Norhtern Technical University | **الجامعة التقنية الشمالية**

Kirkuk Technical Institute | **المعهد الـتـقـنـي /كـركـوك**

Mechanical Power Department | **قسم تقنيات ميكانيك القدرة**

Refrigeraioning Air-conditioning Branch | **فـرع التــبريد و الـتـكـيـيف**

اساسيات تصميم منظومات التكييف

المستوى الثاني /الفصل الدراسي الاول

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Chapter One الفصل الاول

Heat Transfer انتقال الحرارة

1- **Heat Transfer**: is the since that deal with energy (Heat) transfer between two bodies as a result of temperature difference.

Heat-transfer can be described in three modes:

- Conduction, التوصيل
- Convection, and الحمل
- Radiation الاشعاع

1-1 Conduction التوصيل :

Is the mechanism of heat transfer in solid material , such as through walls and roofs.

Fourier's law (قانون فورييه) gives the following relationship:

$$q = -K\,A\,\frac{\Delta T}{\Delta x}$$

Where:

Q: heat transfer "Watt"

K: thermal conductivity "W/m °C"

A: cross-sectional area normal to heat flow "m2"

T: temperature "°C"

Δx: thickness along heat flow "m"

For steady-state heat conduction through a **plane wall for one layer**, as shown in Fig.??, the rate of heat transfer through the section From Fourier's law of conduction,

$$q = -K\,A\,\frac{T_2 - T_1}{\Delta x} = \frac{T_1 - T_2}{\frac{\Delta x}{KA}}$$

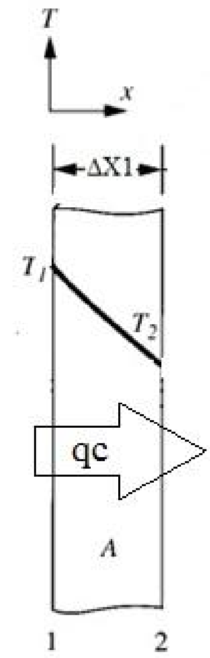


Figure 1-1 heat transfer through single layer wall

$$q = \frac{T_1 - T_2}{\frac{\Delta x}{KA}} \leftrightarrow q = \frac{T_1 - T_2}{R_{th}}$$

Where :

$R_{th} = \frac{\Delta x}{KA}$: Thermal resistance for conduction heat transfer "m. °C/watt"

For steady-state heat conduction through a plane composite wall with perfect thermal contact between each layer, as shown in Fig .?? the rate of heat transfer through each section of the **composite wall must be the same.** From Fourier's law of conduction,

$$q_{concuction} = -K_A \, A \, \frac{\Delta T_A}{\Delta x_1} = -K_B \, A \, \frac{\Delta T_B}{\Delta x_2} = -K_C \, A \, \frac{\Delta T_C}{\Delta x_3}$$

$$R_{th.total} = R_1 + R_2 + R_3 + \dots R_n$$

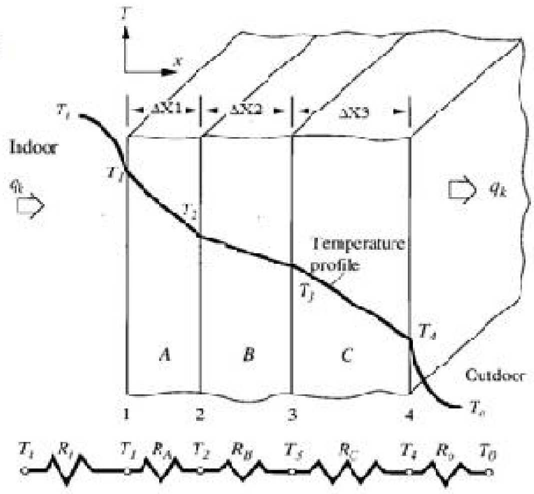


figure 1-2 heat transfer through composite wall

1-2 Convection الحمل:

Is occurs when a fluid comes in contact with a surface at a different temperature, Convective heat transfer can be **divided into two types**: **forced** convection and **natural** or **free** convection.

1-2-a-Natural or free convection الحمل الحر او الطبيعي:

The motion of the fluid is caused by the density difference of the fluid when contacting surface at a different temperature.

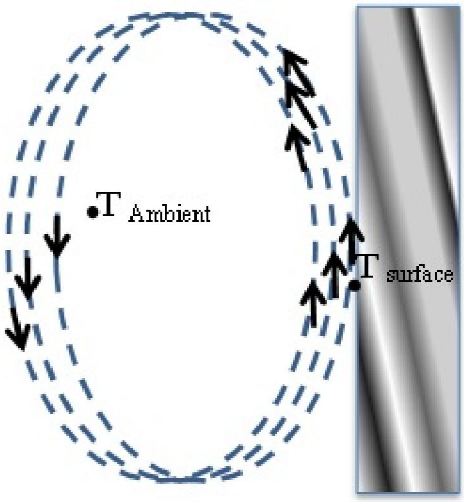


Figure 1-3 heat transfer by natural convection

1-2-b- Forced convection الحمل الحراري القسري:

fluid is forced to move along the surface by an outside motive force, heat is transferred by forced convection.

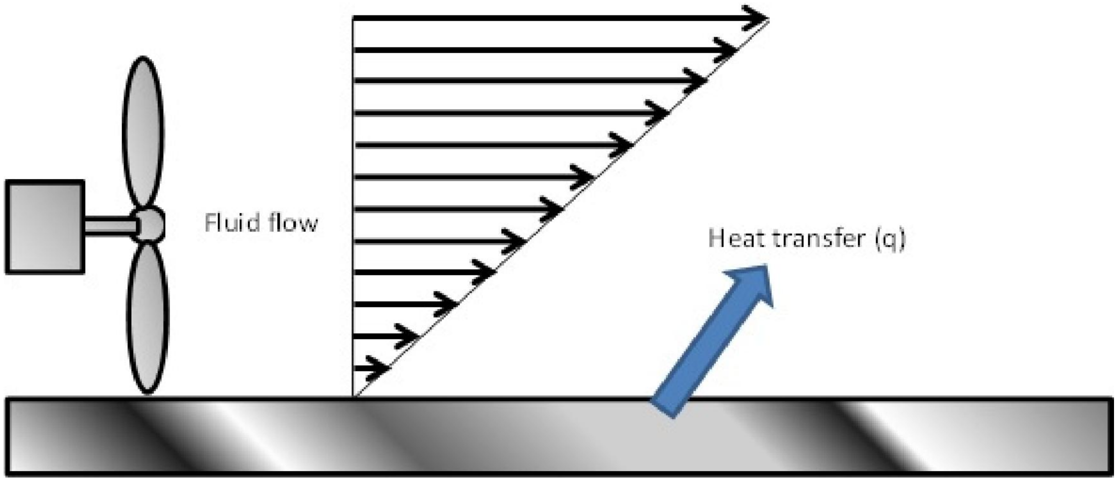


Figure 1-4 heat transfer by forced convection

By expressing Newton law for cooling:

$$q_{convection} = h.A.(T_1 - T_2)$$

Where :

h : convection heat transfer coefficient " W/m^2.°C"

1-3 Overall Heat Transfer Coefficients (U) (معامل انتقال الحرارة الاجمالي (الكلي:

In actual practice, many calculations of heat-transfer rates are combinations of conduction, convection, and radiation.

Consider the composite wall shown in Fig. 3.1; in addition to the conduction through the wall, convection and radiation occur at inside and outside surfaces 1 and 4 of the composite wall. At the inside surface of the composite wall, the rate of heat transfer qi (W):

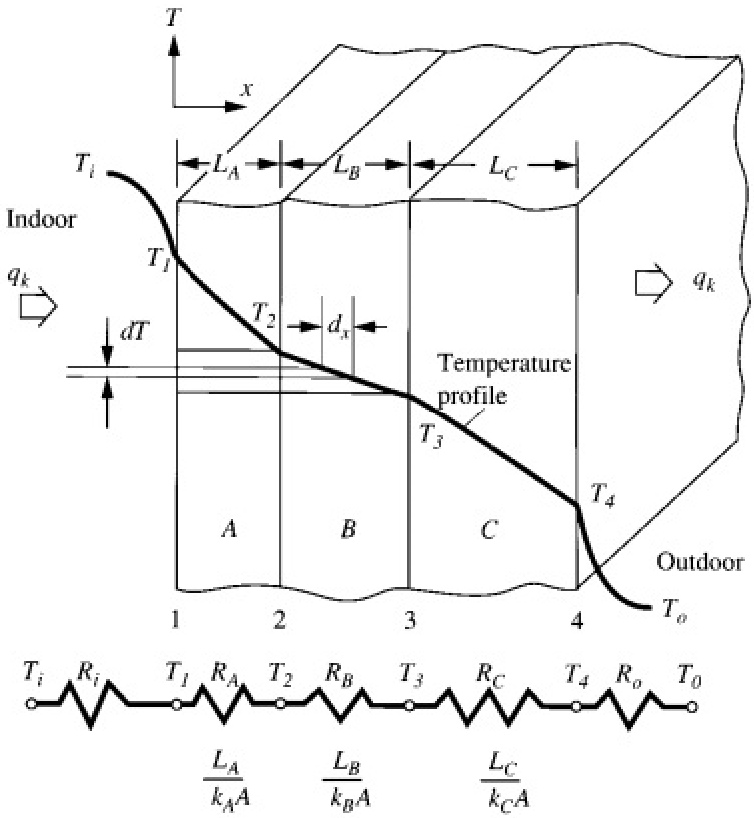


Figure 1-5 heat transfer by convection and conduction method though composite wall

$$q_k = \frac{T_1 - T_2}{\frac{1}{A}*\left[\frac{1}{h_i}+\frac{L_A}{k_A}+\frac{L_B}{k_B}+\frac{L_C}{k_C}+\frac{1}{h_o}\right]} \leftrightarrow q_k = UA(T_1 - T_2)$$

$$U = \frac{1}{\frac{1}{h_i}+\frac{L_A}{k_A}+\frac{L_B}{k_B}+\frac{L_C}{k_C}+\frac{1}{h_o}}$$ Overall heat transfer coefficient " $W/m^2.°C$"

1-3 Radiation الاشعاع:

the heat transfer in radiation by electromagnetic waves.

$$q_r = \sigma A (T^4)$$

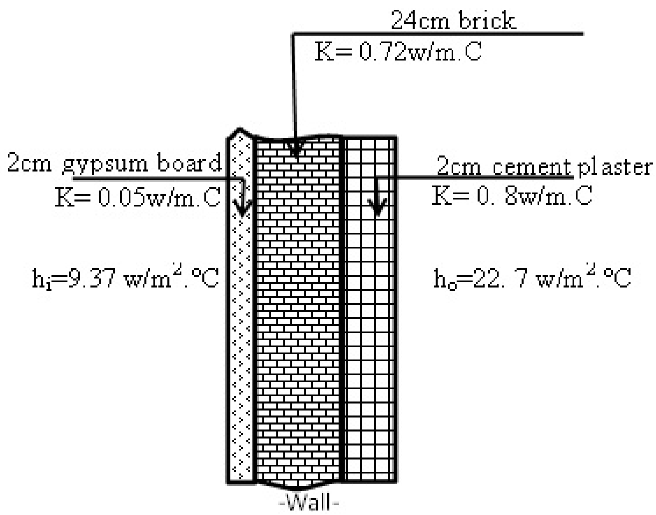
σ : Stefan-Boltzman constant = $5.66*10^{-8}$ $W/m^2.K$

Sheet No.1

Q1/ A certain building wall consist of (0.15m) concrete (K=1.2 w/m.°C) , (0.005m) od fiber glass insulation (K= 0.048 w/m.°C) and (10mm) of gypsum board (K=0.005 w/m.°C) , the inside and outside convection coefficients are (10 and 40) respectively. Calculate the overall heat transfer coefficient for wall

Q2/ in the previous question if one side exposed to air at (30°C) and the other side exposed to air at (18°C) . Calculate quantity of heat transfer for wall dimension (4.2m×2.9m) .

