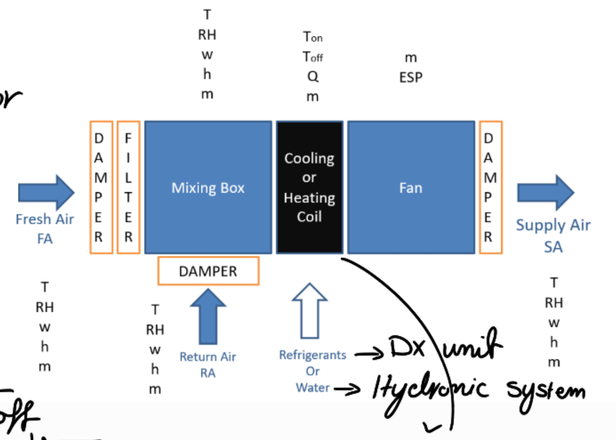
DX conditioner System: uses Vapor Compression cycle to cool air and exchange is between Air and Refrigerant. $(\dot{m}_{Ref}\, h_{fg} = \dot{m}_a C_{p_a} \Delta T_a)$

coil capacitance

$\downarrow$

$T_{on} - T_{off}$

T_{mix} T_{supply}



Phase change

Gas 75% ⟶ 100% Gas

liq 25%

- Where: Dx is Direct expansion

Hydronic System

Same coil as DX But air exchanges heat with water

Hydronic System consists of:

1. Chilled water coil → Heating / Cooling } Separate or together

→ Copper pipes, fins

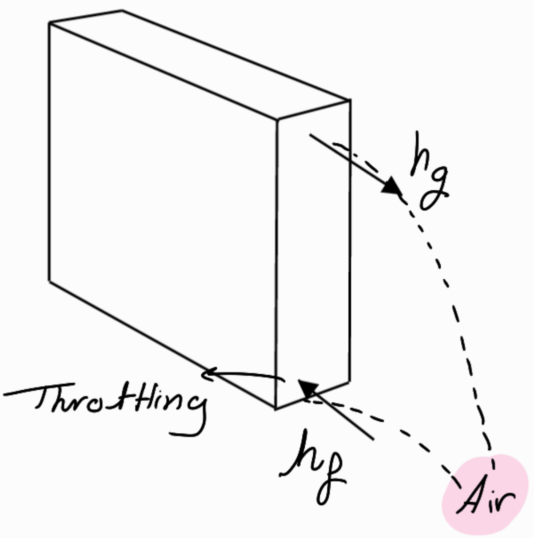
→ named after number of rows

Gas

$$Q = \dot{m}_{Gas} h_{fg}$$

water

$$Q = \dot{m}_{water} C_{p_{water}} \Delta T$$



2. Pump (for circulation)

↳ There are 3 Types of connections

water

3. Piping (Size and insulation) → Darce $\Delta P = f \frac{L}{D} \frac{V^2}{2g}$ / → Haizen

Note:

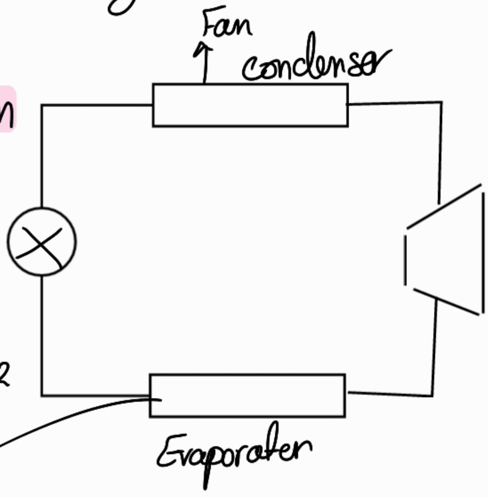
↳ Expansion Tank for water volume changing due to Temperature change.

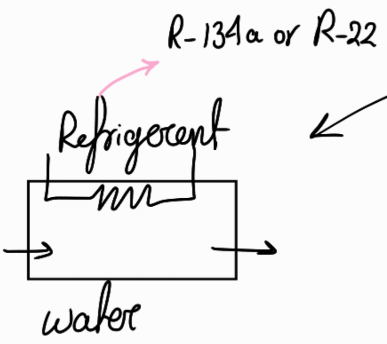
4. Water sources

1. Chiller → Chilled water } Heat Pump
2. Boiler → Heating water }

Chiller construction

غاز و مي





Compressor Types

1. Reciprocating Compressor ← (Cylinder)
2. Scroll compressor
3. Screw compressor
4. Centrifugal

• يعني بالأول نبرد المي بال Chiller
وبعدين بالمي الباردة نبرد الهوا

$$\dot{m}_R h_{fg} = \dot{m}_w C_{pw} \Delta T_w$$

Design standard

$T_{in} = 11.2°$

$T_{out} = 5.6°$

$\Delta T = 5.6 °C = 10 F°$

Example

- Compressor 700 kW
- P_H, P_L Given

↳ How much is the fan flow rate to give Q = ... (heat rejection)

↳ Calculate COP or COP given and calculate flow rate

Types of Pumps

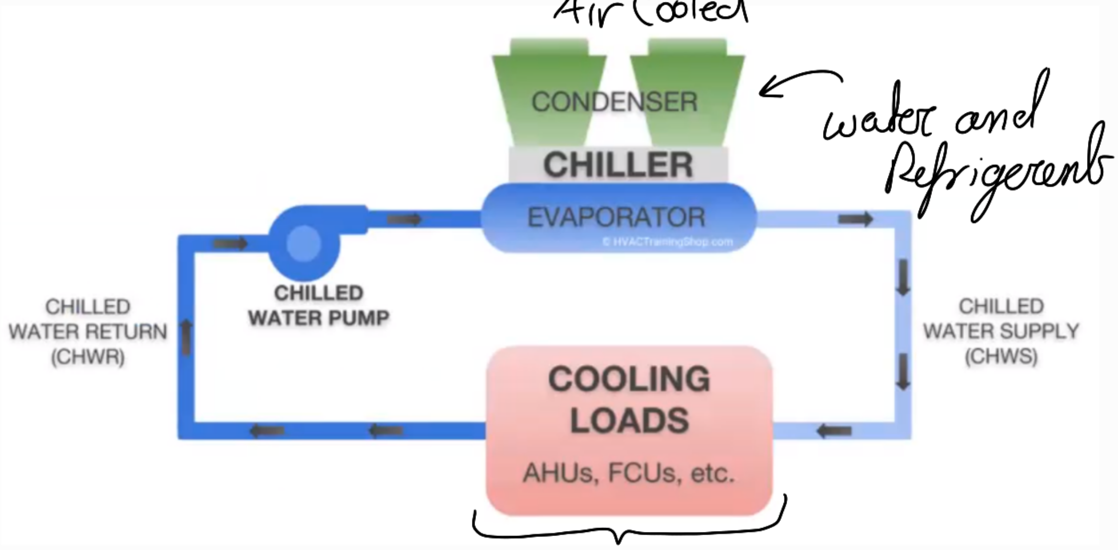
1. Reciprocating
2. Centrifugal
3. vertical, multistage
4. end suction line
5. in line → less friction loss

System of connections

2-pipe System, 3-pipe ......

Hydronic system schematic

Air Cooled

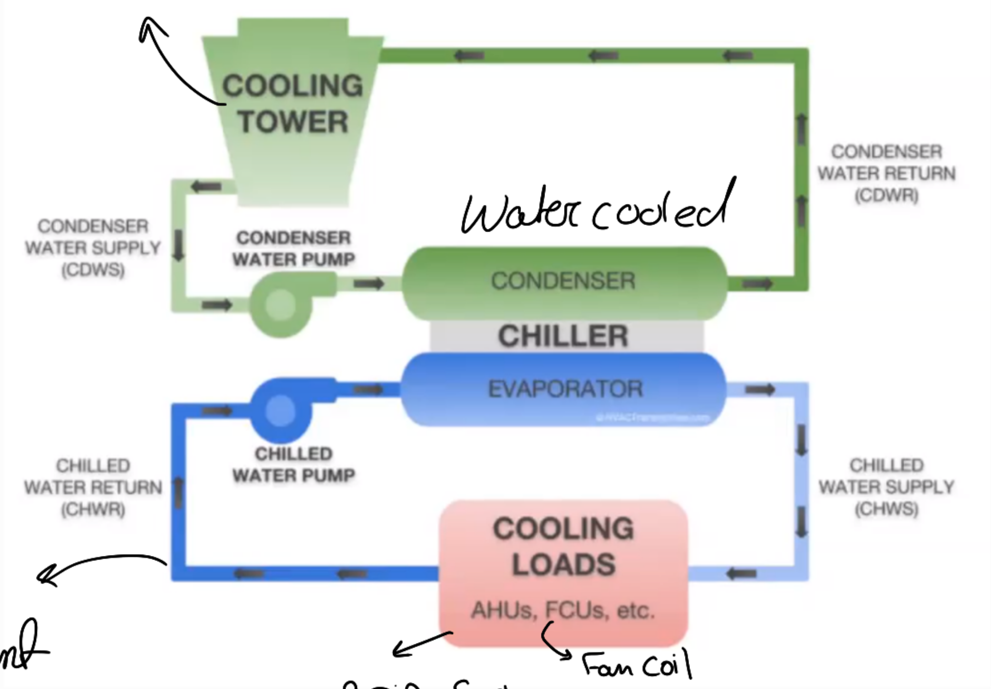


water and Refrigerant

copper coil with air and water

$\dot{m}_{water} c_{pw} \Delta T_w = \dot{m}_a c_{pa} \Delta T_a$ or $\dot{m}_w (3000) \Delta \omega = \dot{m}_a (3000) \Delta \omega_{air}$

