CHAPTER 8

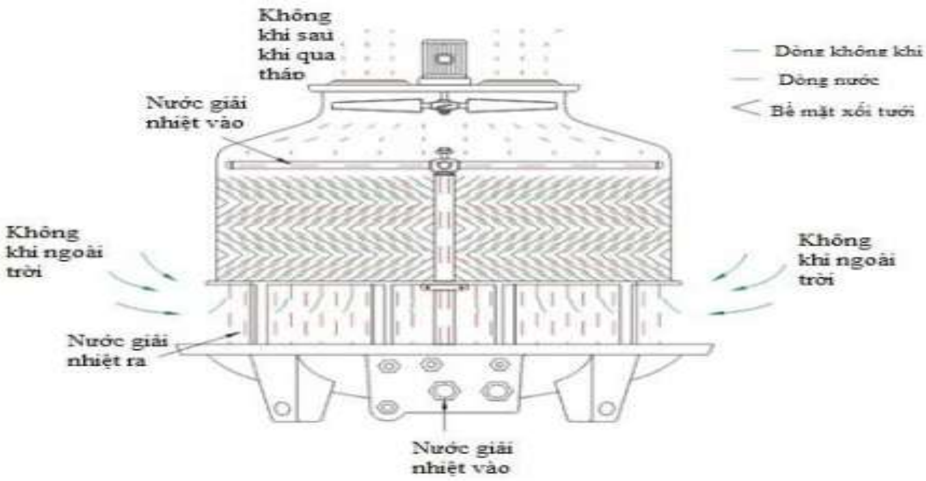
CALCULATION OF COOLING TOWER

8.1 COOLING TOWER

8.1.1 PRINCIPLE OF OPERATION OF COOLING TOWER

Principle of operation and heat transfer process occurs in the cooling tower as follows: hot water after cooling the refrigerant from the condenser and is pumped to the spray tower will eventually spread through tiny holes to fine particles water helps the contact between water and air cooling is better. Water droplets fall on the shield (hold his rig) and under the effect of wind turbines will form smaller particles then flow in thin layers on the surface of shield from top to bottom. On the other hand the air from outside the tower (moist air is not saturated φ <100%) by the fan is taken in from the bottom and out of the tower at the top. When the air in contact with water will make the process of heat exchange and metabolism. The water will heat the air, reducing temperature and returned to the container below. Then pumped to the condenser. The process of heat transfer between the water and the air is done by two methods

The first method is heat transfer by convection due to the temperature difference between the water temperature Δt air temperature tn and tk. When Δt increases, the convective heat transfer between the water and air to rise and vice versa.The second method is heat transfer by transmission by means of evaporation of water into the air. The fact of the cooling tower, the transmission.



8.1.2 CALCULATION COOLING TOWER

With the air conditioning system in a building composed of 4 chiller water clusters. We choose cooling tower with condensing equipment.

The initial parameters of cooling tower:

Determine the water flow to the condenser according to the formula [TL3 CT8.1]:

$$G_{w2} = \frac{Q_k^{'}}{C_w .\ \Delta t_w}$$

In: G_{w2} : flow enter cooling tower

C_w : specific heat of water: C_n = 1 kcal/kg.K = 4,187 (kJ/kg.K)

Δt_w : spread the water temperature was in the Tower: $\Delta t_w = 5^o C$

$$=> G_{W2} = \frac{Q'_k}{C_W .\Delta t_W} = \frac{1361,15}{4,187.5} = 65,01\ kg/s$$

Water temperature in the cooling tower: t_{w1} = 37°C

Water temperature out of the Tower: t_{w2} = 32°C

The difference in temperature between the levels of water in and out of the tower is 5°C.

Balanced equation in cooling tower:

Gw2 = Gw + Gx

Gw = Gw1 + G' + G"

Gbs = G' + G" + Gx

In that :

- Gw - the amount of water going into the cooling system.
- Gw1 - the amount of water going into the container after cooling.
- Gw2 - the amount of water going into the condenser.
- Gx - the amount of water discharged to ensure clean water for the cooling system
- Gbs - the amount of water added to the towers to compensate all losses.
- G' - the amount of water loss due to evaporation.
- G" - the amount of water loss due to the wind carried away.