Q3/ Calculate the heat transfer coefficient for the wall shown in figure below:



Solution of Sheet No.

Q1/ A certain building wall consist of (0.15m) concrete (K=1.2 w/m.°C) , (0.005m) od fiber glass insulation (K= 0.048 w/m.°C) and (10mm) of gypsum board (K=0.005 w/m.°C) , the inside and outside convection coefficients are (10 and 40) respectively. Calculate the overall heat transfer coefficient for wall

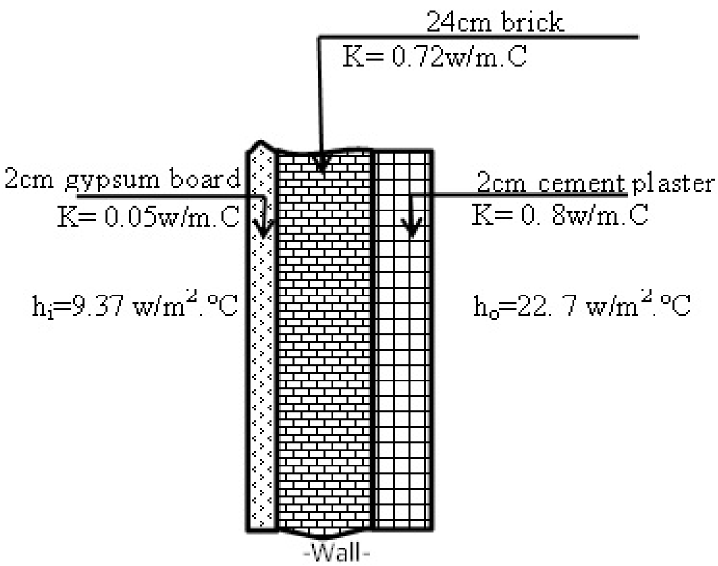
$$U = \frac{1}{\frac{1}{h_i}+\frac{\Delta x_1}{k_1}+\frac{\Delta x_2}{k_2}+\frac{\Delta x_3}{k_3}+\frac{1}{h_o}} = \frac{1}{\frac{1}{10}+\frac{0.005}{0.048}+\frac{0.15}{1.2}+\frac{0.01}{0.005}+\frac{1}{40}} \rightarrow U = 0.0424\ \frac{w}{m^2.°C}$$

Q2/ in the previous question if one side exposed to air at (30°C) and the other side exposed to air at (18°C) . Calculate quantity of heat transfer for wall dimension (4.2m×2.9m) .

$$U = 0.0424\ \frac{w}{m^2.°C}\ , A = 4.2 \times 2.9 = 12.18\ m^2\ ,\ T_i = 18°C\ , T_o = 30°C$$

$$Q = U \times A \times \Delta T = 0.0424\ \times 12.18 \times (30-18) \rightarrow Q = 61.971 \frac{w}{m^2.°C}$$

Q3/ Calculate the heat transfer coefficient for the wall shown in figure below:



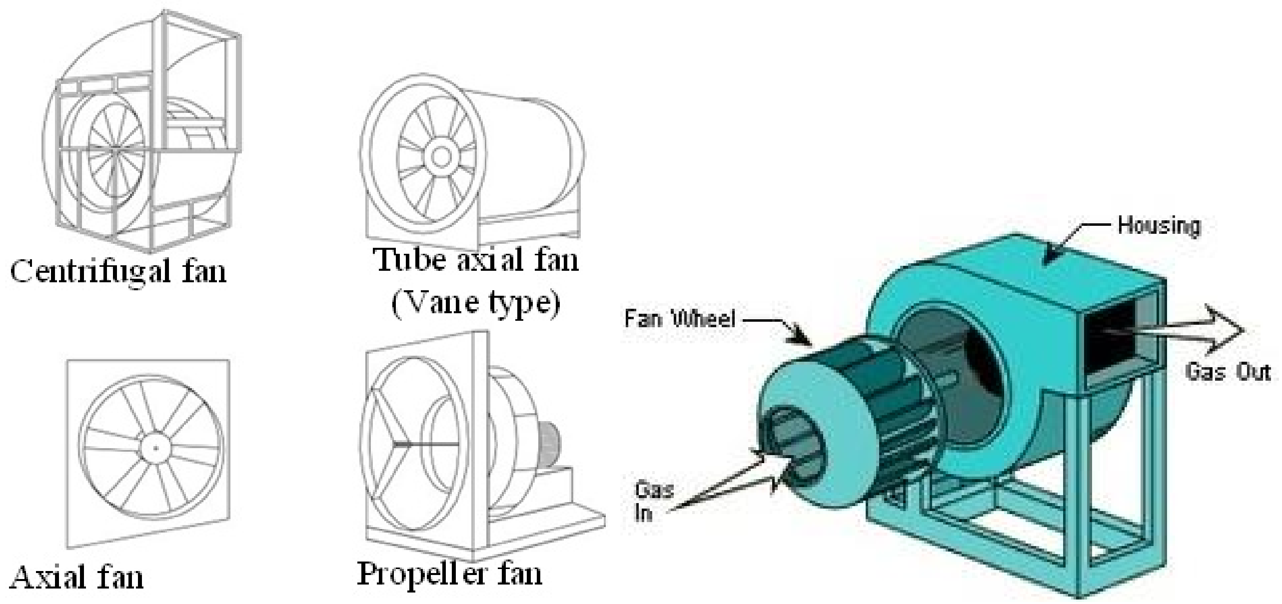
$$U = \frac{1}{\frac{1}{h_i}+\frac{\Delta x_1}{k_1}+\frac{\Delta x_2}{k_2}+\frac{\Delta x_3}{k_3}+\frac{1}{h_o}} = \frac{1}{\frac{1}{9.37}+\frac{0.02}{0.05}+\frac{0.24}{0.72}+\frac{0.02}{0.8}+\frac{1}{22.7}} \rightarrow U = 1.099\ \frac{w}{m^2.°C}$$

الفصل الثاني / المراوح
Chapter Two /Fans

Fans: the equipment that propel air or other gas for air-conditioning applications.

There are four types of fans:

.1) Centrifugal fan 2) Axial flow fan 3) Tube axial fan 4) Propel fan



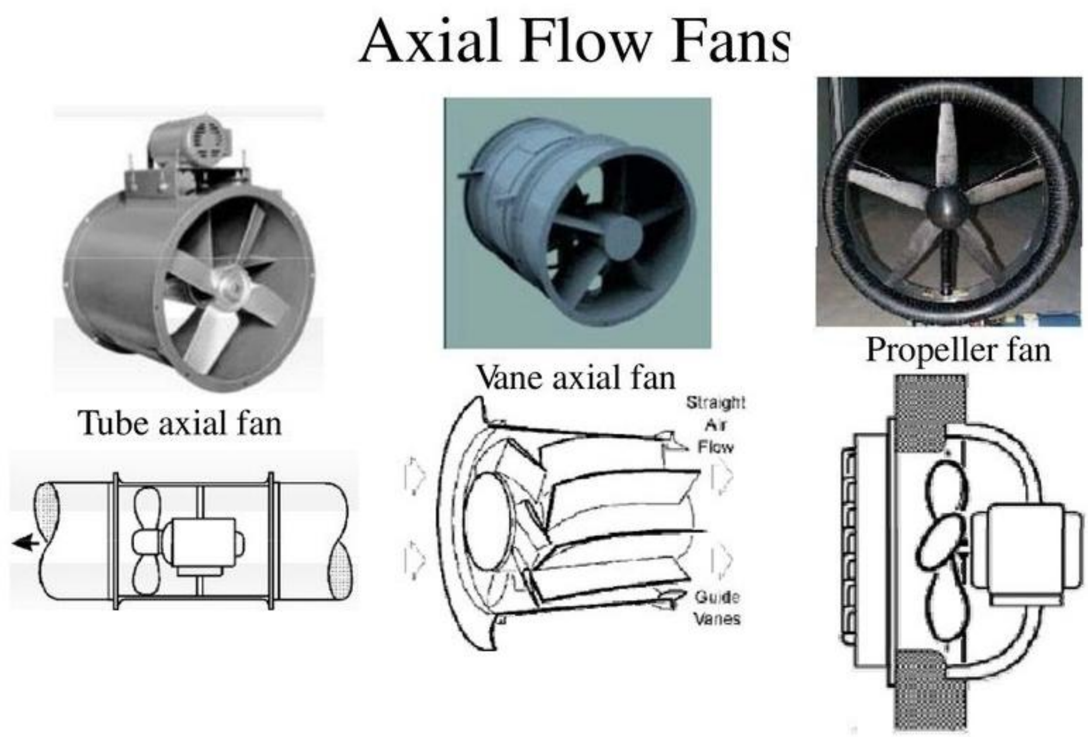


Figure 7-1 types of fans

Air power: - the amount of total pressure the fan can give to the air.

$$\mathbf{W_a = V_{\dot{s}} \times P_t} \text{..(6-1)}$$

Where: - W_a= Air power "watt"

$V_{\dot{s}}$= volumetric air flow rate "m^3/sec" and P_t= total pressure "N/m2 or Pa"

Fan efficiency(η) : It is the ratio of air power to the fan power .

$$\boldsymbol{\eta} = \frac{\textbf{Air power}}{\textbf{Fan power}} = \frac{\mathbf{W_a}}{\mathbf{W_f}} \text{ ....(6-2)}$$

Where: - W_f= Fan power "watt"

Fan static efficiency (η_s): It is the ratio of static air power to the fan power.

$$\boldsymbol{\eta_s} = \frac{\mathbf{W_{a.s}}}{\mathbf{W_f}} = \frac{\mathbf{V_{\dot{s}} \times P_s}}{\mathbf{W_f}} \text{ ....(6-3)}$$

Where: - $W_{a.s}$= Static air power "watt"

P_s= Static Pressure N/m^2 "Pa"

$$P_v = \frac{1}{2} \times \rho \times V^2 \quad and \quad P_t = P_s + P_v \text{ ....(6-4)}$$

Where: - P_v = velocity pressure or dynamic pressure

****

Example :- Fan with 0.65 efficiency draw air from a room and propel it induct , air flow rate in the duct ($1 m^3/sec$), static pressure drop in the duct ($140.25\ N/m^2$) , air velocity in duct (13m/sec);find $\boxed{1}$ air power and $\boxed{2}$ fan power[take :$\rho_{air}=1.2\ kg/m^3$]