Anothe Schematic

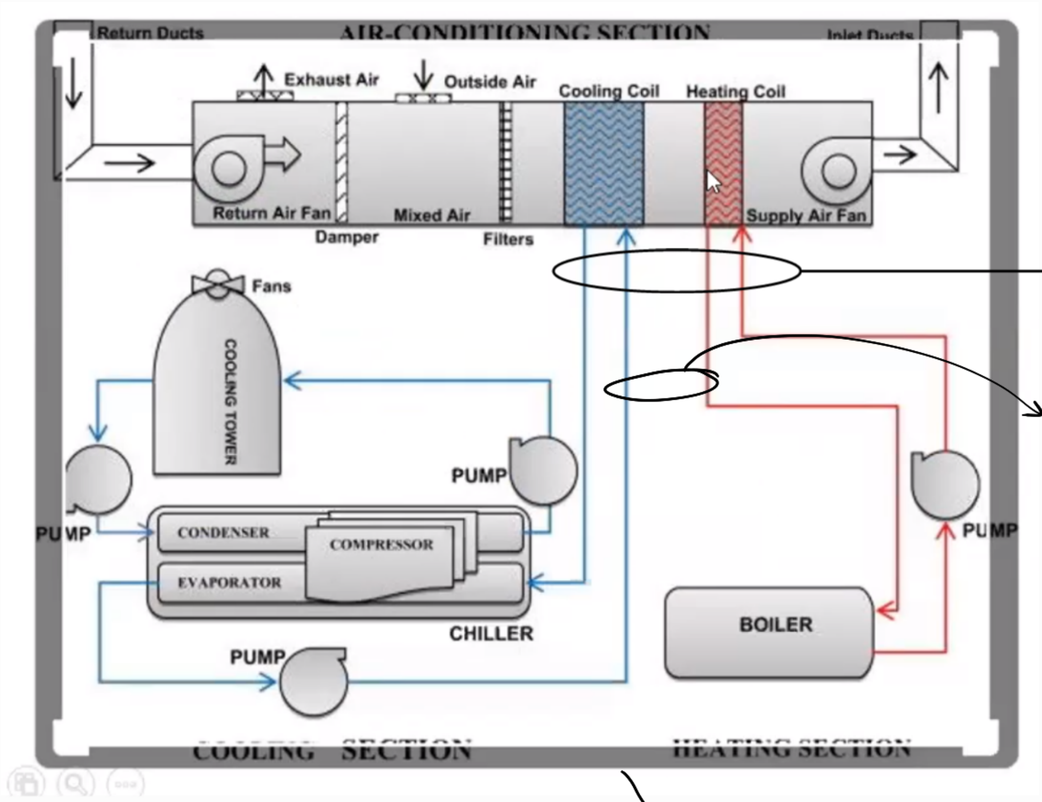


Water cooled

No Refrigerant

2 pipe System

Fan Coil



4 pipe System

3pipe System

هدول بيصيرو واحد

or 2 pipe System

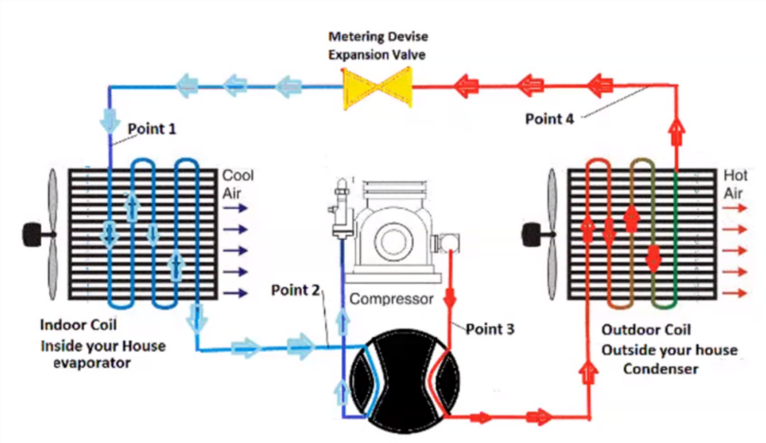
حوالاط

Air cooled Chiller

Summer

Room

Outdoor

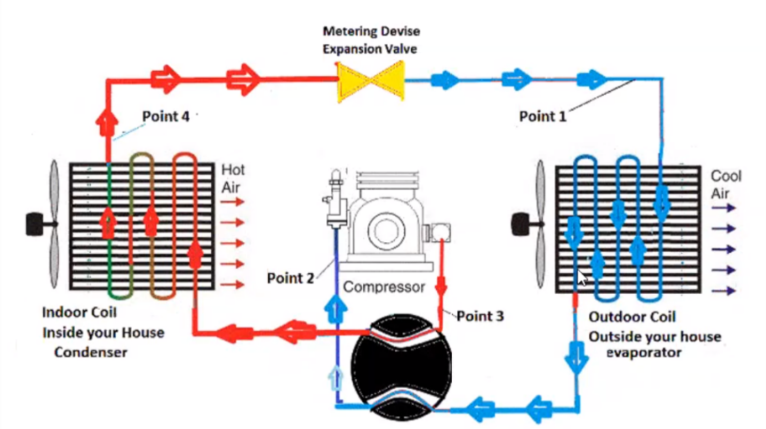


Reversing Valve In position A cooling Mode

Winter

Room

Outdoor



Reversing Valve In position B Heating Mode

تبادل حراري بين الهوا وال Ref

superheated

$h_2 - h_{3/4}$

liquid

$\dot{m}_{Ref}\, \Delta h = \dot{m}_{air}\, Cp_{air}\, \Delta T_{air}$

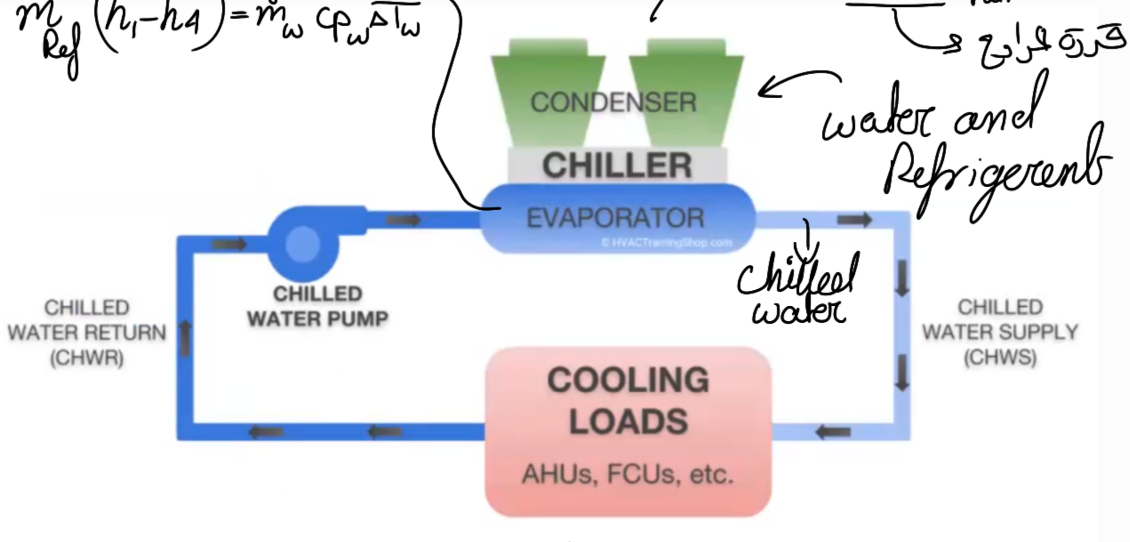
قدرة المراوح

أعلى من Q تاعة ال cooling since COP>1

تبادل حراري بين المي و Ref

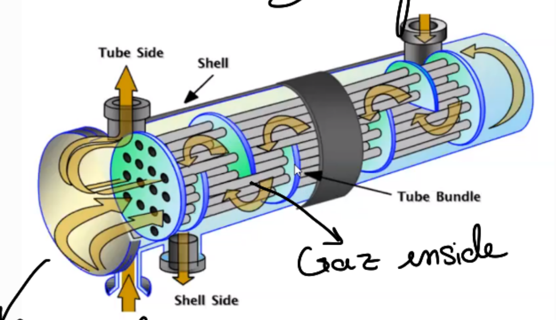
$\dot{m}_{Ref}(h_1 - h_4) = \dot{m}_w\, cp_w \Delta T_w$

water and Refrigerant



chilled water

Condenser & evaporator



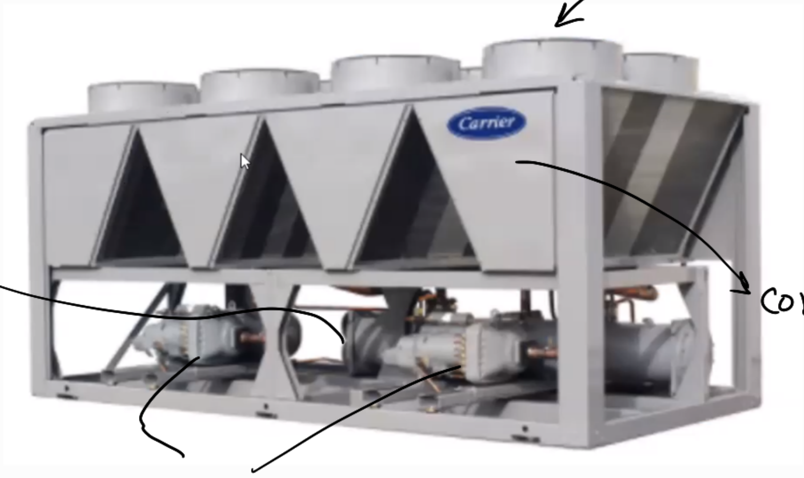
Gaz inside

Refrigerent

Shell and tube HE

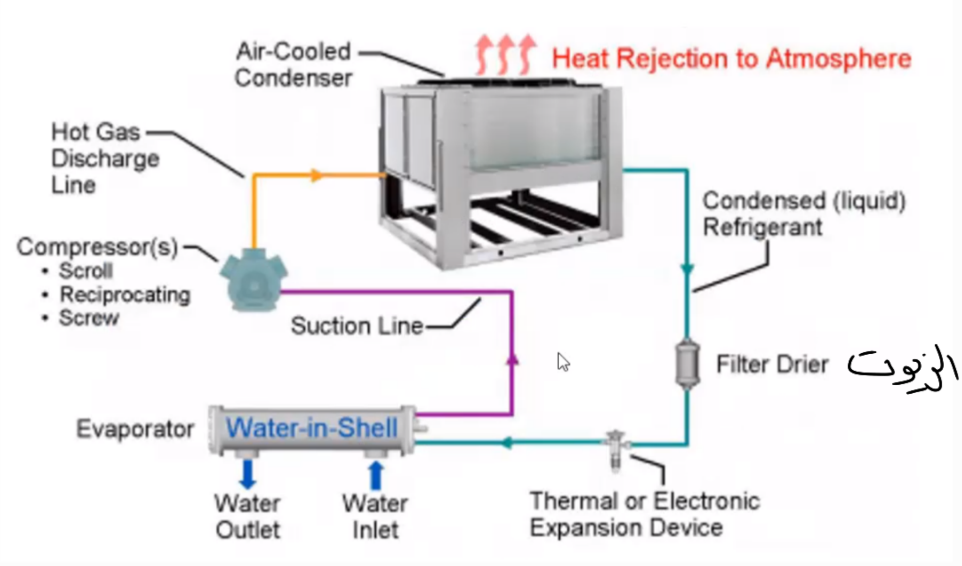
- Extra area (conduction)
- large heat transfer path

مراوح



condenser

compressors



بوحذ كل الزيوت

Pipe Sizing

Friction loss

- Darcy – weisbach equation

$$\Delta h = \frac{\Delta P}{\rho g} = f \frac{L}{D} \frac{V^2}{2g}$$

head

$$\frac{1}{\sqrt{f}} = 1.74 - 2 \log\left(\frac{2\epsilon}{D} + \frac{18.7}{Re\sqrt{f}}\right)$$ If Turbulent

$$f = \frac{64}{Re}$$ If laminar

- Hazen Williams Equation

$$\Delta P = 6.819\, L \left(\frac{V}{C}\right)^{1.852} \left(\frac{1}{D}\right)^{1.167} (\rho g) = \Delta h (\rho g)$$

Roughness factor

C=150 for plastic pipe and copper tubing
=140 for new steel pipe
=100 for badly corroded or very rough pipe

minor losses (valves and fittings)

$$\Delta P = K\rho \frac{V^2}{2}$$

Ashrae → Pipe Sizing

$$\Delta h = K \frac{V^2}{2g}$$

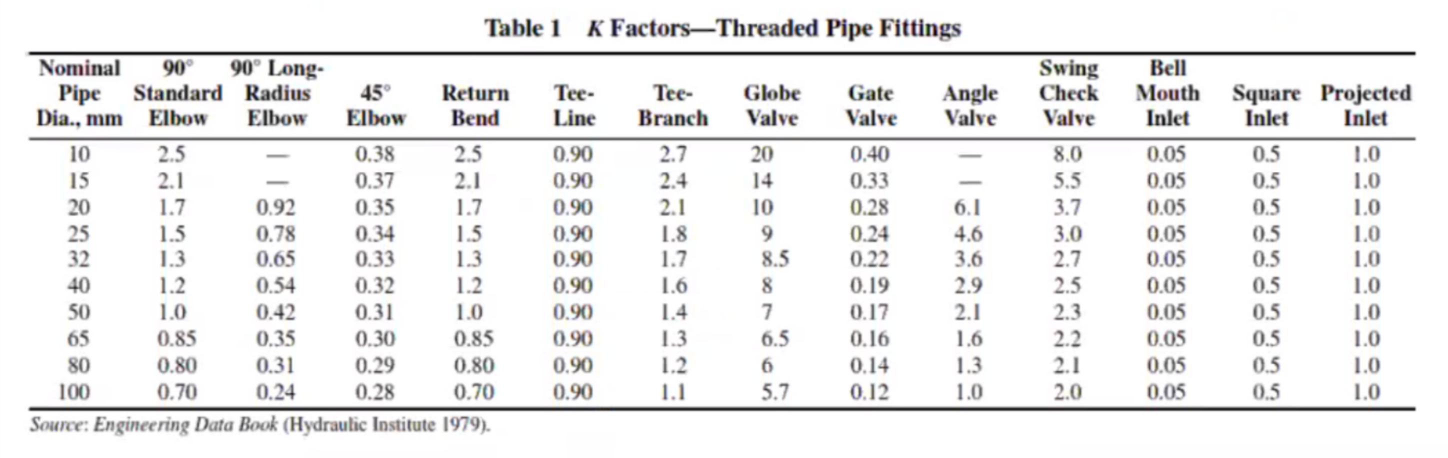


Table 1 *K* **Factors—Threaded Pipe Fittings**

Nominal Pipe Dia., mm	90° Standard Elbow	90° Long-Radius Elbow	45° Elbow	Return Bend	Tee-Line	Tee-Branch	Globe Valve	Gate Valve	Angle Valve	Swing Check Valve	Bell Mouth Inlet	Square Inlet	Projected Inlet
10	2.5	—	0.38	2.5	0.90	2.7	20	0.40	—	8.0	0.05	0.5	1.0
15	2.1	—	0.37	2.1	0.90	2.4	14	0.33	—	5.5	0.05	0.5	1.0
20	1.7	0.92	0.35	1.7	0.90	2.1	10	0.28	6.1	3.7	0.05	0.5	1.0
25	1.5	0.78	0.34	1.5	0.90	1.8	9	0.24	4.6	3.0	0.05	0.5	1.0
32	1.3	0.65	0.33	1.3	0.90	1.7	8.5	0.22	3.6	2.7	0.05	0.5	1.0
40	1.2	0.54	0.32	1.2	0.90	1.6	8	0.19	2.9	2.5	0.05	0.5	1.0
50	1.0	0.42	0.31	1.0	0.90	1.4	7	0.17	2.1	2.3	0.05	0.5	1.0
65	0.85	0.35	0.30	0.85	0.90	1.3	6.5	0.16	1.6	2.2	0.05	0.5	1.0
80	0.80	0.31	0.29	0.80	0.90	1.2	6	0.14	1.3	2.1	0.05	0.5	1.0
100	0.70	0.24	0.28	0.70	0.90	1.1	5.7	0.12	1.0	2.0	0.05	0.5	1.0

Source: *Engineering Data Book* (Hydraulic Institute 1979).

