the pump**

- **Pressure loss of water through the pipe and locally is:**

\[
H_{\text{loss}} = f \times \frac{1}{d_i} \times \frac{\omega^2}{2 \times g} + k \times \frac{\omega^2}{2 \times g}
\]

In which :

- \( f \) : Coefficient of resistance on the pipe
- \( d_i \) : [202.74 (mm)] The inside diameter of the pipe
- \( \omega \) : [1.764 (m/s)] The velocity of the water flow
- \( g \) : [(9.81 m²/s)] Gravitational acceleration
- \( l \) : Total length of discharge pipe (m)
- \( k \) : Coefficient of friction

\[
H_{\text{loss}} \ [m_{H_2O}] \text{: Pressure loss of water through the pipe and locally}
\]

\[
H_{\text{loss}} = f \times \frac{1}{d_s} \times \frac{\omega^2}{2 \times g} + k \times \frac{\omega^2}{2 \times g} = 0.0189 \times \frac{\omega^2}{2 \times g} + (2.4 + 2 + 2 + 0.25 + 0.4) \times \frac{1.764^2}{2 \times 9.81} = 2.035 \ (m_{H_2O})
\]

- **Total discharge pressure in the pipe**

\[
H_d = hd + \frac{P_a - P_v}{\rho \times g} - H_{\text{loss}} + H_{tb}
\]

- \( H_d \) : [(m_{H_2O})] Total pressure in the discharge pipe
- \( hd \) : [11.5 (m_{H_2O})] Height of discharge pipe
- \( P_a \) : [101325 (Pa)] Environment pressure
- \( P_v \) : [7822.82 (Pa)] Vapor pressure of water
- \( H_{\text{loss}} \) : [1.78 (m_{H_2O})] Pressure loss of water through the pipe and locally
- \( H_{tb} \) : Pressure loss of equipment (8 m_{H_2O})
\[ H_d = 11.5 + \frac{101325-7822.82}{992.2 \times 9.81} - 2.035 + 8 = 27.071 \ (m_{H_2O}) \]

- **The working pressure of pump is:**
  \[ H = H_d - H_h = 27.071 - 15.15 = 11.921 \ (m_{H_2O}) \]

In order to work, the working pressure of the pump must be at least 1 bar.

We choose 1.5 bar is the working pressure minimum of pump.

1.5 bar = 15.296 \ (m_{H_2O})

- To working pressure pump 15.296 \ (m_{H_2O}), we add 11.367 \ (m_{H_2O}).
  \[ H = 3.929 + 11.367 = 15.296 \ (m_{H_2O}) \]

*From the data above we choose the pump according to the catalog: (See index 1.7)*

**Brand**: Grundfos

**Model**: NK125-200/226 EUP A2-F-A-E-BAQE

**Type**: Centrifugal

**Flow rate**: 204 m³/h

**Pressure**: 15.15 \ (m_{H_2O})

**Frequency**: 50Hz.

**Pump Inlet**: DN150

**Pump Outlet**: DN125

**Motor power**: 15 Kw kW/ 3Pha/ 50Hz

Check calculations pump

- **Capacity on the shaft of the pump.** *(See index 1.10)*
  \[ N = \frac{\gamma \times Q \times H}{102 \times \eta} \]

  \( N \) : [(kw)] Motor power of pump. (kw)

  \( H \) : [15.15 \ (m_{H_2O})] The pressure of pump

  \( Q \) : \( \left( \frac{205}{3600} \right) \ (m^3/s) \) Flow rate of the pump

  \( \eta \) : [0.829] Efficient of pump (See index 1.8)

  \( \gamma \) [1000 \ (Kg / m³)] Density of liquid

  \[ N = \frac{\gamma \times Q \times H}{102 \times \eta} = \frac{1000 \times \frac{205}{3600} \times 15.15}{102 \times 0.829} = 10.203 \ (kW) \]
Motor Capacity of pump:

\[ P = k \times \frac{N}{\eta_{td} \times \eta_{tr}} \]

- \( P: [(kw)] \) Motor power of pump
- \( N :[(kw)] \) Motor power of pump
- \( \eta_{td} : [0.921] \) The efficient of the pump (See index 1.8)
- \( \eta_{td} : \) Efficient of pump (direct drive by hard coupling) The efficiency of the pump is 1 (because it is a direct drive by a liquid coupling)
- \( \gamma [1000 (\text{Kg} / \text{m}^3)] \) Density of liquid
- \( k : [1.15] \) Safety factor of capacity (See index 1.10)

\[ N_{dc} = k \times \frac{N}{\eta_{td} \times \eta_{tr}} = 1.15 \times \frac{10.203}{0.921 \times 1} = 12.74 (kw) \]