Solution:

$$P_v = \frac{1}{2} \times \rho \times V^2 = \frac{1}{2} \times 1.2 \times (13)^2 = 101.4\ Pa$$

$$P_t = P_s + P_v = 140.25 + 101.4 = 241.65\ Pa$$

$$W_a = \dot{V_s} \times P_t = 1 \times 241.65 = 241.65\ watt$$

$$\eta = \frac{W_a}{W_f} \rightarrow \quad W_f = \frac{W_a}{\eta} = \frac{241.65}{0.65} = 371.8\ watt$$

<u>Fan laws:-</u>

A / For given Fan size, ducting system air density:-

في حالة ثبوت درجة الحرارة للهواء (**اي ثبوت كثافة الهواء**) و تغير السرعة :-

$$\frac{\dot{V}_{s1}}{\dot{V}_{s2}} = \frac{N_1}{N_2} \quad \ldots\ldots(6\text{-}5)$$

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^2 \quad \ldots\ldots(6\text{-}6)$$

$$\frac{W_{f1}}{W_{f2}} = \left(\frac{N_1}{N_2}\right)^3 \quad \ldots\ldots(6\text{-}7)$$

B/ for a given fan size, Ducting system and speed, if density change:-

في حالة ثبوت السرعة و تغير درجة الحرارة للهواء (***اي تغير في كثافة الهواء***):-

$$\dot{V}_{s1} = \dot{V}_{s2} \quad \ldots\ldots(6\text{-}8)$$

$$\frac{P_1}{P_2} = \frac{\rho_1}{\rho_2} \quad \ldots\ldots(6\text{-}9)$$

$$\frac{W_{f1}}{W_{f2}} = \frac{\rho_1}{\rho_2} \quad \ldots\ldots(6\text{-}10)$$

Example :- fan propel 8.2 m3/sec with static pressure 250 Pa when its speed 256 r.p.m of the power absorbed equal (3.4 kw) , if fan speed changed to 300 r.p.m , find air flow rate ,static pressure and power absorbed.

Solution:

$$\frac{\dot{V}_{s1}}{\dot{V}_{s2}} = \frac{N_1}{N_2} \rightarrow \frac{8.2}{\dot{V}_{s2}} = \frac{256}{300} \rightarrow \dot{V}_{s2} = 9.6 m^3/sec$$

$$\frac{P_{s1}}{P_{s2}} = \left(\frac{N_1}{N_2}\right)^2 \rightarrow \frac{250}{P_{s2}} = \left(\frac{256}{300}\right)^2 \rightarrow P_{s2} = 343.3\ Pa$$

$$\frac{W_{f1}}{W_{f2}} = \left(\frac{N_1}{N_2}\right)^3 \rightarrow \frac{3.4}{W_{f2}} = \left(\frac{256}{300}\right)^3 \rightarrow W_{f2} = 5.5\ \mathrm{Kw}$$

Example :- Fan rotates with 1500 r.p.m , supply air with (140 m^3/min) at 15°C and 75mm water total pressure when its efficiency 86% , find air flow rate , total pressure and power consumed for the following cases:-

A/ When air temperature become (increase to) 50°C.

B/Air temperature remain at 50 °C but the fan speed increase to 1700 r.p.m

Note// take air density change by $\frac{\rho_1}{\rho_2} = 1.12$

Solution:

A/ T=increase from 15 to 50 °C

$$\frac{P_{t1}}{P_{t2}} = \frac{\rho_1}{\rho_2} \rightarrow \frac{75}{P_{t2}} = 1.12 \rightarrow P_{t2} = 67mm\ H_2O$$

$$W_{a2} = \dot{V_{s2}} \times P_{t2}$$

$$P_{t2} = \rho \times g \times h_2 = 1000 \times 9.81 \times \frac{67}{1000} = 657.27Pa$$

$$W_{a2} = 657.27 \times \frac{140}{60} = 1533.63\ watt$$

$$\eta = \frac{W_{a2}}{W_{f2}} \rightarrow \quad W_{f2} = \frac{W_{a2}}{\eta} = \frac{1533.63}{0.86} = 1783.23\ watt$$

B/ fan speed increase from 1500 to 1700 r.p.m

$$\frac{\dot{V_{s2}}}{\dot{V_{s3}}} = \frac{N_2}{N_3} \rightarrow \frac{140}{\dot{V_{S3}}} = \frac{1500}{1700} \rightarrow \dot{V_{S3}} = 158.7\frac{m^3}{min}$$

$$\frac{P_{t2}}{P_{t3}} = \left(\frac{N_2}{N_3}\right)^2 \rightarrow \frac{67}{P_{t3}} = \left(\frac{1500}{1700}\right)^2 \rightarrow P_{t3} = 86mmH_2O$$

$$\frac{W_{f2}}{W_{f3}} = \left(\frac{N_2}{N_3}\right)^3 \rightarrow \frac{1783.23}{W_{f3}} = \left(\frac{1500}{1700}\right)^3 \rightarrow W_{f3} = 2595.85watt$$

Sheet No 2

Q1/ An air conditioning supply fan is operating at (600 r.p.m)against (500 pa) static pressure and requiring(4.85 Kw).It is delivering (540 m^3/min) at standard conditions. In order to handle air conditioning load ,more air is desired .in order to increase flow to (610 m^3/min) what are the new speed ,static pressure and power?

Q2/ A fan delivers (230 m^3/min) of air having density of (1.2 kg/m^3) against a static pressure of (500Pa) when the speed is (600 r.p.m) and the power input (3.7 kw) .if the inlet air temperature is changed such that anew density is (9.63) at the same fan speed what is the new flow rate, static pressure and power?

Q3/ A centrifugal fan (910mm) diameter operate at (8.0r.p.s) when handling air at a temperature of (20°C) with a corresponding total pressure development of (600 N/m^2) and shaft power is (3Kw) .if the fan is used for heating purpose and fan handles air at a temperature (50°C) , calculate the total pressure developed and fan power under these new condition?

Q4/the following data is available from a test report of a centrifugal fan volume flow rate (3m^3/sec) , fan power(2.6 kw) , fan static pressure (524 Pa) , fan discharge area (0.3m^2) calculate air power and efficiency ? Take (ρ_{air} =1.2kg/m^3) .

Q5/ A fan delivers (280m3/min) of air against a static pressure of (500Pa) , when the speed is (500r.p.m) and power input is (4.5kw) . What speed, static pressure will be obtained for delivery of (400m^3/min)

الفصل الثالث/ تصميم مجاري الهواء

Chapter three/ Air duct design

3-1 Introduction

The energy conents of moving astream is macroscopically speaking in the kinetic (velocity) and potential (static) forms corresponding to the velocity and ststic pressure

The fan delivers the energy to air in the form of static pressure and dynamic pressure (velocity pressure) and the total will be the summaition of of the tow.

3-2 Main Concepts:

Berneuli equation:-

$\frac{P}{\rho} + \frac{v^2}{2} + gZ = constat$, Where :-

P: pressure "Pa" , v: velocity "m/sec" , Z: height "m"

By multiplying the equation above by (ρ) :-

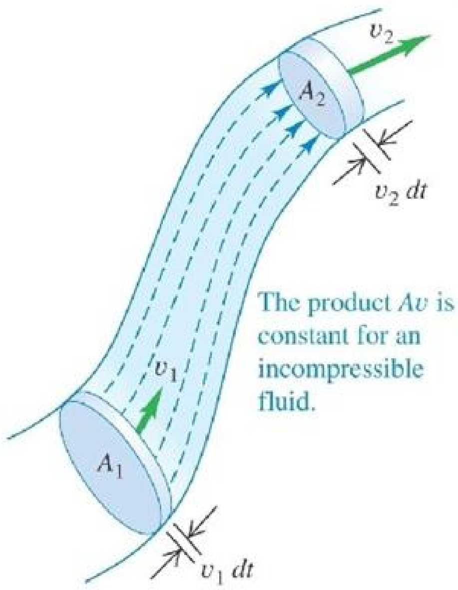
$P + \frac{\rho v^2}{2} + \rho g Z = constat$,

Where : P: static pressure , $P_v = \frac{\rho v^2}{2}$ (velocity pressure)

Continuty equation:-

$\dot{m_1} = \dot{m_2} \Longrightarrow \rho_1 \times A_1 \times v_1 = \rho_2 \times A_2 \times v_2$,

$\dot{m}$: mass flow rate "kg/sec"



When : $\rho_1 = \rho_2$

$A_1 \times v_1 = A_2 \times v_2 \implies \dot{Q_1} = \dot{Q_2}$,

$\dot{Q}$: volumetric flow rate "m^3/sec"

3-3 Head and Pressure

The tearm head and pressure are often interchangeable however , head is the hight of fluid colume supporated by fluid flow , while pressure is the normal force per unit area .

Head $\implies$ pressure and pressure $\implies$ Head

3-4 Fluid Resistance (pressure drop in duct)

Duct system losses are the irreversible transformation mechanical energy into heat .

Ther are two type of losses :- a) Friction losses b) dynamic losses

3-4-1 Friction losses :-

Due to fluid viscosity and aresult of momentum exchange between molecules.

Friction losses occure along the entire duct length and cause losses in static pressure.

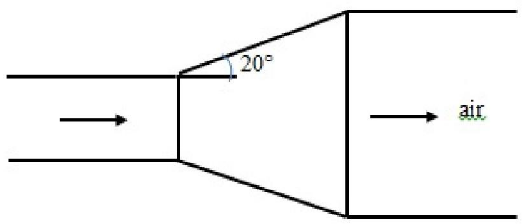
3-4-2 Dynamic losses :-

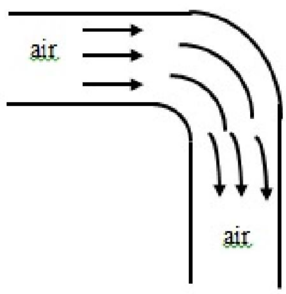
Dynamic losses result from flow distribution cased by duct mounted equipment and fitting that change the air flow path's direction and /or area (change in cross section area of duct) , (losses in velocity pressure these fitting include :- enteries , exits , elbow … etc)

3-5 General Rules in air duct design

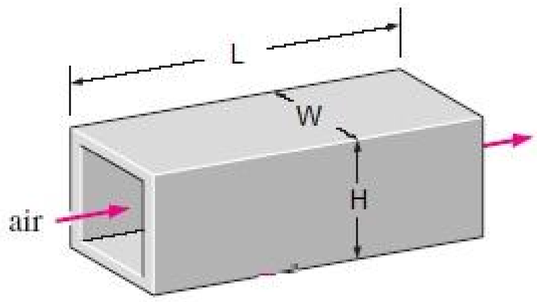
Many rules should be followed in duct design :-

1- Air should be convayed as adirectly as possible to economise power , material ,space …
2- Sudden change in direction should be avoided when there are bends , turning vanes should be used to minimize the pressure loss.
3- Diveriging section should not exceeded 20°





4- Rectangular duct should be made as nearly square as possible this will ensure minimum duct surface and cost for the same air carrying capacity
W/H : is called Aspect ratio and it must be ≤ 4