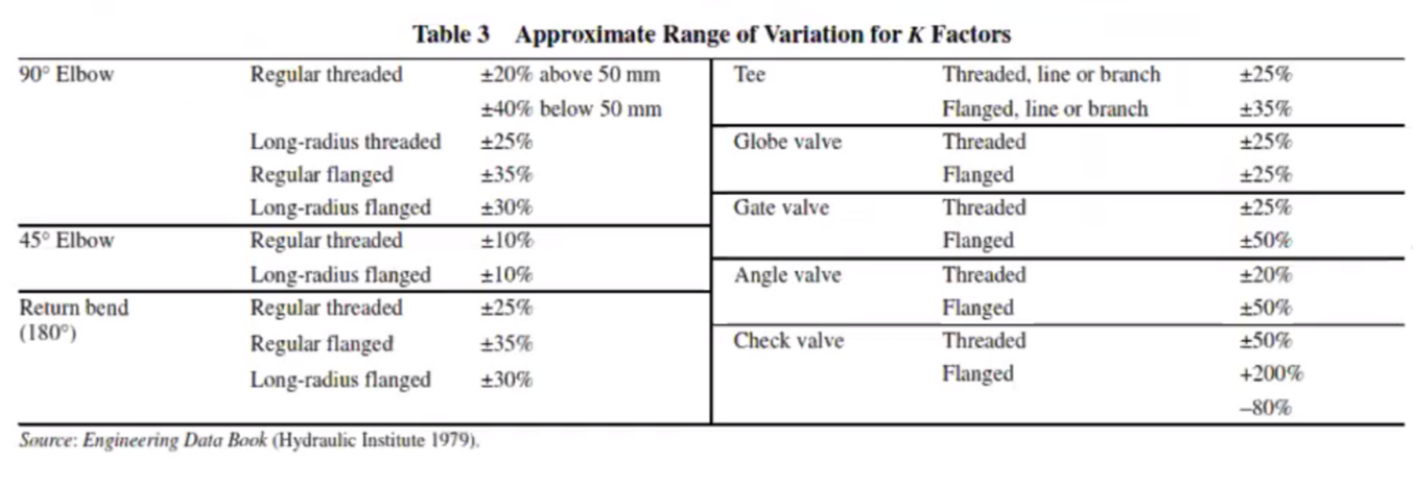


Table 3 Approximate Range of Variation for *K* Factors

90° Elbow	Regular threaded	±20% above 50 mm ±40% below 50 mm
	Long-radius threaded	±25%
	Regular flanged	±35%
	Long-radius flanged	±30%
45° Elbow	Regular threaded	±10%
	Long-radius flanged	±10%
Return bend (180°)	Regular threaded	±25%
	Regular flanged	±35%
	Long-radius flanged	±30%
Tee	Threaded, line or branch	±25%
	Flanged, line or branch	±35%
Globe valve	Threaded	±25%
	Flanged	±25%
Gate valve	Threaded	±25%
	Flanged	±50%
Angle valve	Threaded	±20%
	Flanged	±50%
Check valve	Threaded	±50%
	Flanged	+200% −80%

Source: Engineering Data Book (Hydraulic Institute 1979).

Design limits

Design limits: 1.2 m/s for 50 mm pipe and less

$\Delta P = 400 \text{ Pa/m}$ for more than 50 mm pipe

يعني مايوصل ل هادا الرقم اذا 2" أو اقل

Standard pipe sizing

Standard pipe sizing: 1/4", 3/8", 1/2", 1", 1 1/4, 1 1/2, 2, 2 1/2 .... 4", 5", 6", 8", 10", 12", 14" .... 20"

مضاعفات النص (1 1/2 ... 4")

مضاعفات ال 2 (12" ... 20")

Steps for pipe sizing

1. Pressure and velocity → for diameter
   ↳ $Q = V\,\textcircled{A}$ ↳ $\frac{\pi}{4}D^2$
2. losses → h
   Hazen or Darcy

Example

Q is Given (cooling needed)

↳ Same between Air and water

$Q = \dot{m}_w \, C_{Pw} \, \Delta T$

Q ↳ Given; ΔT ↳ Standard (5.6)

Another approach to find ΔP for valve

$$Q_{water}\ (m^3/s) = A_V \sqrt{\frac{\Delta P}{A}}$$

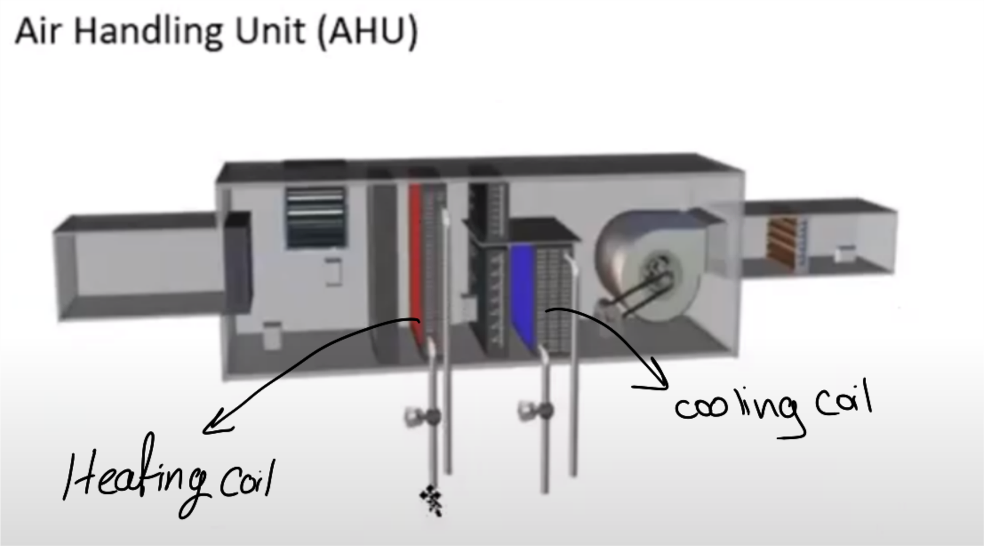
A_V: valve coefficient at 1 Pa

A → 1000

Pump Selection

Lec 18 and 19

Pump



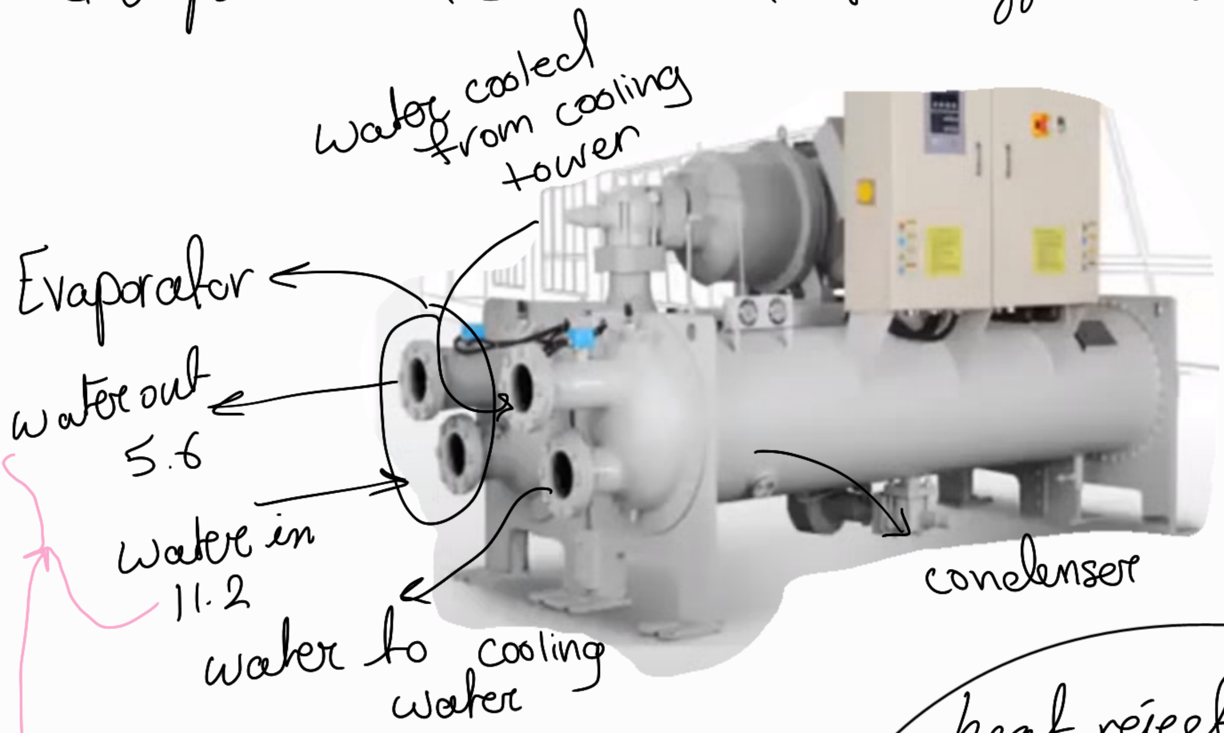
Cooling tower

- For high capacity → with water cooled chiller

Chillers → Air cooled chiller

Chillers → Water cooled chiller → 250 KW as a min
(centrifugal chiller)

$Q_{evaporator} = Q_{zones} = \Sigma Q$ for different loads



5.6°C for Air or water

heat rejection

دائماً أعلى

$$COP = \frac{Q_L}{\underbrace{Q_H - Q_L}_{\rightarrow \text{ work}}}$$

$Q_H > Q_L$

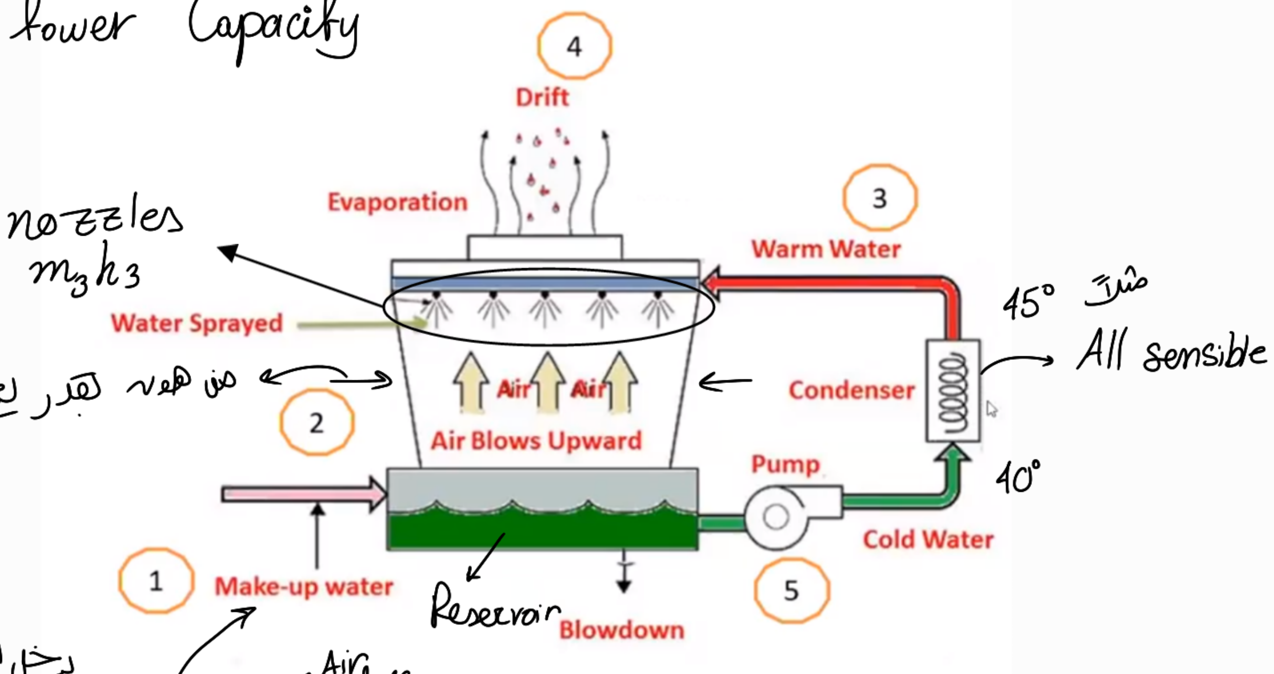
Example

$$\dot{m}_w \underset{\hookrightarrow 4.18}{C_{Pw}} \overset{\rightarrow 5.6}{\Delta T_w} = \underbrace{\text{load from all zones}}_{100 KW}$$