1.5 Phenomenon of cavitation

1.5.1 What is the Phenomenon of cavitation

When the actual pressure in liquid decreases to or below the vapor pressure (phh). For normal water, actual vapor pressure is only dependent on temperature and does not exceed 0.4mmH for temperature \( t \leq 30^\circ C \). At this low pressure, the liquid is boiled and appear steam and air, called bubbles. The bubbles are drawn to the fluid where the hydrostatic pressure is higher than the vapor pressure the vapor in the air bubbles suddenly condenses, causing the vacuum to deep and the surrounding liquid tending to enter mind bubbles to occupy space. The process of cavitation repeated in the liquid. The speed at which the bubbles of the fluid particles are high enough so that the local hydraulic dam causes noise and vibration. At the place where the real gas occurs, the pressure can reach thousands of pressure and cause a loss of hydraulic flow. At the place where the actual pressure occur it can make increase thousands of atmosphere pressure and hydraulic loss flow. If the bubbles breaks down on the contact surface the local high-frequency local impact will over time damage the pump’s contact surface forming the “hydraulic wedges” of the surface material for pumping.

Small amounts of gases are removed from the liquid and bubbles due to too rapid contact with the material, thus the gas is compressed and the temperature rises dramatically. All of these causes lead to the generation of mechanical, electrolyte, heat and chemical agents that damage the surface of the air to the contact surface between the pump and the liquid. The surface of the pump is pitted, heavier than the hole. This destructive form is called “actual gas erosion”.

The erosion phenomenon will damage the working wheels and parts of the pump. When aggression develops, the pump may stop working completely.
The condition that occurs when the reality is somewhere is that the pressure there is less than or equal to the vapor pressure.

From the analysis of the causes of actual atmospheric corrosion, we find that the destructive effects of real air can be minimized if the materials used for making the pump are of high chemical durability, high flexibility and smooth surface machining. On design work: not too high $h_s$ compared to suction tanks, but not too low to avoid large unstructured. For small pumps can increase the diameter and reducing the length of the nozzle, reducing the number of turning points, so the valve on the nozzle to flow to distribute evenly...to reduce losses. For large axial piston pumps, the choice of the suction chamber is also a real gas measure.

1.5.2 We check pumps have Phenomenon of cavitation or not

- **We check pump to cooling tower.**

According to the pump data is $NPSH_{rp}$ of the pump is $3.77 \ (m_{H_2O})$ (see index 1.8)

To avoid cavitation $NPSH_A \geq NPSH_r$

We have the formula:

$$NPSH_r = NPSH_{rp} + S.$$  

In which:

- $NPSH_r$: The lowest pressure suction pump can be suctioned.$[(m_{H_2O})]$  
- $NPSH_{rp}$: The suction pressure of macfacturer$[3.77 \ (m_{H_2O})]$.  
- $S$: Safe factor $[0.5(m_{H_2O})]$  

$$NPSH_r = NPSH_{rp} + S.$$  

$$NPSH_r = 3.77 + 0.5.$$  

$$NPSH_r = 4.27 \ (m_{H_2O})$$

To avoid cavitation we use the formula $NPSH_A \geq NPSH_r$

$$NPSH_A = h_s + \frac{Pa}{\rho \times g} - \frac{Pv}{\rho \times g} \cdot H_{loss}$$

In which:

- $NPSH_A$: Absolute pressure $[(m_{H_2O})]$  
- $h_s$: Height of suction pipe $[6.9 \ (m_{H_2O})]$  
- $H_{loss}$: Pressure loss of water through the pipe and locally $[1.3578 \ (m_{H_2O})]$  
- $Pa$: Suction pressure at free liquid surface $[101325 \ (Pa)]$  
- $Pv$: Vapor pressure of water solution $[7822.82 \ (Pa)]$  
- $g$: Gravitational acceleration $[9.81 \ (m^2/s^2)]$  
- $\rho$: Density of water solution $[1000 \ (kg/m^3)]$

$$NPSH_A = h_s + \frac{Pa}{\rho \times g} - \frac{Pv}{\rho \times g} \cdot H_{loss} = 6.9 + \frac{101325}{1000 \times 9.81} - 7822.82 \times 9.81 = 15.073 \ (m_{H_2O})$$
So:
\[ NPSH_A = 15.073 \ (mH_2O) \geq NPSH_r = 4.270 \ (m_{H2O}) \]

\(\Rightarrow\) This pump does not occur the phenomenon of erosion

- We check the pump from the tank to the working equipment.