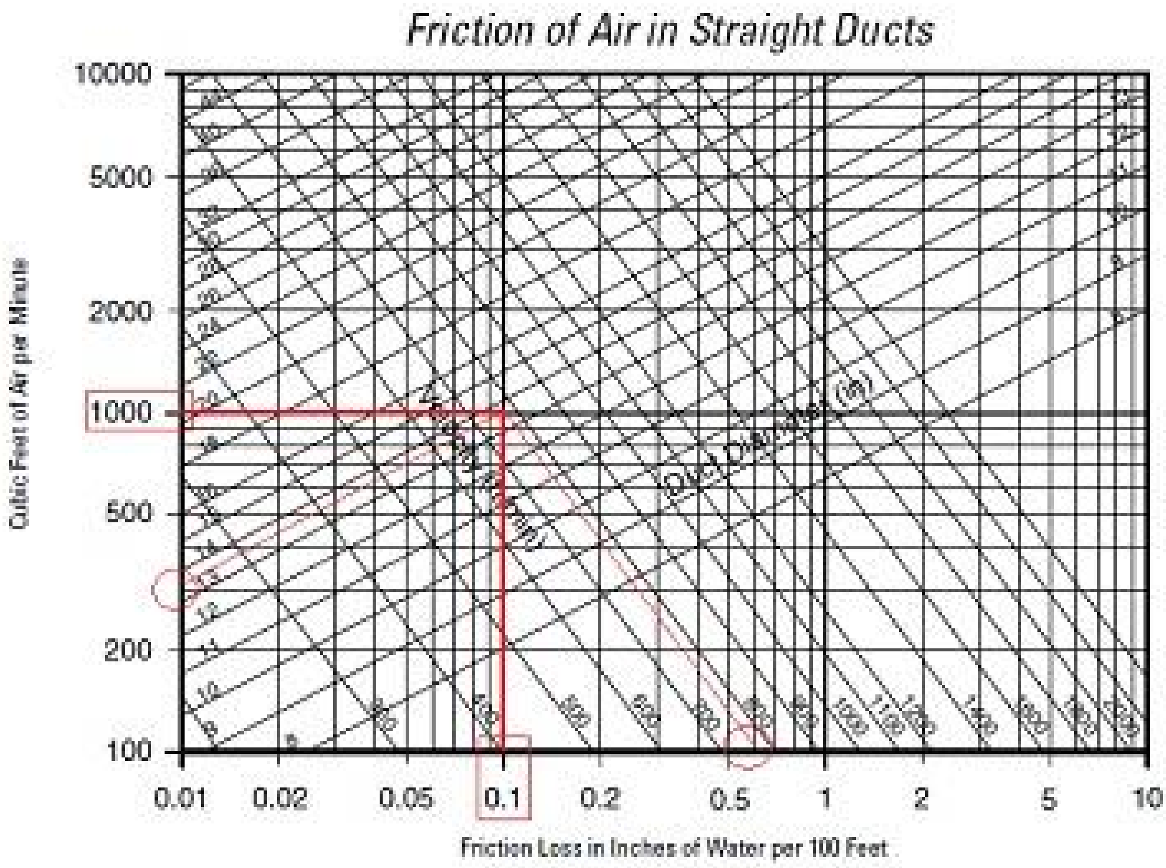


5- Dampers should be provided in each branch outlet for balancing system.

3-6 Methods of duct design

1- Velocity reduction method
2- Equal pressure drop method (equal friction loss method)
3- Static regain method

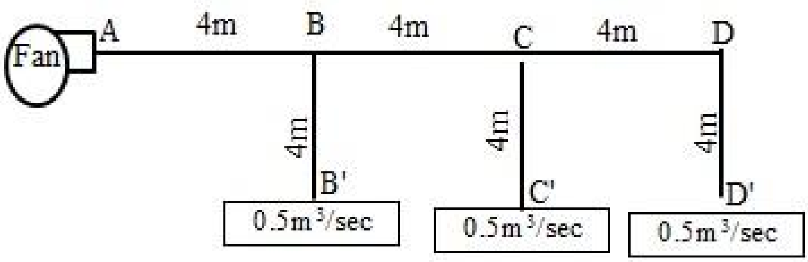
Notes:- the main chart used to select the air duct capacity (dimensions) is friction-air quantity chart shown below:-



Fricton loss – air quantity chart for ducts

<<<<< Examples >>>>>

Ex 3-6-1: For the duct system as shown in figure below with dimentions and flow rates , use velocity reduction method to find the diameters and pressure drops if the air velocity after fan is (7.5m/sec).



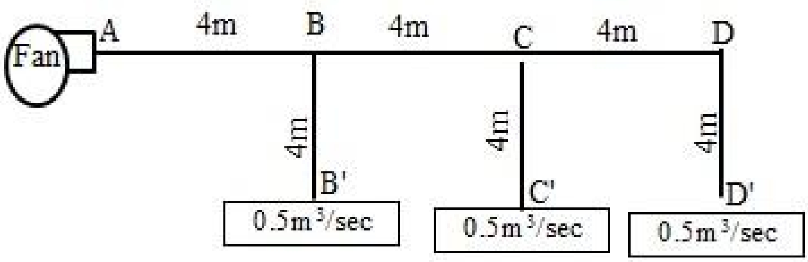
Solution:-

From given data with the figure information :-

- Dividing the diagram to sections (A→B , B→C , C→D' , B→B' and B→C')
- Insert to the table the value of volumetric flow rates
- Depending on the method selected (velocity reduction) by cross (Q&V)on the (friction lose – quantity chart) to calculate ΔP& D
- On the other sections we will choosing velocity for every branch (depending on the main branch velocity and reduction method)

Section	Q(L/sec)	Q(m^3/sec)	V(m/sec)	ΔP(Pa/m)	D (m)
A→B		1.5	7.5		
B→C		1			
C→D'		0.5			
B→B'		0.5			
B→C'		0.5			

Ex3-6-2: Solve the same wxample above by using equal pressure drop method at constant with constant pressure drop (1Pa/m).



Solution:-

From given data with the figure information :-

- Dividing the diagram to sections (A→B , B→C , C→D' , B→B' and B→C')
- Insert to the table the value of volumetric flow rates
- Depending on the method selected (equal pressre method) by cross (Q&V)on the (friction lose – quantity chart) to calculate ΔP& D and consider this ΔP value for all branch
- On the other sections we will cross the value of (ΔP &Q) to calculate (V&D)

section	Q(L/sec)	Q(m^3/sec)	ΔP(Pa/m)	V(m/sec)	D (m)
A→B	1500	1.5	1	6.8	520
B→C	1000	1	1	6.4	450
C→D'	500	0.5	1	5.4	345
B→B'	500	0.5	1	5.4	345
B→C'	500	0.5	1	5.4	345

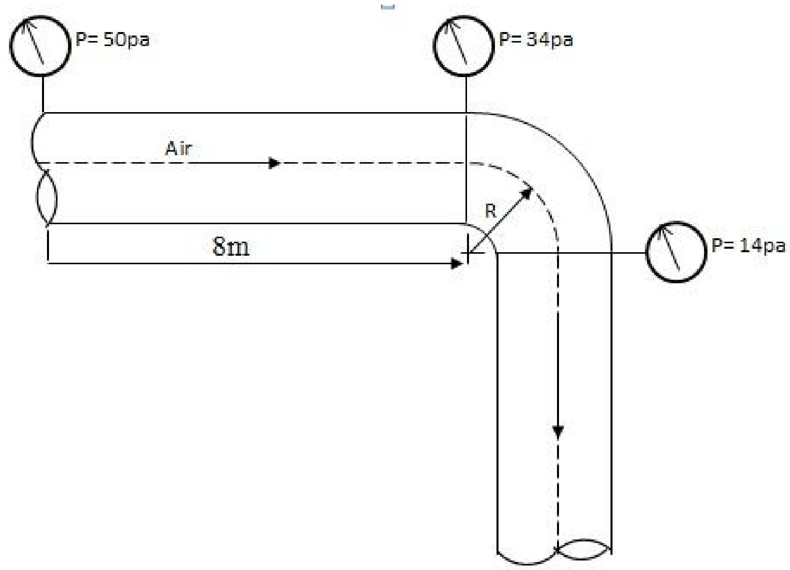
3-7 Index run :-

The index run of any duct is the run having the biggest over all energy loss is termed indexrun.

It is not always possible to leap the conclusion that the run of ducting greatest length is that with the largest loss of energy and is hense the index run.

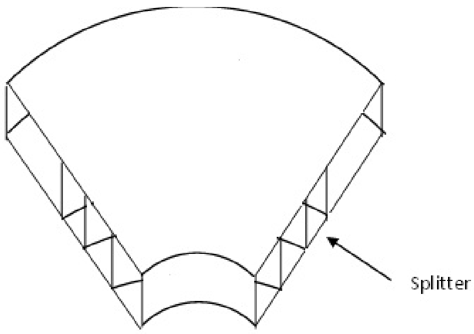
3-8 Air flow around bends(pressure drop in bends):-

Equivelent length of elbow:-



There are two method of minimizing the energy loss around the bends :-

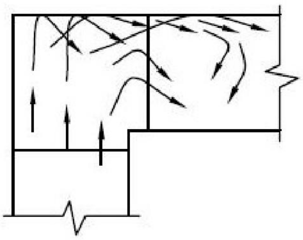
1) **Using siplitters**



2) **using turning vanes**

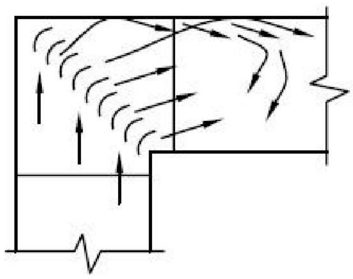
INEFFICIENT

BRANCH LOSS COEFFICIENT - APPX. 1.20
(HEIGHT/WIDTH = 1.0)



LACK OF TURNING VANES CAUSES
EXCESSIVE TURBULENCE IN FITTING:
RESULTS IN VERY HIGH PRESSURE DROP

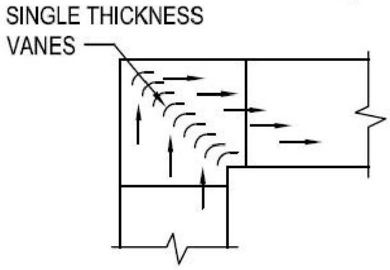
WRONG



INCORRECT VANE ALIGNMENT
CAUSES TURBULENCE; RESULTS IN
HIGHER PRESSURE DROP

EFFICIENT

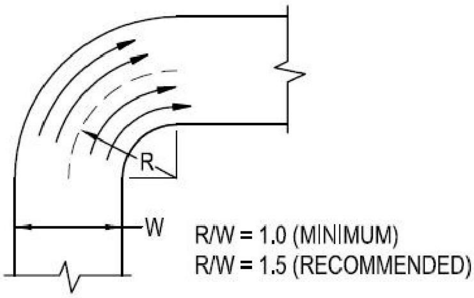
BRANCH LOSS COEFFICIENT - APPX. 0.15
(HEIGHT/WIDTH = 1.0)



TURNING VANES ENSURE
UNIFORMITY OF AIRFLOW, GREATLY
REDUCING TURBULENCE; RESULTS
IN VERY LOW PRESSURE DROP

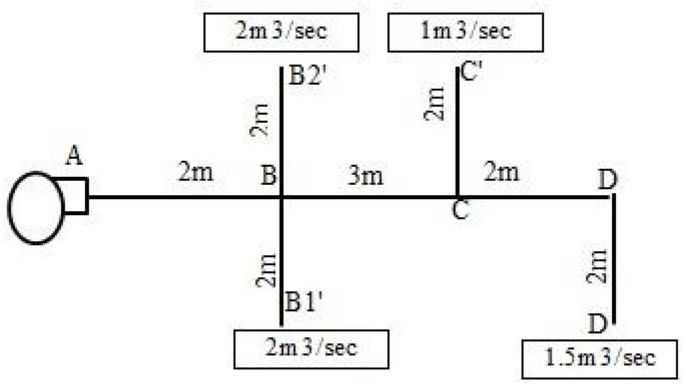
EFFICIENT

BRANCH LOSS COEFFICIENT - APPX. 0.21
(R/W=1.0, HEIGHT/WIDTH = 1.0)



SMOOTH RADIUS ENSURES UNIFORMITY OF
AIRFLOW, GREATLY REDUCING TURBULENCE;
RESULTS IN VERY LOW PRESSURE DROP

Ex3-7-1 :- Design the air duct system as shown in figure below , with dimensions and flow rates by using equal pressure drop method at constant pressure drop (0.5Pa/m) and then find total equivalent length for main duct(index run).