To Solve

$\dot{m}_w \rightarrow Q\ (m^3/s) \rightarrow$ Diameter of pipe $\rightarrow$ use standard with respect to limits $\rightarrow \underline{h_L}$

Cooling tower Capacity



يدخل الهوا بـ ω
ويطلع ω أعلى

Air enters

$$m1h1 + m2h2 + m3h3 = m4h4 + \underline{m5h5}$$

water enters

هي الي رح ارجع استخدمها

$$\underbrace{m1}_{water} = \underbrace{m2}_{air}(\underset{out}{w4} - \overset{in}{w2})$$

$$m2 = m4 = ma$$

- If Air is out saturated → Max efficiency of cooling tower

أي نقطة مي زيادة ما رح يقدر يحملها الهوا

$m_5 \neq m_3$

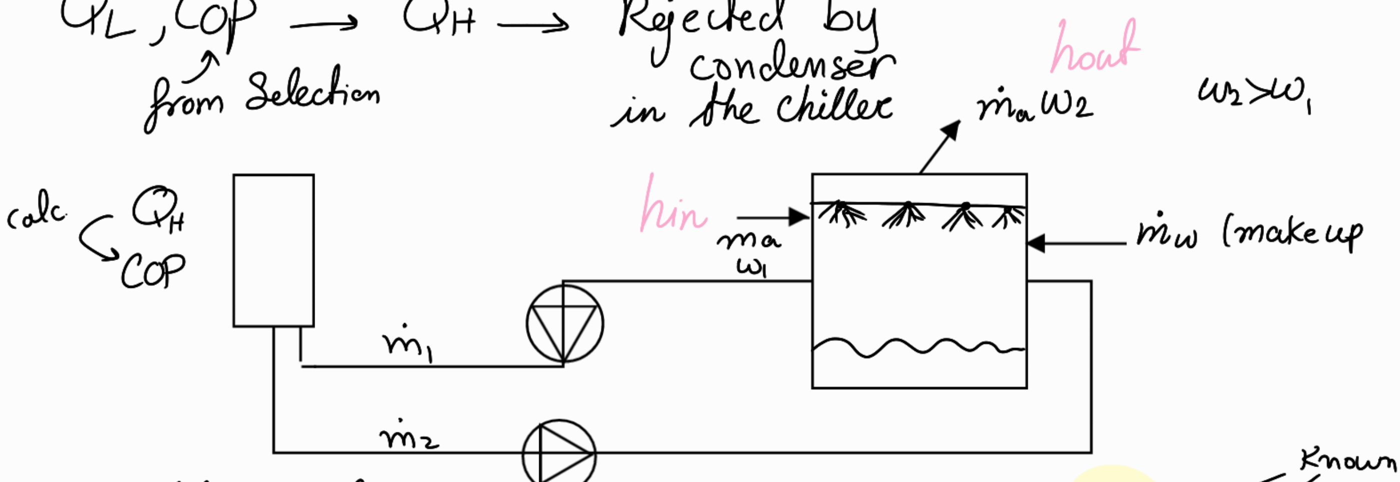
But: $m_3 + m_1 = m_5$

- Steps for finding $\dot m_a$, $\dot m_w$ for cooling tower

$Q_L, COP \rightarrow Q_H \rightarrow$ Rejected by condenser in the chiller

from Selection

$\omega_2 > \omega_1$



$\dot m_1$ should equal $\dot m_2$

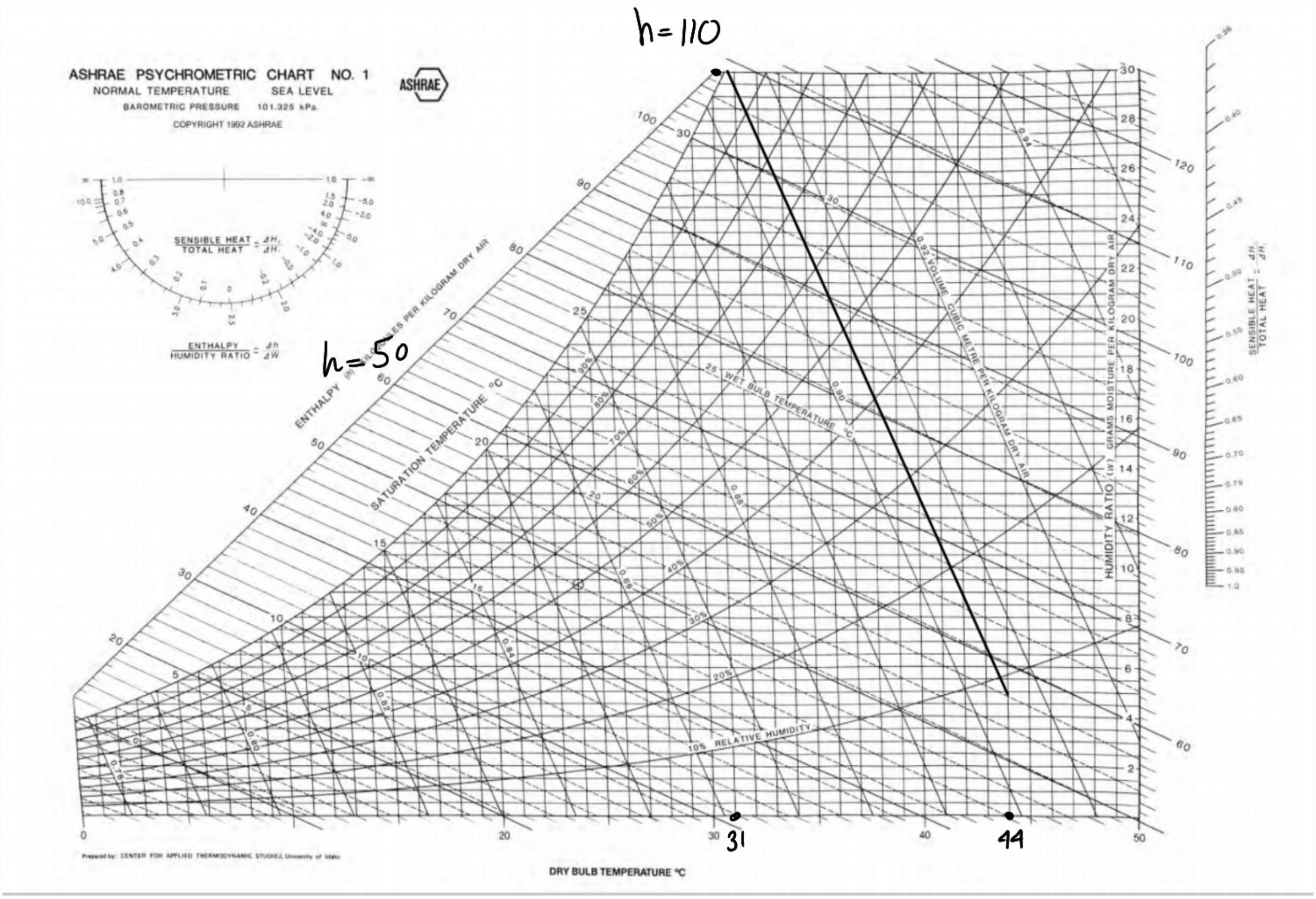
Known → $Q_H = \dot m_w C_{pw} \Delta T_w$ ← Known

5.6°

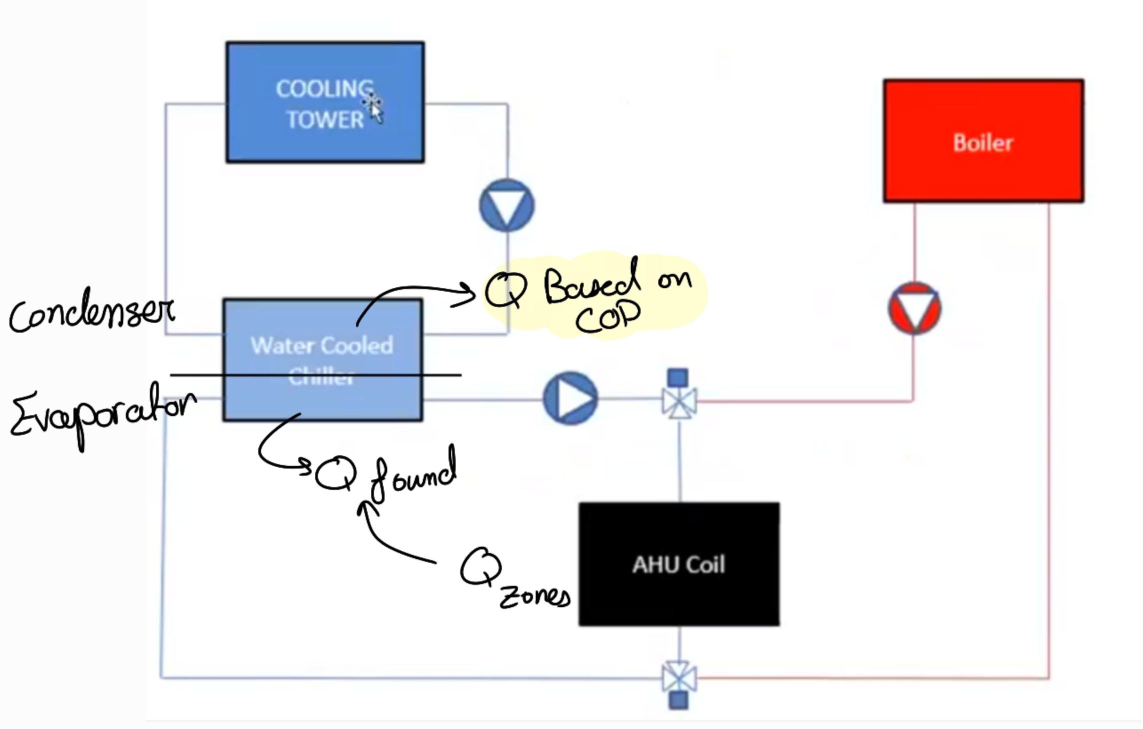
Found

$$Q_{H} = \underbrace{\dot{m}_a \, Cp_a \, \Delta T_{air}}_{\text{Sensible load}} + \underbrace{\dot{m}_a \, 3000 \, \Delta w}_{\text{latent load}} = \dot{m}_a \, \underbrace{\Delta h}_{h_{in} - h_{out}}$$

$\dot{m}_a$ → air (Fan flow rate)



latent load is so high compared to sensible



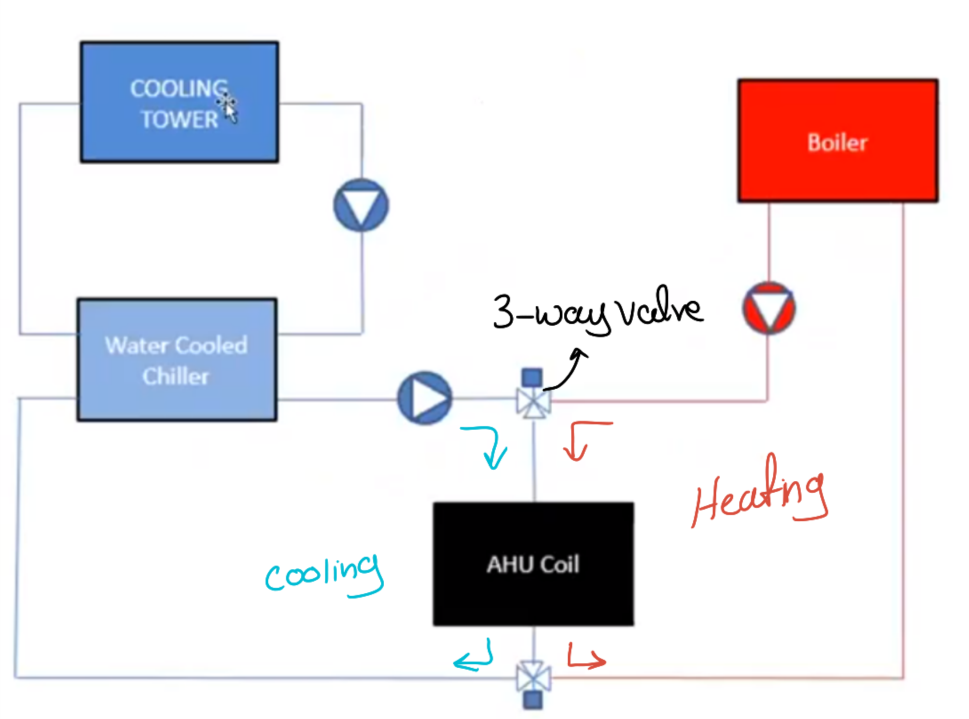
ASK
2way vs 3way

Cooling

Heating

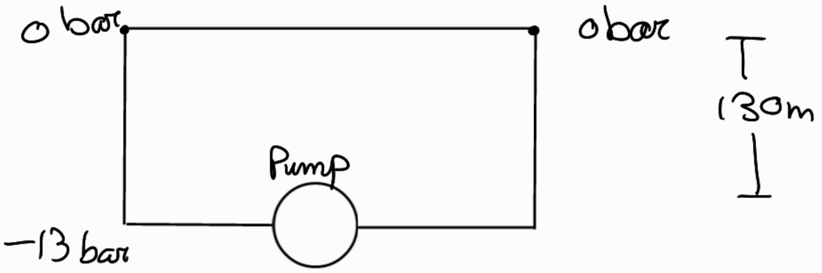
Final Question

2 pipe System



Pump sizing and Selection

I need to know Head (elevation head)