To make sure the cooling water pipes at least corrosive of the hardness of the water should not exceed the permitted limit. We have to discharge water away part, According to the page 311 [Doc 2], the ratio of the amount of water discharged:

$\frac{g_x}{G_w} = G_x > (3 \div 4)\,\%$

We select: $g_x = 5\%$

Water discharge flow is: $G_x = 0{,}05.G_W$

The amount of water going into the cooling system: $G_{W2} = 1{,}05.G_W$

$$=> G_w = \frac{G_{w2}}{1{,}05} = \frac{65{,}01}{1{,}05} = 61{,}91\ (kg/s)$$

The amount of water discharged: $G_x = G_{w2} - G_w = 65{,}01 - 61{,}91 = 3{,}1\ (kg/s)$

The amount of water due to the wind carried away:

$$g'' = \frac{G''}{G_w} = (0{,}3 \div 0{,}5)\,\%$$

We select : $g'' = 0{,}005$

$$G'' = 0{,}005.G_w = 0{,}005.61{,}91 = 0{,}31\ kg/s$$

The amount of necessary air through the Tower:

$$G_{kk} = \frac{Q}{\Delta_i}$$

In that:

- Q - capacity of cooling tower, $Q = Q'_k = 1361{,}15\ kW$
- Δi - spread of the air in the Tower, $\Delta i = i_1 - i_2$

To facilitate the calculation we choose:

$\Delta i = C_W.\Delta t_W = 4{,}187.5 = 20{,}93$ kJ/kg to let the water through the cooling tower and air through the tower by each other: $\frac{G_w}{G_{kh}} = 1$

So the amount of air through the Tower: $G_{kh} = 61{,}91\ kg/s$

The average temperature of the water to come out of the Tower:

$t_{tb} = 0{,}5.(t_{W1} + t_{W2}) = 0{,}5.(37 + 32) = 34{,}5°C$

Air state parameters:

+ When on the Tower, với $t_1 = 36$ °C, $\varphi_1 = 65$ %

$d1 = 0{,}025$ g/kg

$i1 = 99{,}9363$ kJ/kg

+ In the saturated State $t_{tb} = 34{,}5^oC$, $\varphi_W = 100$ %

$dw = 0{,}036$ kg/kg

I''_W = 126,3510 kJ/kg

+ When out of the Tower:

$$i_2 = i_1 + \Delta i = 99{,}9363 + 20{,}93 = 120{,}86\ kJ/kg$$

$$t_2 = t_1 + (t_w - t_1)\frac{i_2 - i_1}{i''_W - i_1}$$

In that:

- i_1 - entanpy of air into the Tower, i_1 = 99,9363 kJ/kg.
- i_2 - entanpy of air out of the Tower, i_2 = 120,86 kJ/kg.
- i''_W - entanpy of the air saturated with heat t_{tb} = 34,5^{o}C.
- t_1 - air temperature on the Tower, t_1 = 36 °C.
- t_2 - air temperature from the Tower.

So:

$$t_2 = 36 + (34{,}5 - 36).\frac{120{,}86 - 99{,}9363}{126{,}3510 - 99{,}9363} = 34{,}81°C$$

The average entanpy between the logarithm in the cooling tower:

$$\Delta i = \frac{(i''_{w1} - i_2) - (i''_{w2} - i_1)}{ln\frac{i''_{w1} - i_2}{i''_{w2} - i_1}}$$

In that:

- i_1 - entanpy of the air is saturating with t_1 = 36^{o}C
- $i''w_1$ - entanpy of the air is saturating with t_{w1} = 37^{o}C
- i_2 - entanpy of the air is saturating with t_2 = 34,81^{o}C
- $i''w_2$ - entanpy of the air is saturating with t_{w2} = 32^{o}C

$$\Delta i_L = \frac{(143{,}5078 - 120{,}86) - (111{,}0935 - 99{,}9363)}{ln\frac{143{,}5078 - 120{,}86}{111{,}0935 - 99{,}9363}} = 16{,}23\ kJ/kg$$