Solution:-

Section	Q(L/sec)	Q(m^3/sec)	ΔP(Pa/m)	V(m/sec)	D (m)
A→B		6.5	0.5		
B→C		2.5	0.5		
C→D'		1.5	0.5		
B→B1		2	0.5		
B→B2		2	0.5		
C→C'		1	0.5		

The Index run is A→D'

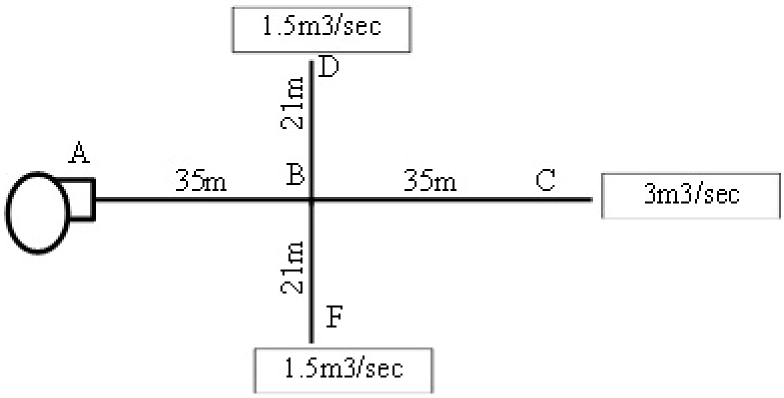
Total equivalent length of index run = length(A→B)+ length(B→C)+ length (C→D) +length (D→D')+length(elbow C→D')

length(elbow C→D')→ L/D=g →L=D×g= 590×9.81=5310mm/1000=5.31m

length(elbow C→D')=5.31m

Total equivalent length of index run = 2+3+2+2+5.31=14.31m

Ex3-7-2:- In aduct system as shown below with dimensions and air flow rates use balanced pressure lose method to find the diameters of main duct and branches , if the static pressure at ((A)) point equal to 21Pa ,and calculate dynamic pressure (velocity pressure) P_v for all sections.



Solution:-

Main duct length = 35+35=70m

$P_s at\ A = 21Pa$ and for calculating friction losses per meter length (ΔP) :

$$\Delta P_s = \frac{P_s at\ A}{L} = \frac{21}{70} = 0.3\ {}^{Pa}/_{m}$$

Air flow rate (air quantity)at A=3+1.5+1.5 = 6m^3/sec

By usinf friction loss-air quantity chart :

Section	Q(L/sec)	Q(m^3/sec)	ΔP(Pa/m)	V(m/sec)	D (m)
A→B	6000	6.0	0.3		
B→C	3000	3.0	0.3		

For branchs : B→D and B→F

Ps at B=(PsatA)-(35×0.3) =21-10.5 =10.5 Pa

$\Delta P_s = \frac{P_s at\ B}{L} = \frac{10.5}{21} = 0.5\ {}^{Pa}/_{m}$ for both B→D and B→F branchs

By usinf friction loss-air quantity chart :

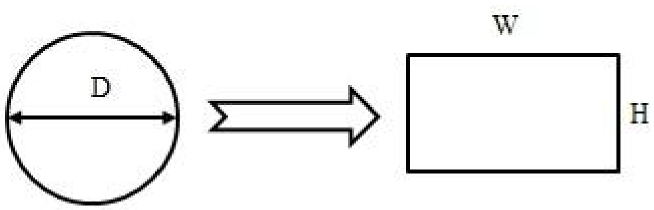
Section	Q(L/sec)	Q(m^3/sec)	ΔP(Pa/m)	V(m/sec)	D (m)
B→D	1500	1.5	0.5		
B→F	1500	1.5	0.5		

For calculating dynamic pressure (velocity pressure) P_v for all sections , by using :

$P_v = \frac{1}{2} \times \rho \times v^2$ with taking in corresponding ρ=1.2Kg/m^3

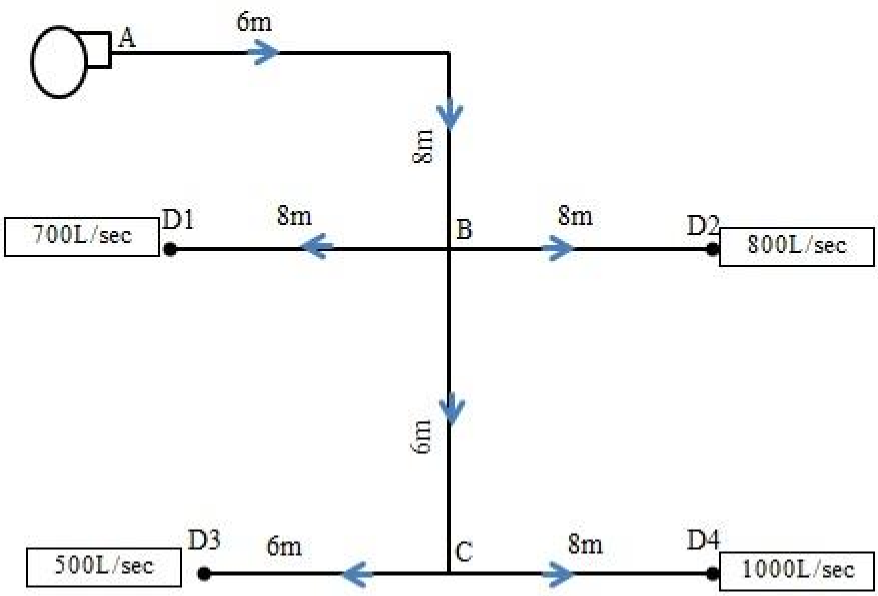
Section	$P_v = \frac{1}{2} \times \rho \times v^2$
Pv(A→B)	$Pv_{AB} =$
Pv(B→C)	$Pv_{BC} =$
Pv(B→F)	$Pv_{BF} =$
Pv(B→E)	Pv_{BE}

3-9 Circlar equivalents of rectangular ducts: the head loss due to friction is greater for a rectangular duct than for a circular duct for the same cross-sectional area and capacity , there for we must find the rectangular cross sectional area diamentsions equivalent to the cicular cross section area dimeters for the duct with equal friction loss and capacity .



$$D = 1.3\ \frac{[H \times W]^{0.625}}{[H + W]^{0.25}}$$

Ex3-9-1:- aduct system as shown below with dimeters and air flow rates use equal pressure method to find the dimeters and equivalent rectangular ducts then find the static pressure after fan . if the velocity after fan position is 8m/sec.



Solution:

Section	Q(L/sec)	V(m/sec)	ΔP(Pa/m)	D (m) circular	W×H rectangular
A→B	3000	8			
B→C	1500				
B→D1	700				
B→D2	800				
C→D3	500				
C→D4	1000				

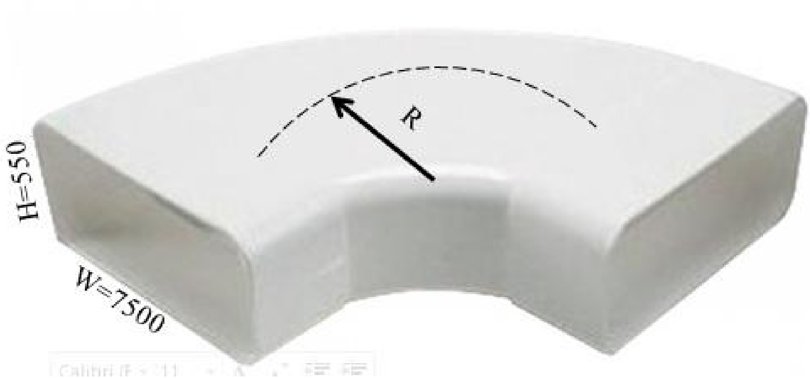
لايجاد الضغط الاستاتيكي بعد المروحة (*Stativ pressure after the fan*) نتبع الخطوات التالية :-

- معرفة طول المسار في المجرى (اي المسار الذي يكون فيه اكبر خسائر للضغط) وهو مايسمى بالمجرى الدليلي (*Index run*) ومن خلال ملاحظة مخطط منظومة مجاري الهواء فان اطول مسار هو من نقطة (*A*) الى نقطة (*D4*)

length of index run(A→D4) =[L(A-B)+ L(elbow A-B)]+ [L(B-C)+ L(C-D4) + L(elbow C-D4)]

بعدها يجب ايجاد طول الحنيتين في المعادلة اعلاه

الحنية *(elbow A-B)*:



- يتم حساب نسبة *(H/W)* $\frac{H}{W}=\frac{550}{750}=0.73$
- يتم حساب نسبة *(R/W)* واذا لم تعطى معلومات كافية لحسابها فتؤخذ افضل نسبة *(R/W=1.5)*
- باستخدام جدول طول الحنيات الموضح ادناه :
- تستخرج النسبة *(L/W)* من الجدول ومنها نجد قيمة *L* التي تمثل طول الحنية

L/W= 4.46 → L/750=4.46 → L=3345mm = 3345/1000=3.345m

وهكذا بنفس الطرقة يتم حساب طول الحنية الحنية *(elbow C-D4)*:

H/W=350/500=0.7 →R/W=1.5→ L/W=4.4 →L/500=4.4 → L=2.2m

والان تعوض اطوال الحنيات و اطوال المقاطع في معادلة المجرى الدليلي *(Index run)*

length of index run(A→D4) =[L(A-B)+ L(elbow A-B)]+ [L(B-C)+ L(C-D4) + L(elbow C-D4)]

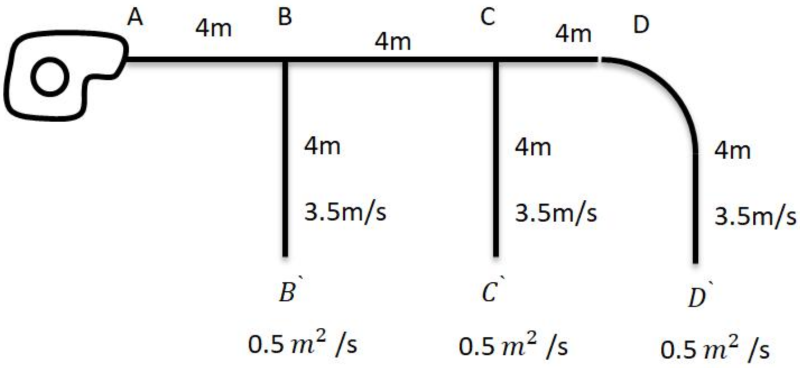
length of index run(A→D4) =[6+3.34+8] +[6+2.2+8] = 33.545m