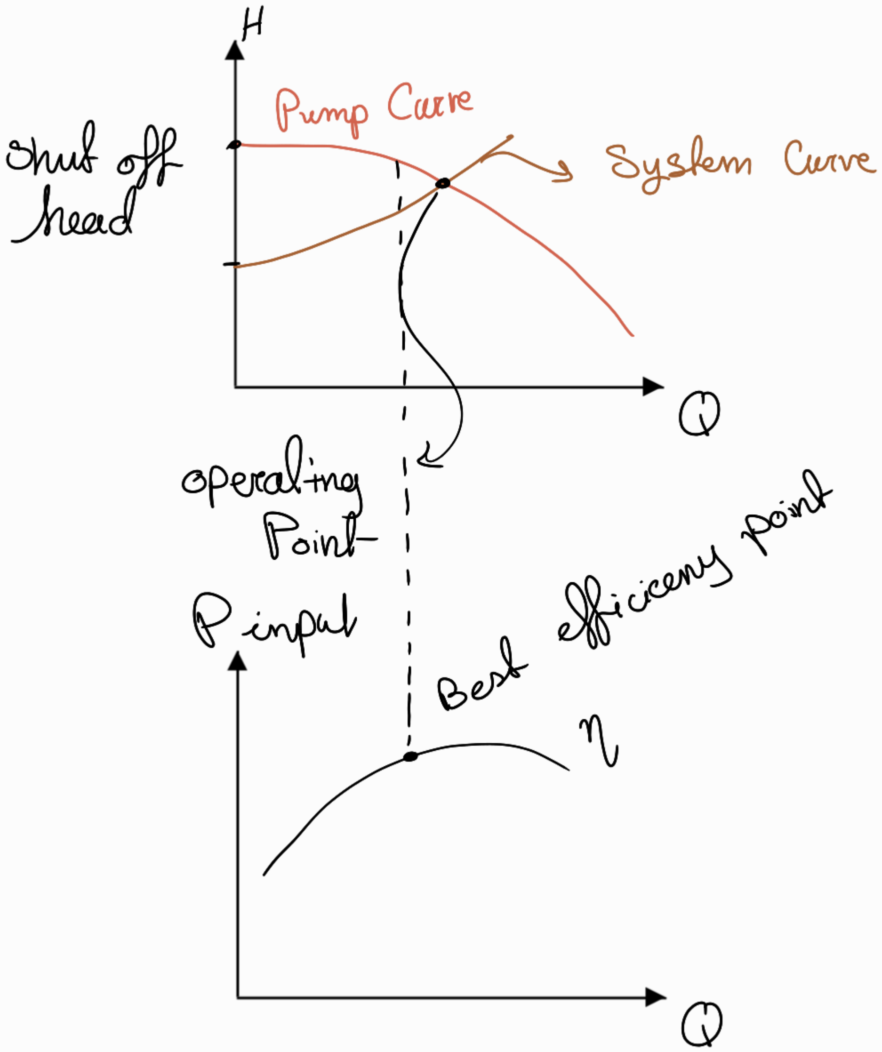
$$H_p + \cancel{\frac{P_1}{\gamma_w}} + \cancel{\frac{V^2}{2g}} + \cancel{Z_1} = \cancel{Z_2} + \cancel{\frac{V_2^2}{2g}} + \cancel{\frac{P_2}{\gamma_w}} + h_L + h_m + \overset{0}{\cancel{h_T}} + \text{friction loss furthest coil}$$

$$h_L \rightarrow f\frac{L}{D}\frac{V^2}{2g}$$

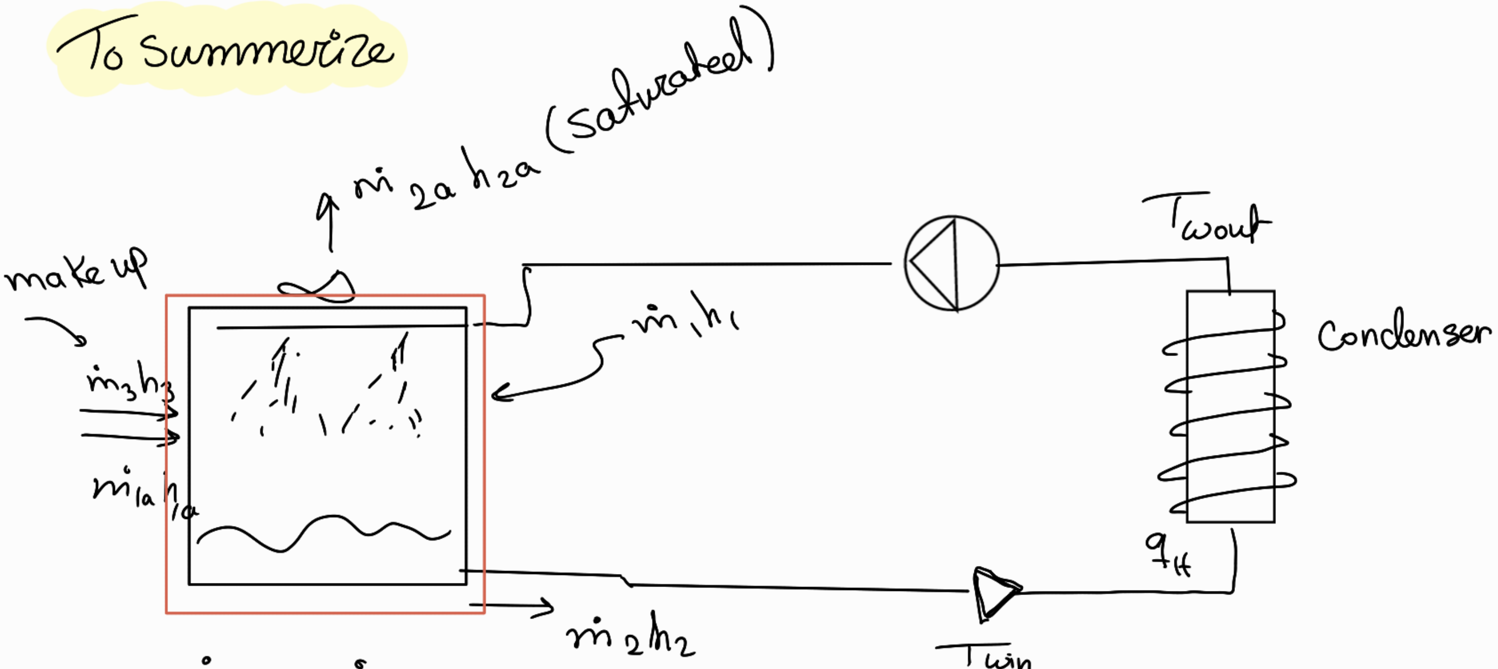
$$h_m \rightarrow \boxed{K}\frac{V^2}{2g} \rightarrow \text{valve, elbow}$$

or Hazen williams

So $$H_p = h_L + h_m + \underset{\text{shut off}}{\underline{h_c}} + \underset{\text{constant}}{\Delta Z}$$



To Summerize



$\dot{m}_{1ⓐ} = \dot{m}_{2a}$

air

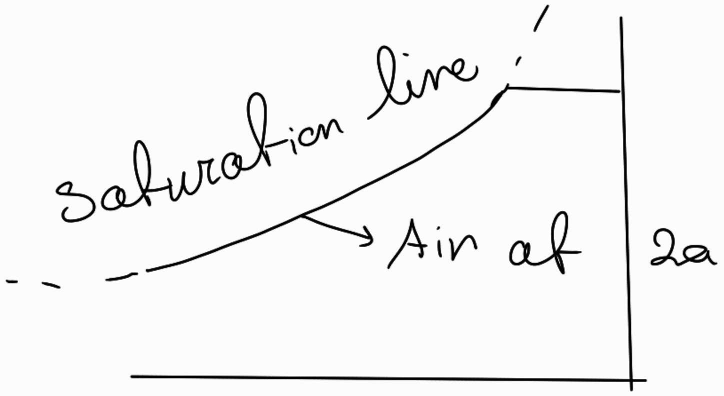
$= \dot{m}_3$

$(\dot{m}_w) = \dot{m}_a \ (\omega_2 - \omega_1)$

make up

Energy Saving

$$\dot{m}_{1a} h_1 + \dot{m}_1 h_1 + \dot{m}_3 h_3 = \dot{m}_{2a} h_{2a} + \dot{m}_2 h_2$$



Included Chapters
Piping: ch 7
cooling tower: ch 19
vapor compression: Ch 10
AHU and Control: ch 9

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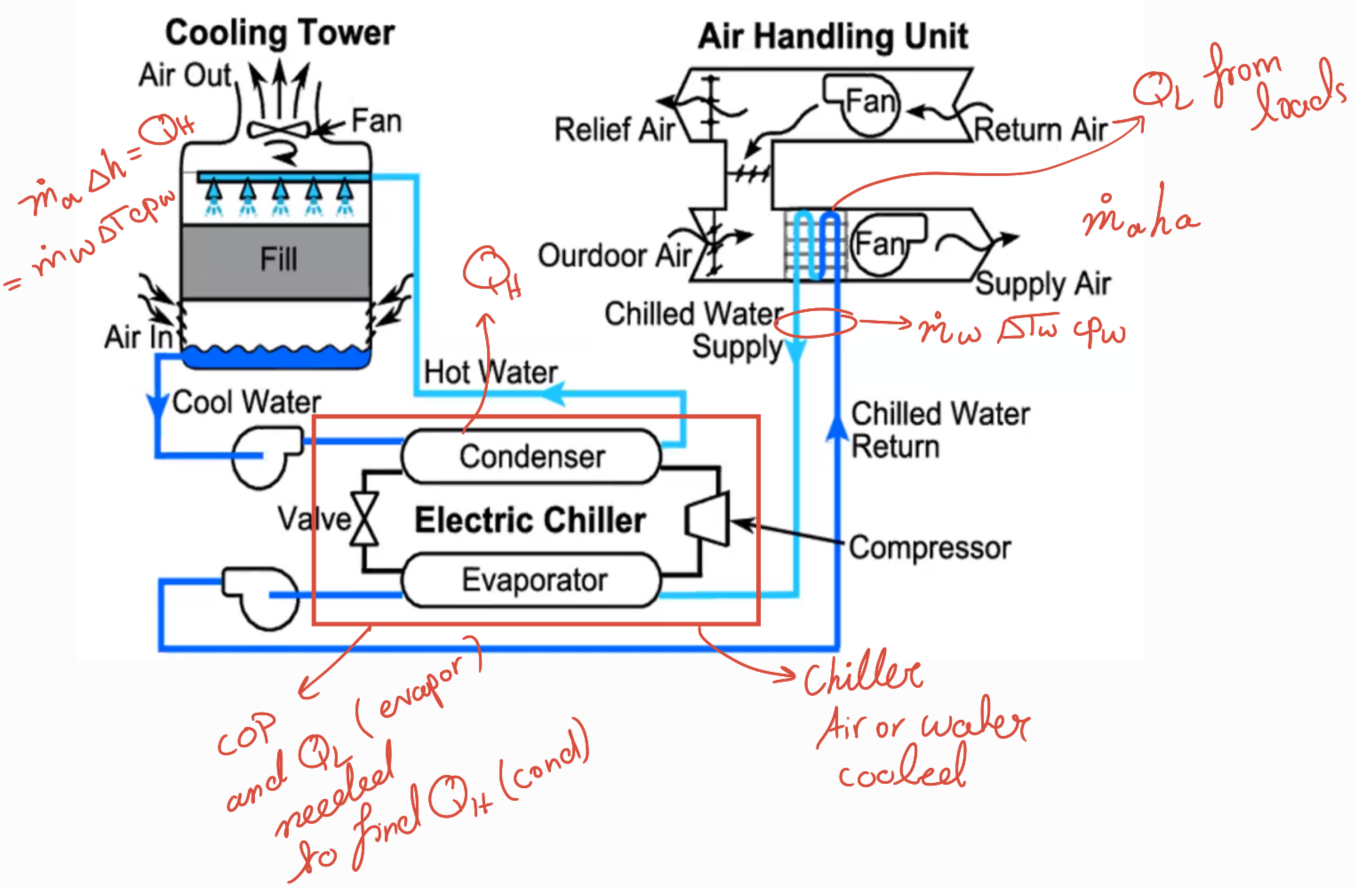
lec 20/5 + 25/5