Select the surface irrigation drain made from plastic plates PVC works very well when skinning met light water, withstand axit, easy to clean surface. Drain surface water the wavy shape:

Private area $F_v = 640\ m^2/m$

Equivalent diameter: $\mathrm{d_{td}} = 5{,}35\ \mathrm{mm}$

Free volume $\mathrm{V_o} = 0.91\ \mathrm{m^3/m}$

Evaporation coefficient σ ($\mathrm{Kg/m^2.s}$) for surface irrigation drain is the hive and slot can define by:

$$\sigma = 0.284(\omega_p)^{0.57} g_L^{0.29} \left(\frac{H}{d_{td}}\right)^{-0.515}$$

With:

- ω_p: the velocity of the air in the gutter surface irrigate, kg/$m^2 s$
- g_L : the density of drain watering on 1 m the perimeter of the cross-section being absorbent kg/ m.s
- d_{td}: the equivalent diameter of the hive or slits, m
- H- in height slot or hive, m

We have :

$$\omega_p = \frac{G_{kh}}{F.V_o}$$

With:

- F : an area of cross-section of the Tower, m^2

$$F = \frac{G_w}{g_w} = \frac{61{,}91}{3} = 20{,}64\ m^2$$

That is:

- g_w: the density of drain watering

$$g_w = 2.5 \div 3\ kg\ /m^2.s => chosse\ g_w = 3\ kg/m^2.s$$

$$=> \ \omega_p = \frac{G_{kh}}{F.V_o} = \frac{61{,}91}{20{,}64\ .0{,}91} = 3{,}3\ kg/m^2.s$$

- g_L is defined by:

$$g_L = \frac{g_w}{P/F} = \frac{g_w}{F_v} = \frac{3}{640} = 0{,}0046\ kg/ms$$

Select height of drain surface irrigate: H= 200mm

So:

$$\sigma = 0{,}284(\omega_p)^{0.57} g_L^{0.29}.\left(\frac{H}{d_{td}}\right)^{-0.515}$$

$$= 0{,}284\ .\ 3{,}3^{0.57}.\ 0.0046^{0.29}.\ \left(\frac{200}{5{,}35}\right)^{-0.515}$$

$$= 0{,}018\ kg/m^2.s$$

Concrete drain side of the irrigation area of the Tower:

$$F_x = \frac{Q'k}{\sigma.\Delta i_l} = \frac{1361{,}15}{0{,}018.16{,}23} = 4659{,}24m^2$$

The total perimeter of the cross-section Groove

$$P = F.F_v = 20{,}64\ x\ 640 = 13209{,}6m^2$$

Surface irrigation drain capacity:

$$V_x = \frac{F_x}{F_v} = \frac{4659{,}24}{640} = 7{,}28\ m^3$$

Height of drain surface irrigate:

$$H = \frac{V_x}{F} = \frac{7{,}28}{20{,}64} = 0{,}35\ m$$

Internal diameter of the Tower:

$$D_{tr} = \sqrt{\frac{4.F}{\pi}} = \sqrt{\frac{4\ x\ 20{,}64}{3.14}} = 5{,}13\ m$$

Cross-section for air travel through:

$$f = F.\ V_o = 20{,}64\ x\ 0{,}91 = 18{,}78\ m^2$$

8.2 TEMPERATURE FOR THERMAL COOLING

To select the fan for the Tower we need to calculate gas for the Tower, meaning that we count back the force of the air through the Tower from which to select appropriate ventilators.

The speed of movement of the air in the different cross-section of the tower are all related to each other according to the equation of continuity:

$$\frac{G_{kk}}{\rho} = f_1.\omega_1 = f_2.\omega_2 = f_3.\omega_3 = f_4.\omega_4$$

In that:

f1 - cross-section area at the entrance.