Ps at (A)= L(index run) ×ΔP = 33.545 ×0.9=30.2Pa

-

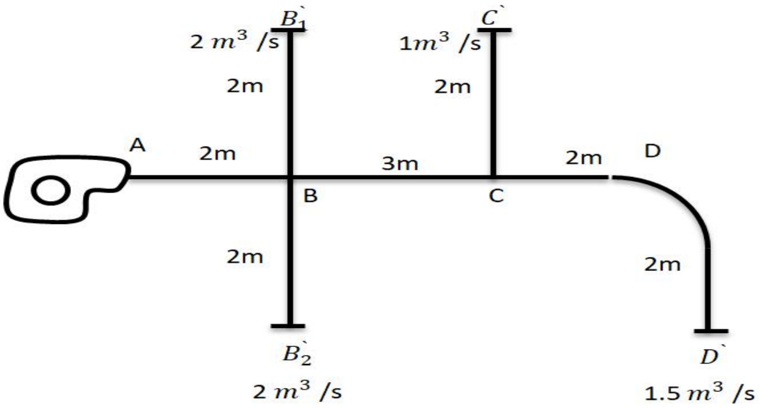
Sheet NO 3 (Air duct design problems)

Q1:- for duct system as shown in fig. with dimensional flow rate , Use velocity reduction method to find the diameters and pressure drops , if the air velocity after the fan equal 7.5 m/s .

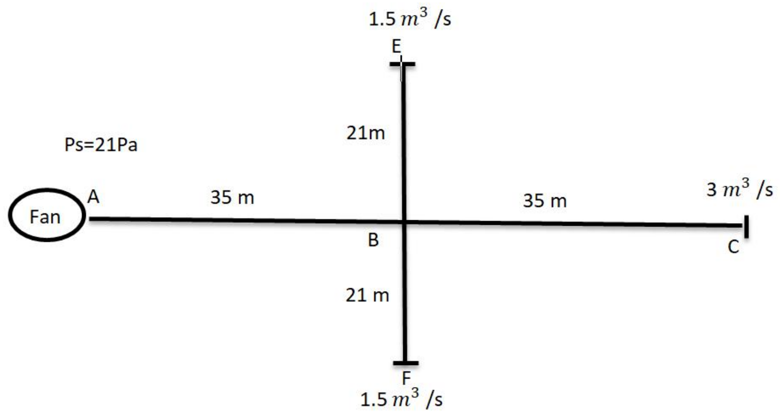


Q2:-Solve the same example at first method but use equal pressure drop method at constant pressure drop (1Pa/m)

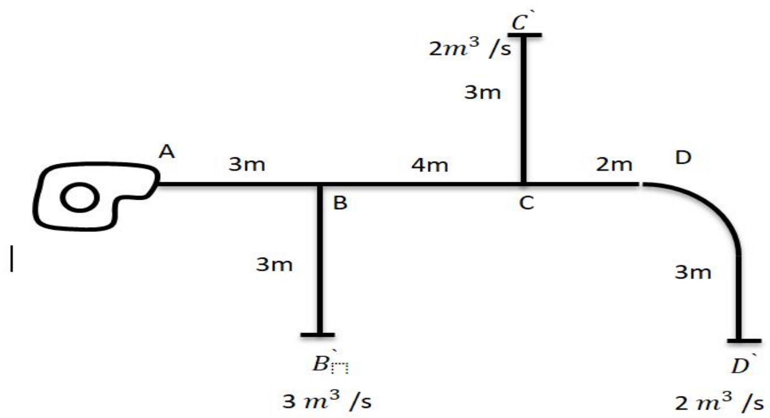
Ex3:- Design the air duct system as shown in fig. with dimensions and flow rates by using equal pressure drop method at constant pressure drop (0.5Pa/m) and find total equivalent length for main duct (index run).



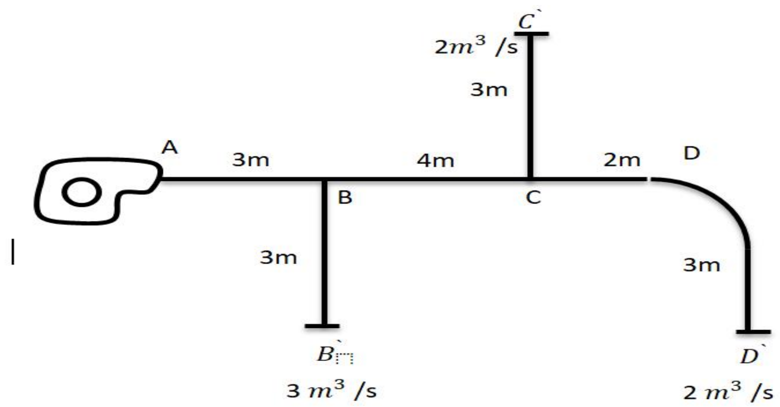
Q4:- In a duct system as shown below the dimensions and air flpw rate , using balanced pressure method to find the diameter of the main duct and branches also find the velocity at each section . if the static pressure at A equal (21Pa) ?



Q5:- Design the air duct system as shown in fig. by using equal pressure method at constant pressure drop (0.5Pa/m) .



Q6:- Design the air duct system as shown in fig. by using equal pressure method at constant pressure drop (0.6 Pa/m) .



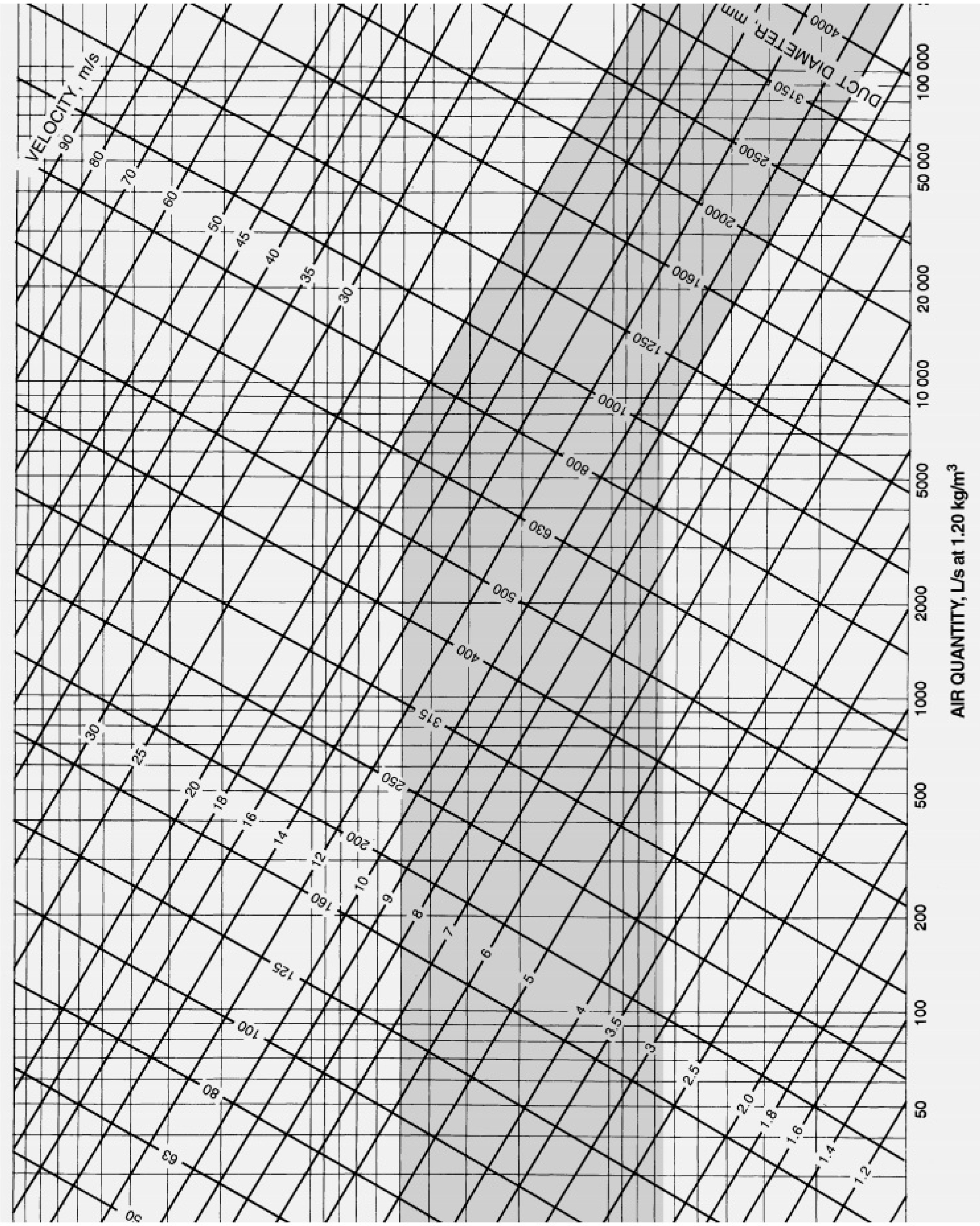


Fig. 9 Friction Chart for Round Duct ($\rho = 1.20$ kg/m^3 and $\varepsilon = 0.09$ mm)

Friction losses – air quantity chart for air duct design

[(Findig D(mm) , Q(L/sec), V(m/sec)and ΔP (Pa/m)]

Chapter 4

Pimped and pipe system

الانابيب و المضخات

4-1 Introduction:-

Pipe system: - is connecting air-conditioning units with water sources (chillers or boiler …………..)by pump.