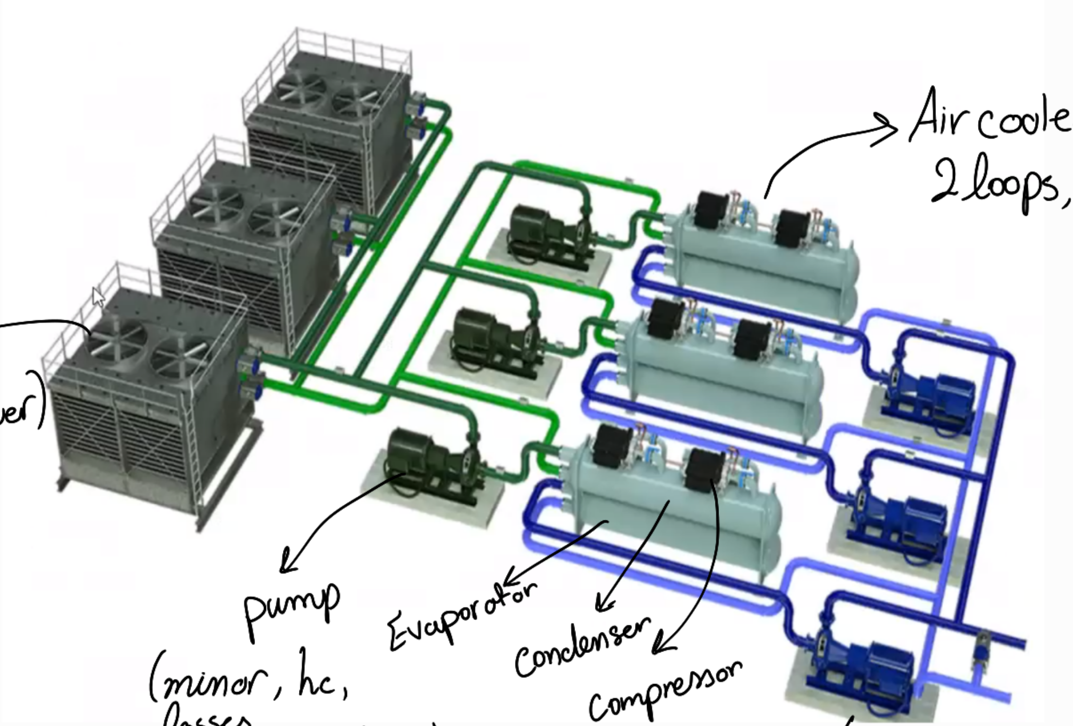


$\dot{m}_a \Delta h = Q_H$
$= \dot{m}_w \Delta T c_{pw}$

$\dot{m}_w \Delta T_w c_{pw}$

COP and Q_L (evapor) needed to find Q_H (cond)

Chiller Air or water cooled



Air cooled chillers
2 loops, 4 pipe system

Evaporative condenser
(Cooling Tower)

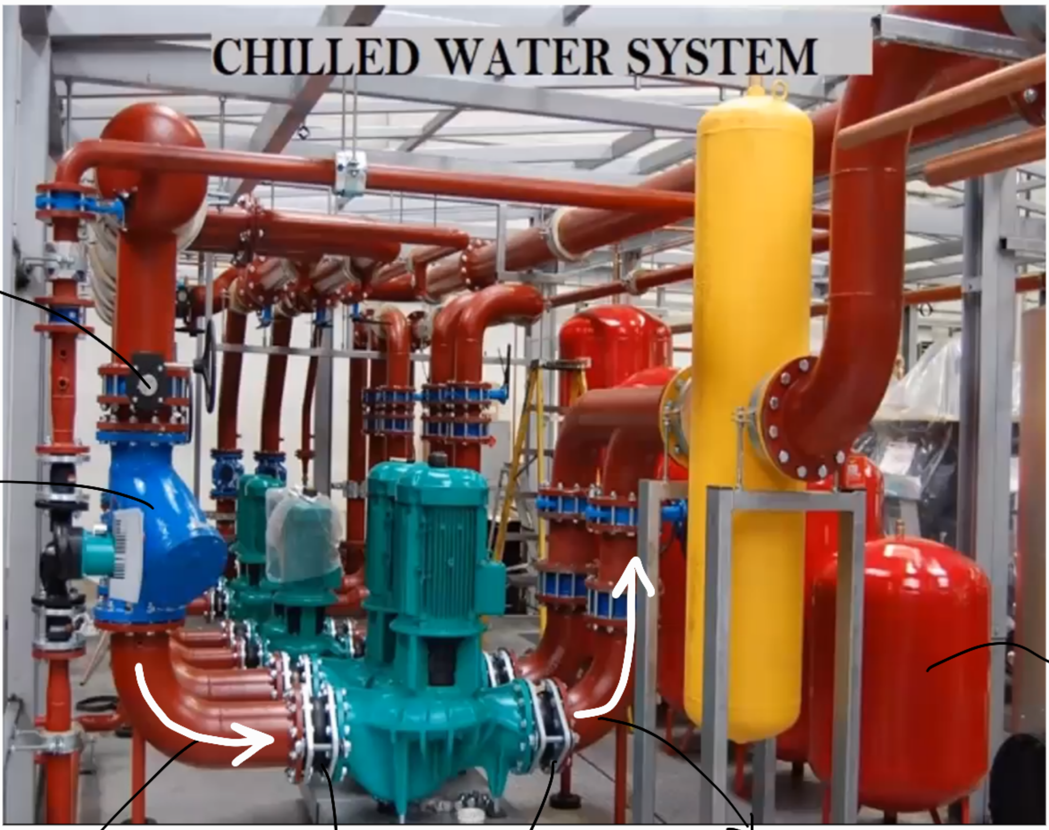
pump
(minor, hc, losses
friction losses)

Evaporator

Condenser

Compressor

pumps



Isolating valve
عشان لما نصلح

strainer
منع الشوائب

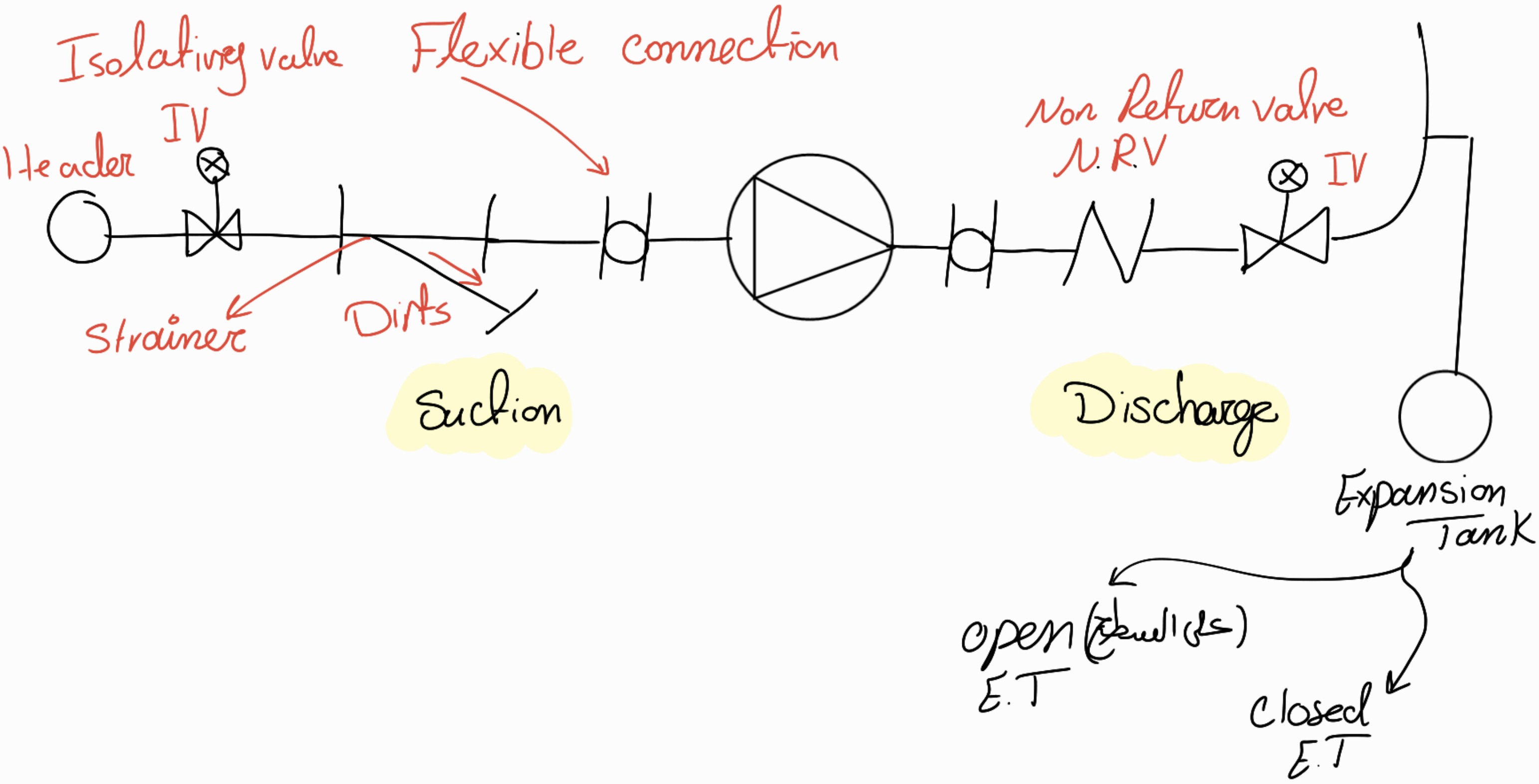
Expansion Tank

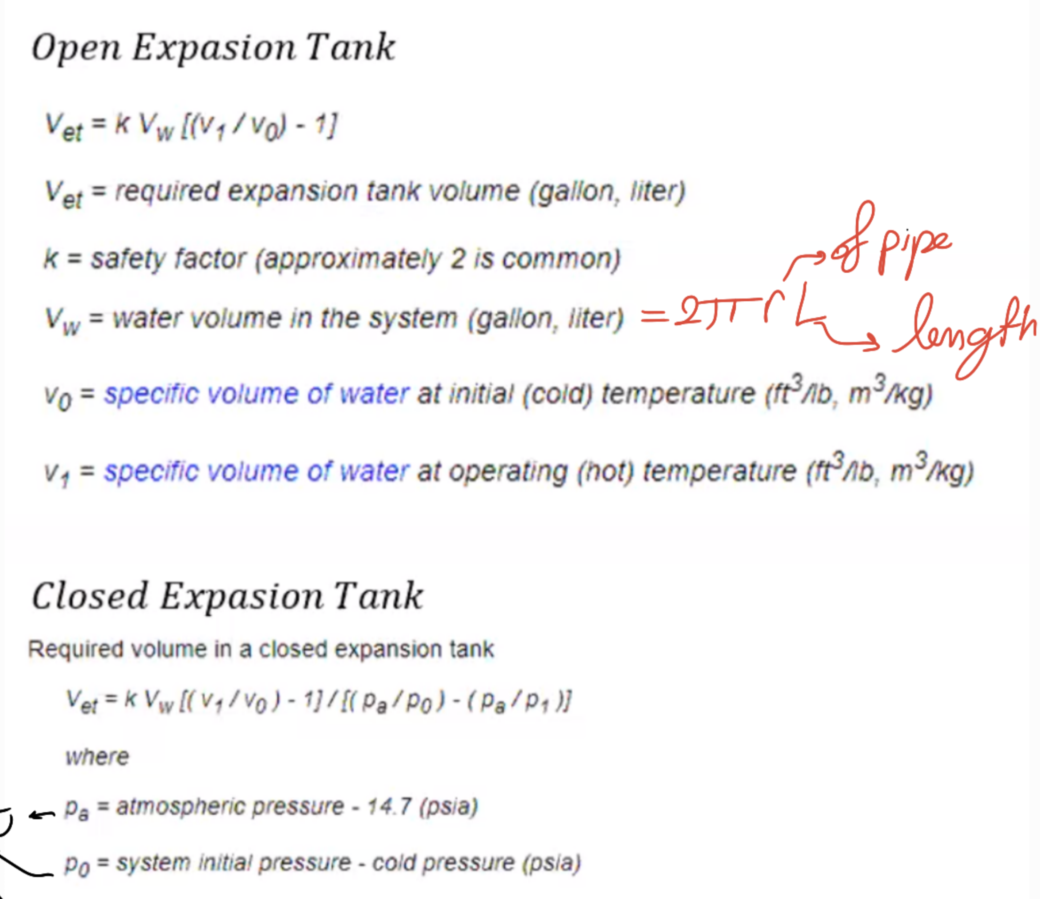
Suction line

flexible connection

Discharge line

Pump Typical connection





Open Expasion Tank

$V_{et} = k V_w [(v_1 / v_0) - 1]$

V_{et} = required expansion tank volume (gallon, liter)

k = safety factor (approximately 2 is common)