Parameters pumps:
- Flow rate: 205 \( m^3/h \)

\[ \text{Determine the kinematic viscosity of water at temperature 31°C (see index 1.4)} \]

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>30</th>
<th>31</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>V ( (m^2/s) \times 10^{-6} )</td>
<td>0.8007</td>
<td>X</td>
<td>0.6579</td>
</tr>
</tbody>
</table>

\[ \frac{31-30}{40-30} = \frac{X-0.8007}{0.8007-0.6579} \]

\[ X = 0.81498 \times 10^{-6} \ (m^2/s) \]

- Determine the resistance Reynolds (Re):

\[ \text{Re} = \frac{\omega \times d_i}{v} \]

In which:

- Re: Coefficient of resistance
- \( \omega \): Velocity in pipes [1.764 (m/s)]
- \( d_i \): The inside diameter of the water pipe [0.20274 (mm)]
- \( v \): Kinematic viscosity at temperature 31°C [0.981498 \times 10^{-6}]

\[ \text{Re} = \frac{\omega \times d_i}{v} = \frac{1.764 \times 0.20274}{0.981498 \times 10^{-6}} = 438824.71 \]

- Coefficient of friction \( f \):

Determine \( f \) based on \( F_{DASH} \)

When \( f = F_{DASH} \ (F_{DASH} > 0.018) \)

\[ f = 0.85 \times F_{DASH} + 0.0028 \ (F_{DASH} \leq 0.018) \]

We have:

\[ F_{DASH} = 0.11 \times \left( \frac{\varepsilon}{d} + \frac{68}{\text{Re}} \right)^{0.25} \]
f : Coefficient of resistance on the pipe

\( F_{DASH} \) : Factor to determine f.

\( \varepsilon \) : Roughness of galvanize pipe [0.15(mm)]

d : The inside diameter of the pipe [202.74(mm)]

Re : Coefficient of resistance [438824.71]

\[
F_{DASH} = 0.11 \times \left( \frac{\varepsilon}{d} + \frac{68}{Re} \right)^{0.25} = 0.11 \times \left( \frac{0.15}{202.74} + \frac{68}{438824.71} \right)^{0.25} = 0.01903
\]

So:

\[
f = F_{DASH} = 0.01903 \ (F_{DASH} > 0.018)
\]

**Determine the resistance to friction of the pipe**

Total length of the suction pipe: 49.2 m.

Height of suction pipe : 9.4 m.
Determination of resistant factor of valves and fittings at suction pipe (see index 1.11)

Butterfly valve DN200: \( \zeta = 2 \times 1 = 2 \).

Strainervalve: \( \zeta = 2 \times 1 = 2 \).

Reducer: \( \zeta = 0.25 \times 1 = 0.25 \).

Tee: \( \zeta = 0.4 \times 4 = 1.6 \).

Elbow 90: \( \zeta = 0.6 \times 9 = 5.4 \).

We calculate the total suction pressure of the pump.

Pressure loss of water through the pipe and locally is:

\[
H_{\text{loss}} = f \times \left( \frac{1}{d_l} \right) \times \frac{\omega^2}{2 \times g} + k \times \frac{\omega^2}{2 \times g}
\]

In which:

- \( f \): Coefficient of resistance on the pipe [0.01903]
- \( d_l \): The inside diameter of the pipe [202.74 (mm)]
- \( \omega \): The velocity of the water flow [1.764 (m/s)]
- \( g \): Gravitational acceleration [9.81 (m²/s)]
- \( k \): Coefficient of friction
- \( l \): Total length of suction pipe. [(m)]

\( H_{\text{loss}} \): Pressure loss of water through the pipe and locally

\[
H_{\text{loss}} = f \times \left( \frac{1}{d_l} \right) \times \frac{\omega^2}{2 \times g} + k \times \frac{\omega^2}{2 \times g} = 0.01903 \times \frac{49.2}{202.74} \times \frac{1.764^2}{2 \times 9.81} + (2 + 2 + 0.25 + 1.6 + 5.4) \times \frac{1.764^2}{2 \times 9.81} = 2.517.
\]
Determine the pressure of water at temperature 31°C

<table>
<thead>
<tr>
<th>T (℃)</th>
<th>30</th>
<th>31</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>ρ[ Pa]</td>
<td>4245.1</td>
<td>X</td>
<td>5626.3</td>
</tr>
</tbody>
</table>