Types of pipe system:-

1. Open system ….. figure 4-1-a
2. Closed system ……figure4- 1-b

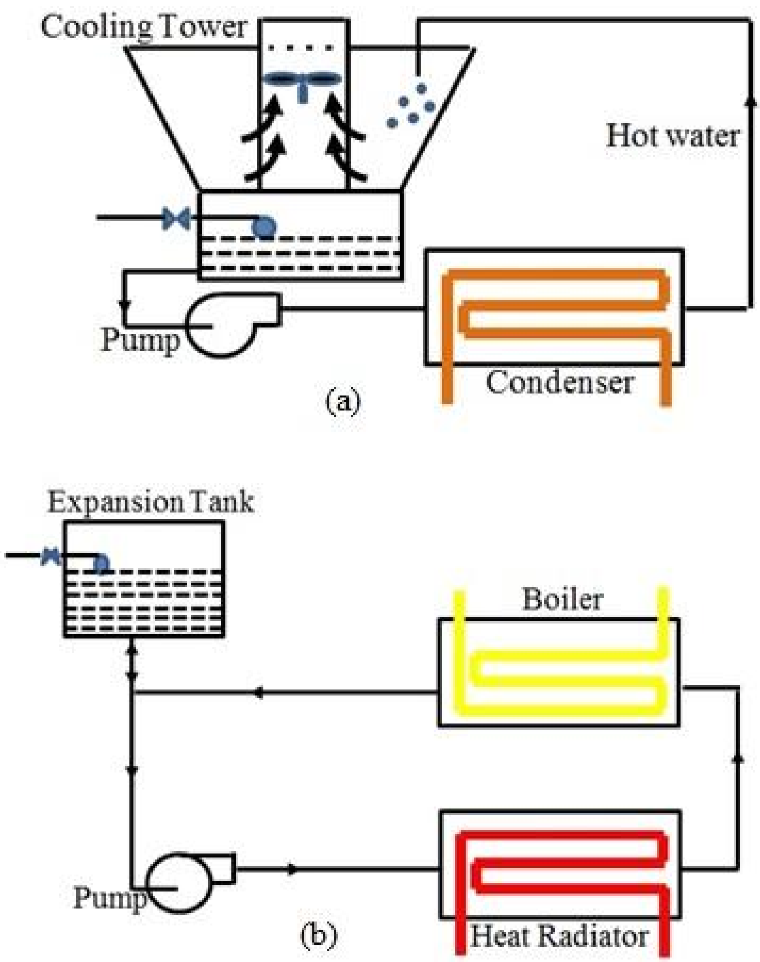


Figure 4-1 (a)Open type piping system, (b) closed type piping system

4-2 Classification of closed pipe systems:-

4-2-1 / According to the number of pipes used in the system:-

1. One pipe system.
2. Two pipe system.
3. Three pipe system.
4. Four pipe system.

4-2-2/ According to the return pipes:-

1. Direct return.
2. Reverse return. Figure 4-2

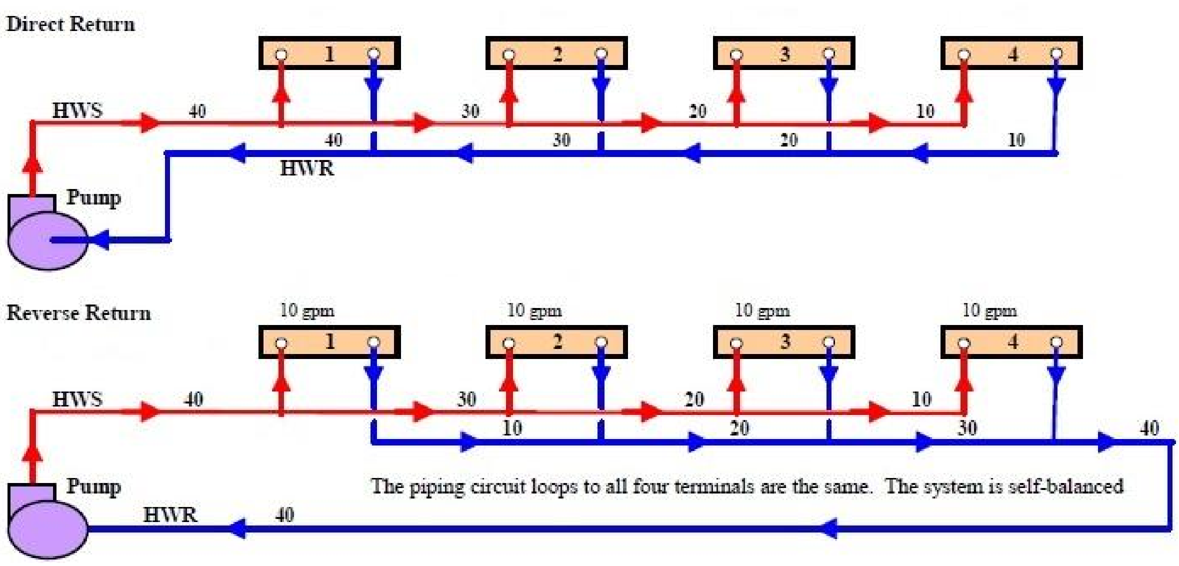


Figure 4-2 direct and reverse return in piping system

Direct return used with units need different water flow rates, reverse return used with units need same water flow rates. The reverse return closed pipe system is self balanced because the length of water cycle (supply and return) for all units is equal.

4-3 / Elements of pipe system:-

1. pipes :- from glovanized steel or black steel.

2. Elbow :-change the direction of fluid

3. Tee:- use with branches

4. Reducer :- decrease the diameter of pipe .

5. Union: - connect two pipes together.

6. Gate valve: - used for on l off it used with each A/ C unit.

7. Globe valves: - to control the water flow rate.

8. Check valve: - used to prevent the flow of water in opposite direction / pumps.

9. Strainer: - connected with supply pipe for each A/C unit.

10. Expansion joint:-used with long pipes and pumps.

11. Expansion tank:-

a- keeps the system pressure when working temperature change.

b- The way to refill the system with water.

4-4/ Pumps types:-

1. Centrifugal pumps.
2. Radial flow pumps.
3. Axial flow pumps.
4. Scroll case pumps.

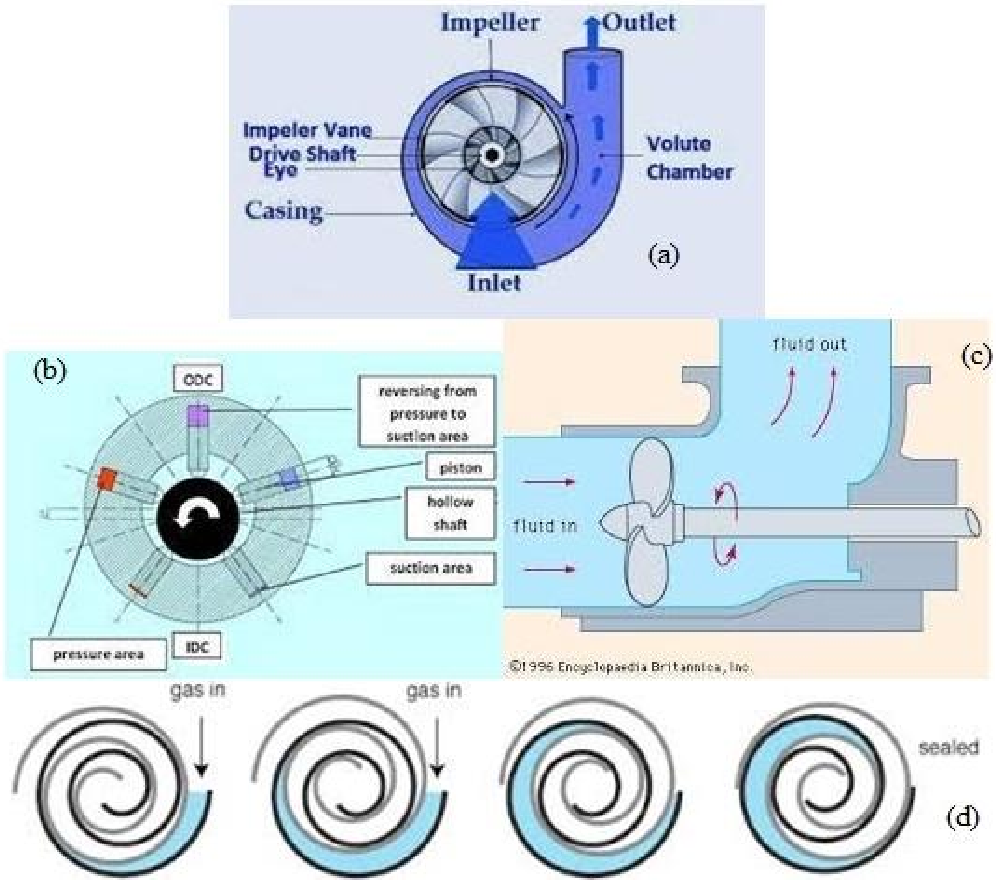


Figure 4-3 (a- centrifugal fan , b- radial fan , c- axial fan ,d-scroll fan)

4-5/Pumps connection :-

4-5-1 /Parallel connection :-

$Q_{total} = Q_1 + Q_2 + Q_3 + \cdots.$

$P_{total} = P_1 = P_2 = P_3 = \cdots.$

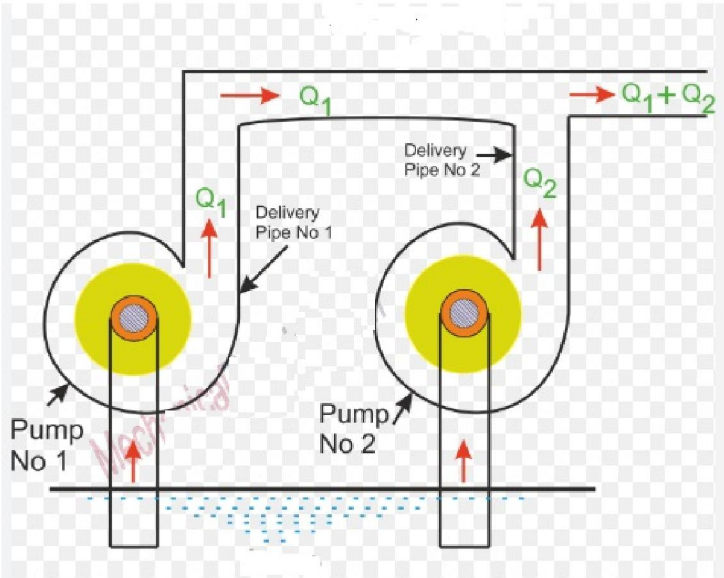


Figure 4-4 pumps in parallel connection

4-5-2/ Series connection:-

$$P_{total} = P_1 + P_2 + P + \cdots$$

$$Q_{total} = Q_1 = Q_2 = Q_3 = \cdots$$

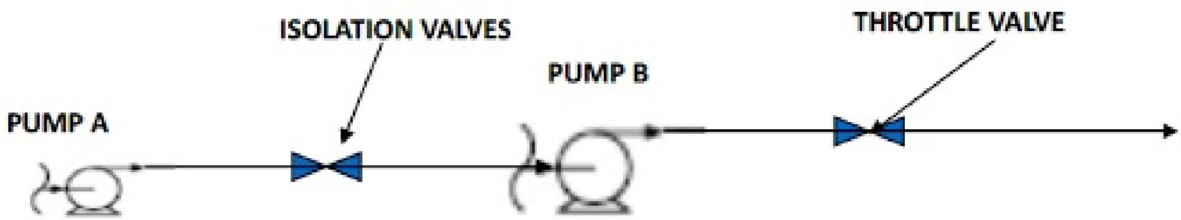


Figure 4-5 pumps in series connection

4-6/ Pumps Law

$$P_t = \left(P_d + \frac{1}{2}\,\rho\, V_d^2\right) - (P_s - \frac{1}{2}\,\rho\, V_s^{\,2})$$

Where:-

P_d:-static pressure at discharge line.