V_w = water volume in the system (gallon, liter) $= 2\pi r L$ → of pipe, → length of pipe

saturated ←
v_0 = specific volume of water at initial (cold) temperature (ft^3/lb, m^3/kg)

v_1 = specific volume of water at operating (hot) temperature (ft^3/lb, m^3/kg)

Closed Expasion Tank

Required volume in a closed expansion tank

$V_{et} = k V_w [(v_1 / v_0) - 1] / [(p_a / p_0) - (p_a / p_1)]$

where

Absolute ← p_a = atmospheric pressure - 14.7 (psia)

p_0 = system initial pressure - cold pressure (psia)

p_1 = system operating pressure - hot pressure (psia)

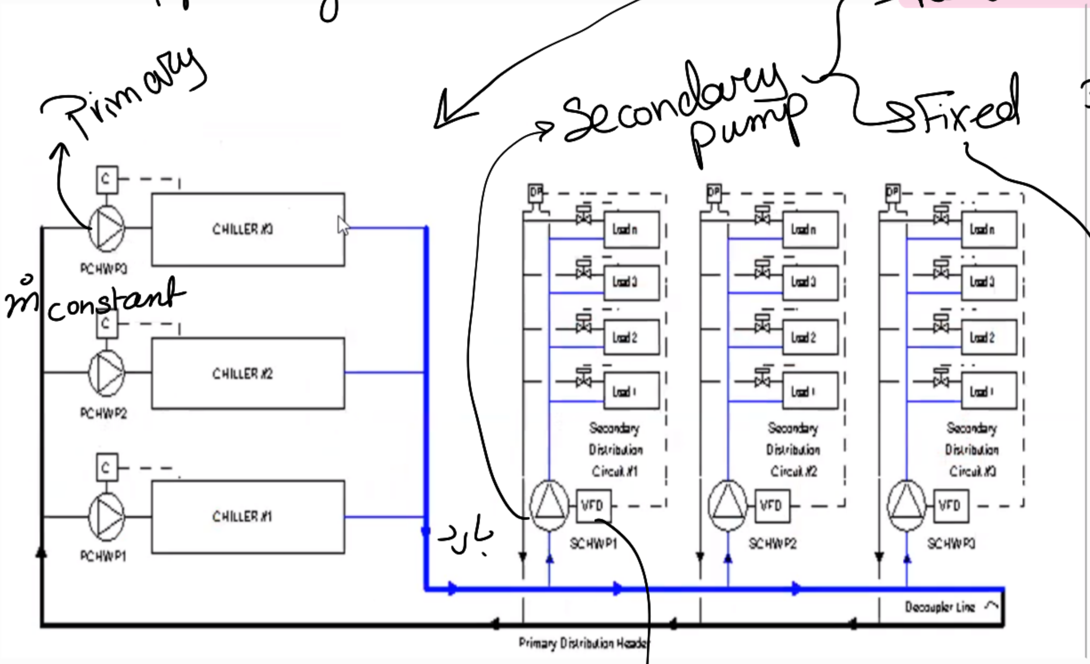
from KPa → Absolute (+ 1 atm)
101 KPa

There are 3 pipe System

variable speed (VFD + Modulating valve)

Secondary pump

Fixed 3way valve



Primary

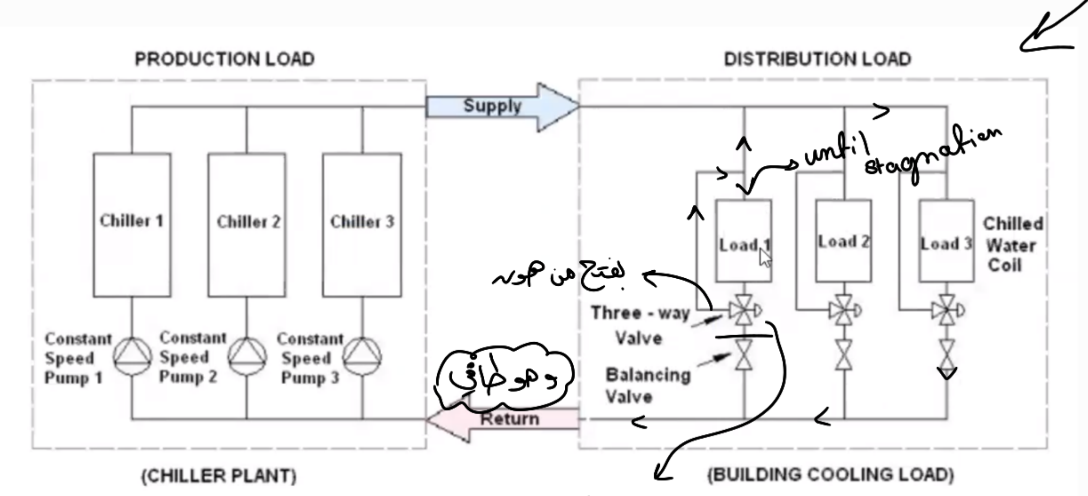
$\dot{m}$ constant

بارد

Same Q load

تقلل ال flow بناء على ال RPM والكهربا.

Variable freq. Drive



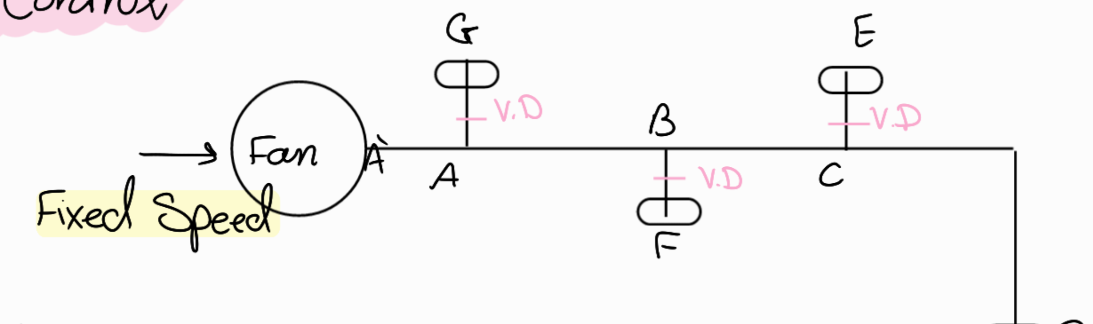
until stagnation

يفتح من جهه

وهو طافي

يسكر الطريق من جهه

Air Control



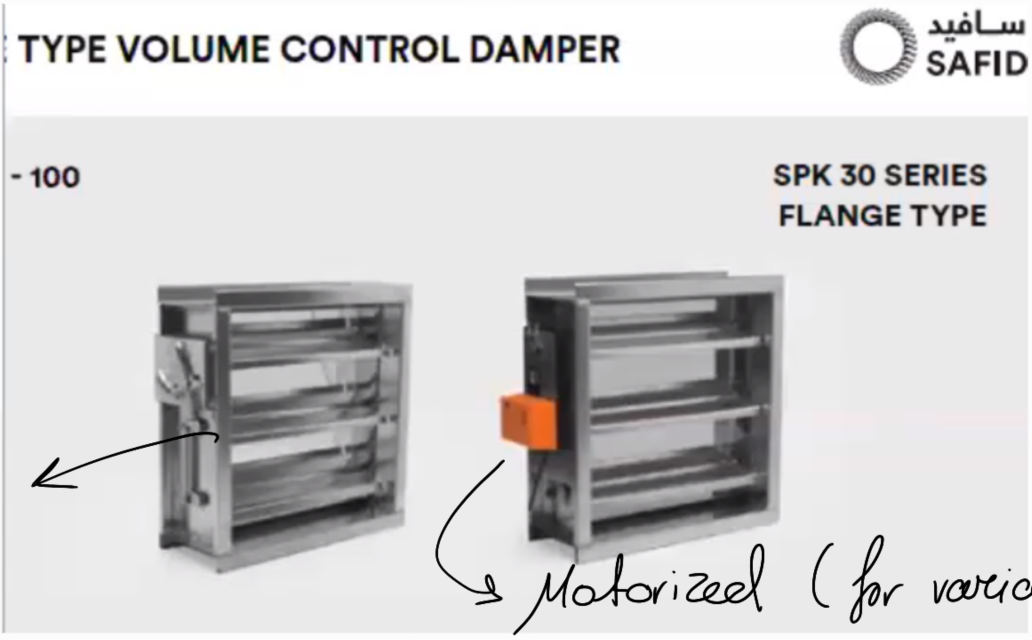
ESP = Path A – B – C – D

Equal friction method: $f_{A'D} = f_{A'E} = f_{A'F} = f_{A'G}$

→ To assure that:-

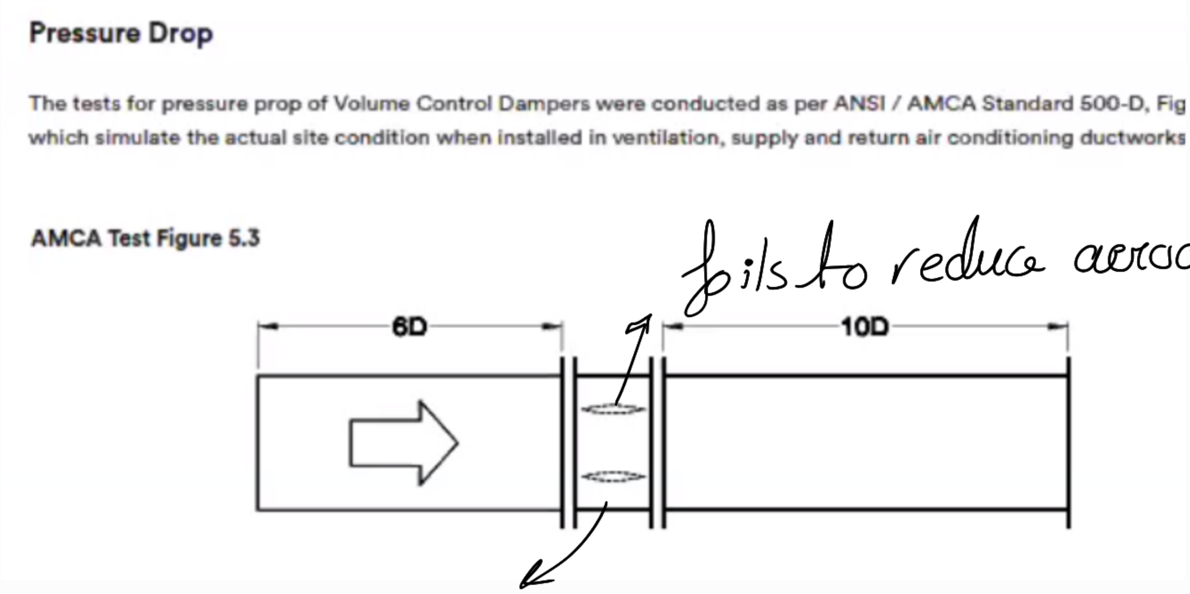
1. Sizing modification (Bad since it exceeds velocity limits)
2. Use a volume control damper or variable air volume devic
   open and closes until ΔP is reached
   For Example: if $\Delta P_{A'-D} = 50Pa$ then we need $\Delta P_{A'-E} = 50$

- If $\Delta P_{A'-E} < 50$, I close V.D and so we add a
$\Delta P_{V.D} \Longrightarrow \Delta P_{V.D} + \Delta P_{A'-E} = 50Pa$



Manual Drived

Motorized (for variable fan)



Pressure Drop

The tests for pressure prop of Volume Control Dampers were conducted as per ANSI / AMCA Standard 500-D, Fig
which simulate the actual site condition when installed in ventilation, supply and return air conditioning ductworks