Using a method of interpolation we have:

\[
\frac{31-30}{35-30} = \frac{X-4245.1}{5626.3-4245.1} \]

\[
X = 4521.34 \text{[ Pa]}
\]

Total pressure at the suction pipe is:

\[
H_s = h_s + \frac{P_{a-Pv}}{\rho \times g} - H_{loss}
\]

Hs : Total pressure at the suction pipe[( m\text{H}_2\text{O} )]
hs : Height of suction pipe[( m\text{H}_2\text{O} )]
Pa : Environment Pressure [101325(Pa)]
Pv : Vapor pressure of water [2337(Pa)]
H_{loss} : Pressure loss of water through the pipe and locally[( m\text{H}_2\text{O} )]

\[
\frac{101325-4521.34}{992.2 \times 9.81} = 2.517 = 16.83 \text{ m}\text{H}_2\text{O}
\]

According to the pump data is NPSH_{rp} of the pump : 0.28 bar = 2.86 ( m\text{H}_2\text{O} )
( see index 1.9 )
To avoid cavitation NPSH_{A} ≥ NPSH_{r}
We have the formula:

\[
NPSH_r = NPSH_{rp} + S
\]

In which:
NPSH_{r} : The lowest pressure suction pump can be suctioned.[(m\text{H}_2\text{O})]
NPSH_{rp} : The suction pressure of macfactuner[2.86 (m\text{H}_2\text{O}).]
S : Safe factor [0.5(m\text{H}_2\text{O})]

\[
NPSH_r = NPSH_{rp} + S.
NPSH_r = 2.86 + 0.5.
NPSH_r = 3.36 ( m\text{H}_2\text{O} )
\]

To avoid cavitation we use the formula NPSH_{A} ≥ NPSH_{r}
\[ NPSH_A = hs + \frac{Pa}{\rho \times g} - \frac{Pv}{\rho \times g} - H_{loss} \]

In which:
- \( NPSH_A \): Absolute pressure \([m_{H_2O}]\)
- \( hs \): Height of suction pipe \([9.4 \ m_{H_2O}]\)
- \( H_{loss} \): Pressure loss of water through the pipe and locally \([2.511 \ m_{H_2O}]\)
- \( Pa \): Suction pressure at free liquid surface. [101325(Pa)]
- \( Pv \): Vapor pressure of water [4521.34 (Pa)]
- \( g \): Gravitational acceleration [9.81 \ (m^2/s)]
- \( \rho \): Density of water [1000 \ (kg/m^3)]

\[ NPSH_A = hs + \frac{Pa}{\rho \times g} - \frac{Pv}{\rho \times g} - H_{loss} = 9.4 + \frac{101325}{1000 \times 9.81} - \frac{4521.34}{1000 \times 9.81} - 2.517 = 16.751 \ (mH_2O) \]

So:
\[ NPSH_A = 16.751 \ (m_{H_2O}) \geq NPSH_r = 3.36 \ (m_{H_2O}) \]

\[ > \]This pump does not occur the phenomenon of erosion

### 1.6 Calculation for the buffer tank
We have formula:
\[ V = \pi \times r^2 \times H \]

In Which:
- \( V \): Volumn of tank \([5 \ (m^3)]\)
- \( D \): Diameter[1(m)]
- \( R \): Radius[ \( m \)]
- \( H \): Height of tank[6.369(m).]

- **Radius of buffer tank**:
  \[ r = \frac{d}{2} = \frac{1}{2} = 0.5 \ m. \]

- **Height of buffer tank**:
  \[ V = \pi \times r^2 \times H \Leftrightarrow H = \frac{V}{\pi \times r^2} = \frac{5}{3.14 \times 0.5^2} = 6.369 \ m. \]

- **The Thinkness of body tank**:
  \[ s = \frac{p \times D}{200 \times \varphi \times \delta_{cp}} - p + C \]
\[ s = \frac{1.01325 \times 1000}{200 \times 0.8 \times 15.69 - 1.01325} + 5 = 5.404 \text{[mm]} \]

In Which:

- \( p = 1.01325 \text{[bar]} \), design pressure for tank.
- \( \varphi \): Coefficient weld strength vertical body. \( \varphi = 0.8 \) (đồng han).
- \( \delta_{cp} \): Allowable stresses of material \( \delta_{cp} = 15,69 \) (SS 400)
- \( C \): Additional thickness coefficient (we choose 5)
- \( D \): Inside diameters of Tank [mm]