Select the height of the wind door in the Tower: h1 = 0,6 m

⇨ $f_1 = \pi.D_{tr}.h_1 = 3{,}14\ .5{,}13.\ 0{,}6 = 9{,}66\ m^2$

⇨ f2 - an area of Tower body, f2 = $\frac{\pi.D_{tr}^2}{4}$ = $20{,}66\ m^2$

⇨ f3 - area right at the class hive, f3 = f = 18,78 m^2

f4 - area right at the door of the Tower.

Select the diameter in the door of the Tower:

$D_4 = 0{,}6D_{tr}$ = 0,6.5,13 = 3,08 m

⇨ $f_4 = \frac{\pi.D_4^2}{4} = \frac{3{,}14.3{,}08^2}{4}$ = 7,45 m2

ρ - a separate volume of air, ρ= 1,1391 Kg/m^3 with the average air temperature:

$$t_{tb} = 0{,}5.(t_1 + t_2) = 0{,}5.(36 + 34{,}81) = 34{,}4°C$$

From structures on the line's speed, we determine the atmosphere at the different cross-section is defined as follows:

$$\omega_1 = \frac{G_{kh}}{\rho.f_1} = \frac{61{,}91}{1{,}1391.9{,}66} = 5{,}62\ m/s$$

$$\omega_2 = \frac{G_{kh}}{\rho.f_2} = \frac{61{,}91}{1{,}1391.20{,}66} = 2{,}63\ m/s$$

$$\omega_3 = \frac{G_{kh}}{\rho.f_3} = \frac{61{,}91}{1{,}1391.18{,}78} = 2{,}89\ m/s$$

$$\omega_4 = \frac{G_{kh}}{\rho.f_4} = \frac{61{,}91}{1{,}1391.7{,}45} = 7{,}29\ m/s$$

The total return of the air flow through the Tower:

ΣΔP= ΔPv + ΔPn + ΔPx + ΔPp + ΔPc + ΔPk + ΔPra [Doc 2]

Back at the door:

$$\Delta P_v = 0{,}55.\rho\frac{\omega_1^2}{2} = 0{,}55.1{,}1391\frac{5{,}62^2}{2} = 9{,}89\ Pa$$

Back at the spot of the air-line brackets:

$$\Delta P_n = 0{,}55.\rho\frac{\omega_2^2}{2} = 0{,}55.1{,}1391\frac{2{,}63^2}{2} = 2{,}16\ Pa$$

Back surface of gutter drip irrigation, with ω_p =3,46 Kg/m^2.s < 4,5 Kg/m^2.s

$$\Delta P_x = 13{,}3.(\omega\rho)^{1{,}3}g_L^{0{,}6}(\frac{H}{d_{tđ}})^{0{,}47}$$

⇨ $\Delta P_x = 13{,}3.3{,}3^{1{,}3}.0{,}0046^{0{,}6}.65{,}42^{0{,}47}$= 17,74 Pa

Prohibitive in cross-section have fountains: $\Delta P_p = \xi_p . \rho . \frac{\omega_2^{\ 2}}{22}$

ξP - back to the local force multiplier in cross-section are defined under fountains 8-19 [Doc 2], We identified: ξP = 0,74

$$\Delta P_p = 0{,}74.1{,}1391.\frac{2{,}63^2}{2} = 2{,}91 \text{ Pa}$$

Back at the shutters keep the water: $\Delta P_c = \xi c . \rho . \frac{\omega_2^{\ 2}}{2}$

ξC - back to the local force multiplier in the shutters keep the country defined by Figure 8-19 [Doc 2], We identified: ξC = 0,75

$$\Delta P_c = 0{,}75.1{,}1391.\frac{2{,}63^2}{2} = 2{,}95\ Pa$$

Prohibitive in the insect-shaped tower, with coefficient of prohibitive con figure:

$$\xi_k = 0{,}5.\left(1 - \frac{f_4}{f_2}\right) = 0{,}5.\left(1 - \frac{7{,}45}{20{,}66}\right) = 0{,}32$$

$$\Delta P_k = \xi_k . \rho . \frac{\omega_2^2}{2} = 0{,}32.1{,}1391\frac{2{,}63^2}{2} = 1{,}26\ Pa$$