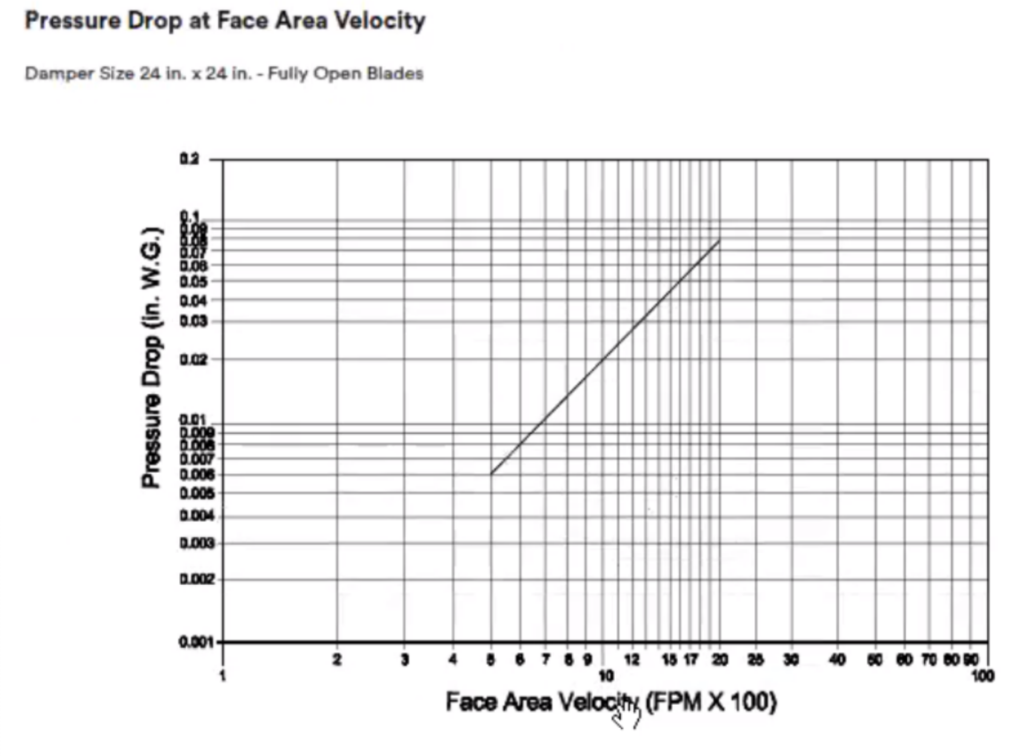
AMCA Test Figure 5.3

foils to reduce aerodynamic friction

Air damper

- For Selection

→ Pressure drop is specified



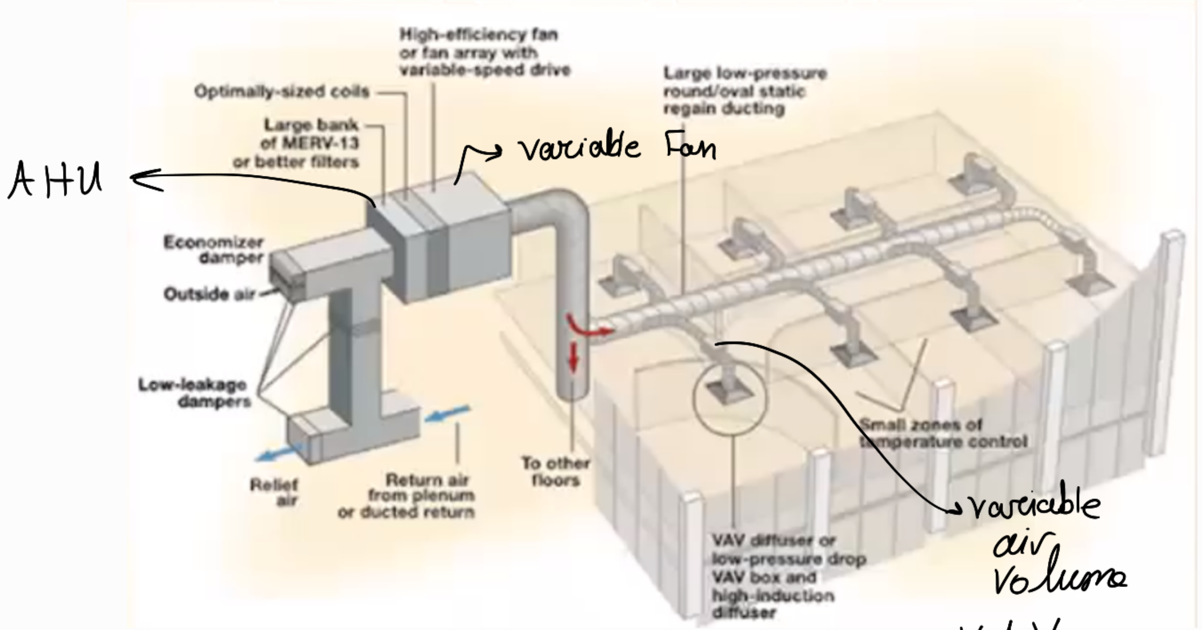
Pressure Drop at Face Area Velocity

Damper Size 24 in. x 24 in. - Fully Open Blades

variable air volume device

Pitot tube to measure fluid velocity
↳ Q is calculated

- Also Temp is measured and blade is closed and opened to control $\dot{m} c_p \Delta T$ and so cooling capacity

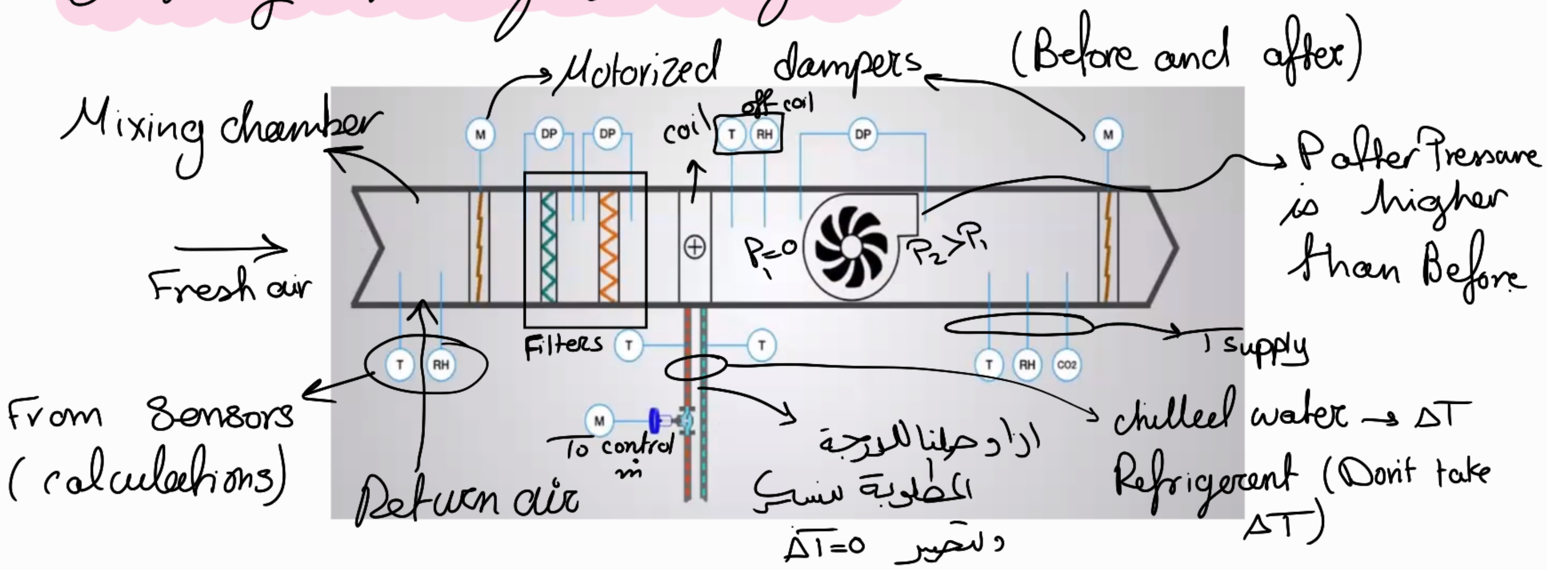


Advantages:

- Energy savings
- less noise → For Quite applications

V.A.V
Related to
variable Fan Speed
Gives feedBack to Fan

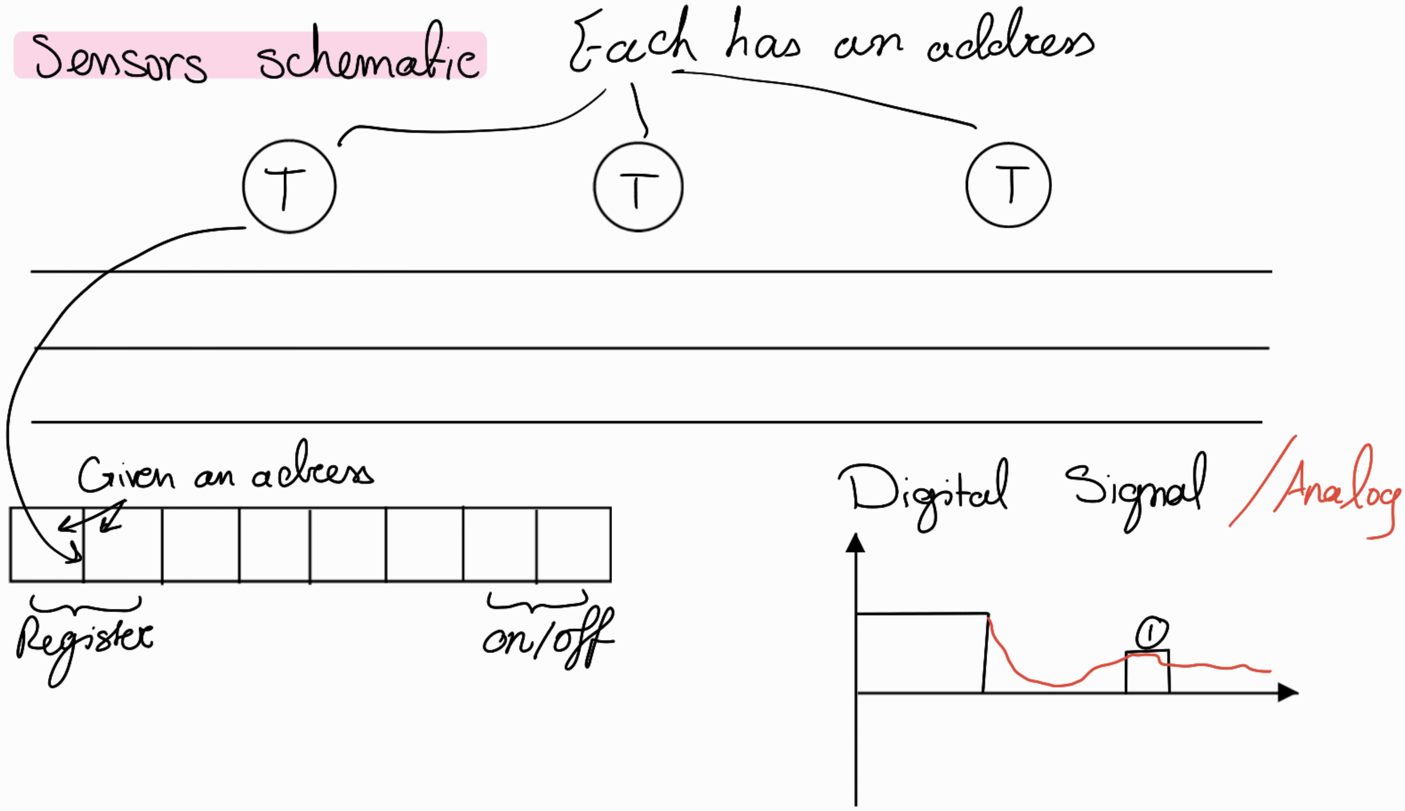
Building managment System



- T, RH : Analog signal
- M : Digital signal (on,off) or Analog (Modulated)
- DP : Differential pressure switch For Filters to Know when to replace filter (Digital)

- For coil: sensible load ΔT } $\dot{m}\Delta h$ to take both
  latent load Δw }

Sensors schematic



lec 30

Pumps

$$\Delta P_2 = \Delta P_1 \left(\frac{Q_2}{Q_1}\right)^2$$

عند تغير ال flow rate تتغير ΔP

والعلاقة طردية

$$Re = 66.4\, D_H V$$

Recovery methods efficiency :

Energy wheel : 85% of sensible heat

Plate heat exchanger : 76% of sensible

optimum of energy wheel 75%

optimum of plate heat exchanger 65%

Exam ideas

1. hydronic system analysis → Water

2. pipe sizing + pump selection + Volume damper → Ducts air

3. Midterm
   - → vapor-compression cycle
   - → AHU → heat recovery
   - → loads

Ex: given: $Cop = 3$ $Q_{tot} = 5kW$ $\Delta h = 50\ kJ/kg$

q_{tot} is the load from all the rooms, which in turn is equal to the heat transfer of the evaporator

hence,

$$Q_L = \dot{m}_w \, cp_w \, \Delta T_w \rightarrow \text{Design standard } (5.6°C)$$

$$4 = \dot{m}_w * 4.18 \times 5.6$$

$$Cop = \frac{Q_L}{Q_H - Q_L} \rightarrow 3 = \frac{Q_2}{Q_A - Q_2}$$

Volume flow rate of air?

make up water?

$\dot{m}_a = \dot{m}_1 = \dot{m}_2$

$\dot{m}_4 = \dot{m}_a (\omega_2 - \omega_1)$

for $\dot{m}_a$:

$\dot{m}_w C_{p_w} \Delta T = \dot{m}_a \Delta h_{air}$ → Psychromatric chart

$40 (4.2)(40-30) = \dot{m}_a (107 - 45)$

$\boxed{\dot{m}_a = 27.1 \text{ kg/s}}$ Volume flow rate of air

$\dot{m}_4 = \dot{m}_a (\omega_2 - \omega_1)$

$= 27.1 (0.0296 - 0.0088)$

$\boxed{\dot{m}_4 = 0.56 \text{ kg/s}}$ Make up water