- Follow thickness standard, we choose thickness steel:
  \[ s = 6 \text{[mm]} = SCH XS \]

- **The Height between cap and body Tank**:
  \[ h_0 = 0.255 \times d + 0.365 \times t \]

In Which:

- \( h_0 \): The height between cap and body Tank [mm]
- \( d \): Inside diameters of Tank [mm]
- \( t \): The thickness body (6 mm)

\[ \iff h_0 = 0.255 \times 1000 + 0.365 \times 6 = 257.19 \text{[mm]} \]

- **The thickness of cap**:

\[ s = \frac{p \times D}{400 \times z \times \delta_{cp}} \times \frac{D}{2 \times h_0} + C \]

Conditions to apply above formula is:
\[ \frac{h_0}{D} \geq 0.2 \]

In Which:

- \( h_0 \): The height between cap and body tank [mm]
- \( D \): Inside diameters of tank [mm]

\[ \iff \frac{h_0}{D} = \frac{257.19}{1000} = 0.257 \geq 0.2 \]

So:

\[ s = \frac{p \times D}{400 \times z \times \delta_{cp}} \times \frac{D}{2 \times h_0} + C \]

\[ \iff s = \frac{1.01325 \times 1000}{400 \times 1 \times 15.69} \times \frac{1000}{2 \times 257.19} + 5 = 5.314 \text{[mm]} \]
In Which :

- $p = 1.01325 [bar]$ , design pressure for tank.
- $z = 1$
- $\delta_{cp}$ : Allowable stresses of material $\delta_{cp} = 15.69$ (SS 400)
- $C$ : Additional thickness coefficient (we choose 5)
- $h_0$: The length between cap and body tank (mm)
- $D$ : Inside diameters of tank [mm]

To ensure the safety of Tank, select the thickness of body and cap is 6 mm.

- **The height from body to cap** :
  
  $$h_1 = 3 \times s$$

In Which :

$h_1$ : The height from body to cap (mm)
$s$ : The thickness body (mm)

$$\iff h_1 = 3 \times s = 3 \times 6 = 18 \ [mm]$$

- **Total height from body to top of cap** :
  
  $$h = h_1 + h_0$$

In Which :

$h$ : Total height from body to top of cap (mm)
$h_1$ : The height from body to cap (mm)
$h_0$ : The length between cap and body tank (mm)

$$h = h_1 + h_0 = 18 + 257.19 = 275.19 \ [mm]$$

- **The height of body tank** :
  
  $$H = (2.5 \sim 3). d \ (\text{Select } H = 3)$$

In Which :

$H$ : The height of body Tank (m)
d : Inside diameters of tank (m)

$$\rightarrow \text{Chọn } H = 3 \times 1 = 3 \ [m].$$
• **Total height of tank**:

\[ H_t = 2\times h + H \]

In Which:

- \( H_t \): Total height of Tank (m).
- \( h \): Total height from body to top of cap (m)
- \( L \): The height of body Tank (m)

\[ H_t = 2\times h + H = 2 \times 0.28 + 7 = 7.56 \text{ [m]} \]

2. **Calculation coolant system have temperature \(-5^\circ\text{C}\)**

2.1 **Calculation Temperature**

We design cooling system at Ho Chi Minh City, so we choose temperature, humidity at location to calculation

<table>
<thead>
<tr>
<th>Location</th>
<th>Temperature</th>
<th>Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average year</td>
<td>Wet bulb</td>
</tr>
<tr>
<td>TP.HCM</td>
<td>27(^{\circ}\text{C})</td>
<td>28(^{\circ}\text{C})</td>
</tr>
</tbody>
</table>

- Wet bulb temperature:

\[ t_{wb} = 28^{\circ}\text{C} \]

2.1.1 **Condensing temperature**

In the condenser, Heat dissipation is mainly due to water evaporation, so the water temperature in the condenser is always constant \( t_w = \text{const} \)

The water temperature in condenser is equal to wet bulb temperature plus \((3 \div 5)^{\circ}\text{C}\)

\[ t_w = t_{wb} + (3 \div 5)^{\circ}\text{C} \]

In which:

- \( t_{wb} \): Wet bulb temperature \((28^{\circ}\text{C})\)
- \( t_w \): Water temperature out of the condenser \((^\circ\text{C})\)

\[ t_w = t_{wb} + (3 \div 5)^{\circ}\text{C} = 28 + 4 = 32^{\circ}\text{C} \]

- We take condensing temperature is greater than water temperature out of the condenser \((3 \div 5)^{\circ}\text{C}\)