Back at the door of the Tower:

$$\Delta P_{ra} = \rho . \frac{\omega_4^2}{2} = 1{,}1391\frac{7{,}29^2}{2} = 30{,}26\ Pa$$

So : $\Delta P\Sigma = \Delta Pv + \Delta Pn + \Delta Px + \Delta Pp + \Delta Pc + \Delta Pk + \Delta Pra$

$\Delta P\Sigma = 9{,}89 + 2{,}16 + 17{,}74 + 2{,}91 + 2{,}95 + 1{,}26 + 30{,}26$

$\Delta P\Sigma = 67{,}17$ Pa

Blower power (kW electric motor pull fans):

$$N = \frac{1{,}2.G_{KK}.\Delta P_{\Sigma}.10^{-3}}{\rho.\eta}, \quad KW,$$

In : G_{Kh} - Flow pass cooling tower , Kg/s

ΔP_{Σ} - Total resistance for cooling tower, Pa

ρ - Specific of air, Kg/m^3

η - The performance of the fan. Chosse η = 0,65

$$=> N = \frac{1{,}2\ .61{,}91\ .67{,}17.10^{-3}}{1{,}1391.0{,}65} = 6{,}74 \text{ Kw}$$

8.3 SELECT THE COOLING TOWER

The Tower design parameters:

- V = 61,91 l/s = 3714,6 l/min
- $t_{w1} = 37^oC$; $t_{w2} = 32^oC$
- $T_{out} = 36^oC$; RH = 65%

we choose 4 cooling tower (because we have 4 chillers) with each of the following parameters:cooling tower Liang Chi code LBC-300

Mã Tower Model	Khả năng làm mát Cooling Capacity Kcal/Hr * 1	Dòng chảy Nominal Water Flow L/min	Kích thước Dimensions		Lắp quạt Fan Assembly			Nối ống Pipe Connection (A)					
			Chiều cao H	Đường kính DØ	Mô tơ Motor HP	Lượng gió Air Volume m³/min	Quạt Fan DØ mm	Vào Inlet	Ra Outlet	Dẫn nước Drain	Tràn Over Flow	Ống nước bổ sung ∗3 Tự động (Ba)	Châm tay (O)
LBC-25	97500	325	1800	1380	3/4	200	770	65	65	25	25	15	15
30	117000	390	1735	1580	1	225	770	65	65	25	25	15	15
40	156000	520	1890	1820	1½	280	970	65	65	25	25	20	20
50	195000	650	1890	2000	1½	330	970	80	80	25	25	20	20
60	234000	780	1895	2000	1½	420	1170	80	80	25	25	20	20
70	273000	910	2015	2175	1½	500	1170	100	100	25	25	20	20
80	312000	1040	2015	2175	2	540	1170	100	100	25	25	20	20
100	390000	1300	2160	2650	3	700	1470	100	100	25	25	25	25
125	487500	1625	2210	3050	3	830	1470	125	125	25	25	25	25
150	585000	1950	2285	3300	5	950	1750	125	125	50	50	25	25
175	682500	2275	2485	3300	5	1150	1750	125	125	50	50	25	25
200	780000	2600	2990	3770	5	1250	1750	150	150	50	50	32	32
225	877500	2925	3190	3770	7½	1750	2360	150	150	50	50	32	32
250	975000	3250	3190	3770	7½	1750	2360	200	200	50	50	32	32
300	1170000	3900	3350	4440	10	2200	2360	200	200	50	50	32	32
350	1365000	4550	3390	4790	10	2200	2360	200	200	50	50	32	32
400	1560000	5200	3890	5180	15	2600	2970	200	200	50	100	50	50