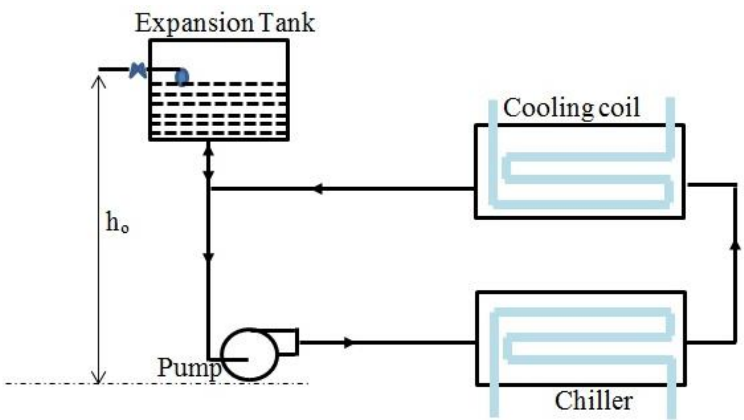
P_s:- static pressure at suction line .

V_d^2:- water velocity at discharge line.

$V_s^{\,2}$:- water velocity at suction line.

4-7/ Pressure calculation in the system :-

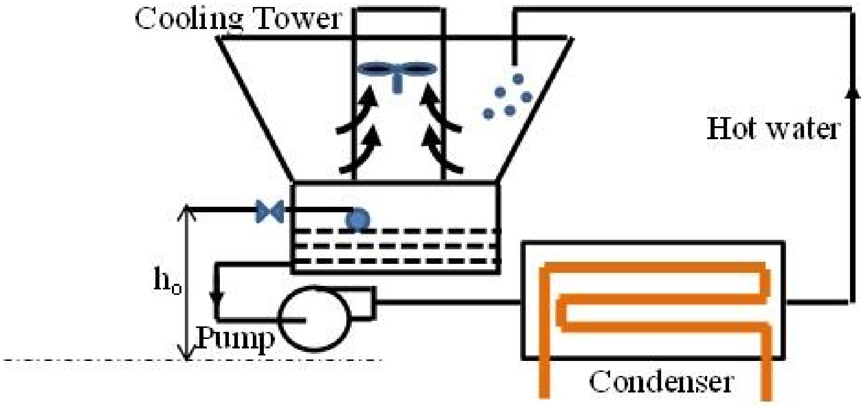
4-7-1/Closed system:-



h_o :- head pressure in the system (minimum pressure). Or static pressure (p_o)

p_o=$\rho . g . h_o = P_s$

4-7-2/Open system :-



h_o :- head pressure in the system (minimum pressure). Or static pressure (p_o)

h_o=$\rho . g . h_o = P_s$

4-8/ Pump power:- (W_p)

A mount os energy supplied to the water .

$W_p = Q . P_t$

Where:

Q:- volumetric rate of water (m^3/s)

P_t :- total pressure (Pa)

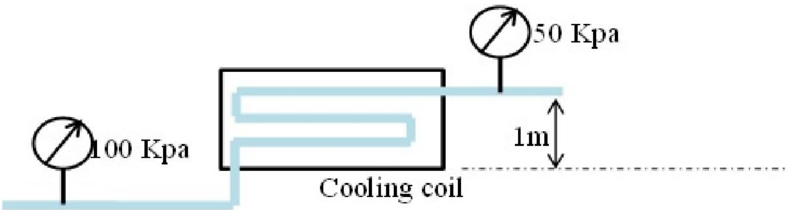
4-9/ Pump efficiency (ζ)

The rate of energy supply to the water divided by the rate of energy consumed in the pump's impellers

$\zeta = \frac{W_p}{W_s}$

W_s :- power consumed by pumps impeller

Ex4-1:- the pressure gauge reading in the inlet of cooling coil is (100Kpa) the reading of another pressure gauge in the exit (50 Kpa) the second gauge is (1m) above than the first gauge . Calculate the pressure drop in the cooling coil ? the coil run by chilled water .



Solution :-

Pressure due to 1m of water is:-

$$P = \rho \times g \times h = 1000 \times 9.81 \times 1 = 9810pa \leftrightarrow P = 1.89kpa$$

Total Pressure at inlet pipe =50+9.81 = 59.81 kpa

Pressure drop =100-59.81=40.19kpa.

For calculation pressure drop for pipes we use the chart of pressure drop (friction) shown below:

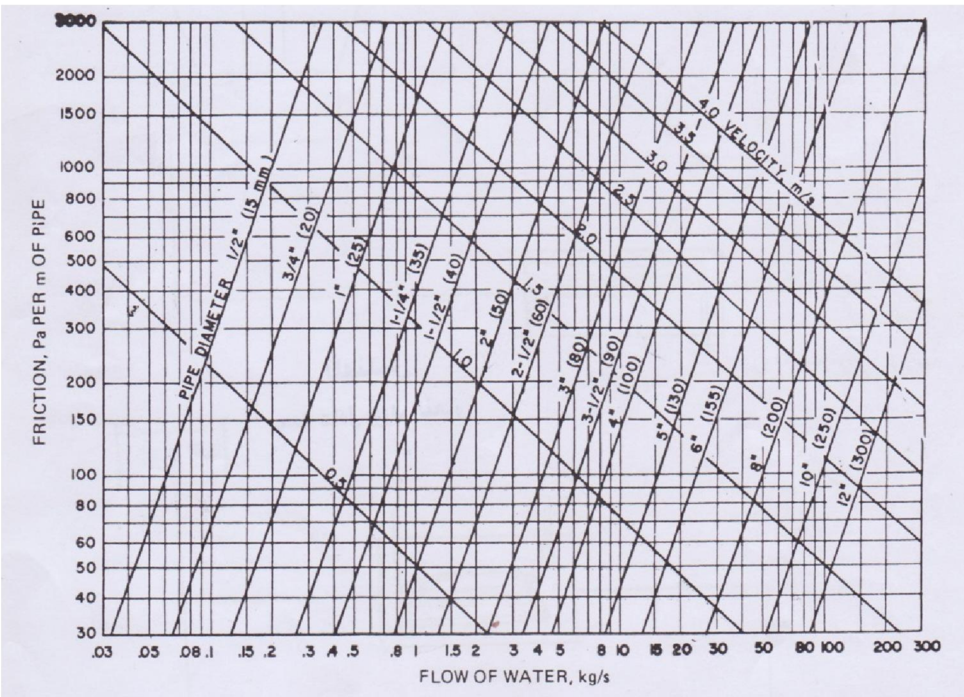


Figure 4-6 friction loss – flow rates piping losses chart

For calculating equivalent length for bends and fittings, we must use the table below:

Table 4-1 the equivalent length for bends and fitting piping system

حجم الانبوب عقدة(ملمتر)						
$\frac{3}{4}$ (20)	1 (25)	$1\frac{1}{4}$ (35)	$1\frac{1}{2}$ (40)	2 (50)	3 (80)	التركيب
						عكس
1·6	2·1	2·6	3·1	4·2	6·5	90°
1·1	1·5	1·8	2·2	2·9	4·5	45°
0·8	1·0	1·3	1·6	2·1	3·0	90° طريل
						تقسيم
2·8	3·8	4·7	5·6	7·5	13	100 °/ₒ تحويل، جانبي
6·3	8·3	10·4	12·5	16·7	25	50 °/ₒ تحويل جانبي
14·3	18·7	23·4	28·1	37·5	56	33 °/ₒ تحويل جانبي
25	33·3	41·6	49·8	66·7	100	25 °/ₒ تحويل جانبي
						صمامات
18·7	25·0	33·8	36·8	50·0	66	كروي (مفتوح)
0·8	1·0	1·3	1·6	2·1	3·0	بوابي (مفتوح)
1·6	2·1	2·6	3·1	4·2	6·5	سداد (مفتوح)
3·6	4·2	5·2	6·2	8·3	12·5	زاوي (مفتوح)
0·6	0·8	1·0	1·3	1·7	2·5	مصغر
4·7	6·3	7·8	9·4	12·5	19	أو وحدة تدفئة

After calculating the friction loss of the pipe, it should be known that this value is not quite correct, and a correction coefficient should be used to correct it.

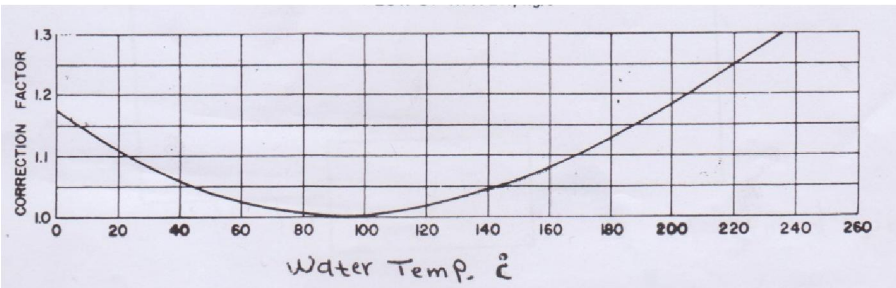


Figure 4-7 correction factor with water temperature chart

Ex4-2:- find the equivalent length for a pipe (d=50mm) and its length (40m) , consist of :- 1 globe valve , two long elbow 90° , 1 tee with 50% by pass ?

Solution:-

From table 4-1 :

1 global valve =1×50=50feet

2 elbow (90°) long = 2×2.1 = 4.2 feet

1 Tee 50% = 1×16.7 = 16.7 feet

Equivlent length for fitting = 50+4.2+16.7=70.9 feet /3.28=21.6m

Total length for pipe and fitting = 40+21.6 =61.6m

Ex4-3

If the system in previous example transmits chilled water with (3.5kg/s) and its temperature (8°C) find the pressure drop in system.

Solution:

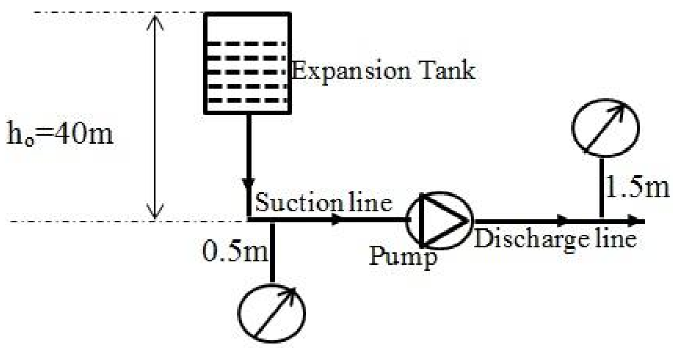
From chart at Q=3.5kg/d and d=50mm we specified pressure drop (ΔP=550pa/m) , the correction factor at (T=8°C) is equal to (1.15):

ΔP_c= ΔP×correction factor = 550×1.15=632.5pa/m

Total pressure drop in system (ΔP_t)= ΔP_c×total length = 632.5×61.6 = 38.931Kpa

Ex4-4 :- in a closed pipe system the total pressure drop (50 Kpa) , the expansion tank located at (40m) high a bove the suction line of the pump . find the water head and pressure which the pressure gauge read it as follow :-

1. Down the suction line by (0.5m).
2. A bove the discharge line of the pump by (1.5m).



Solution:-

$h_o = 40m \rightarrow \ P_o = P_s$

$P_s = \ \rho \times g \times h_o = 1000 \times 9.81 \times 40 = 392400Pa = 392.4Kpa$

$$\text{Pressure due to } (0.5\text{mH2o}) = \rho \times g \times h_o = 1000 \times 9.81 \times 0.5 = 4905Pa = 4.905kpa$$

1) Pressure gage reading = 392.4+4.905 = 397.305 kpa ,

Water head =40+0.5= 40.5mH_2O

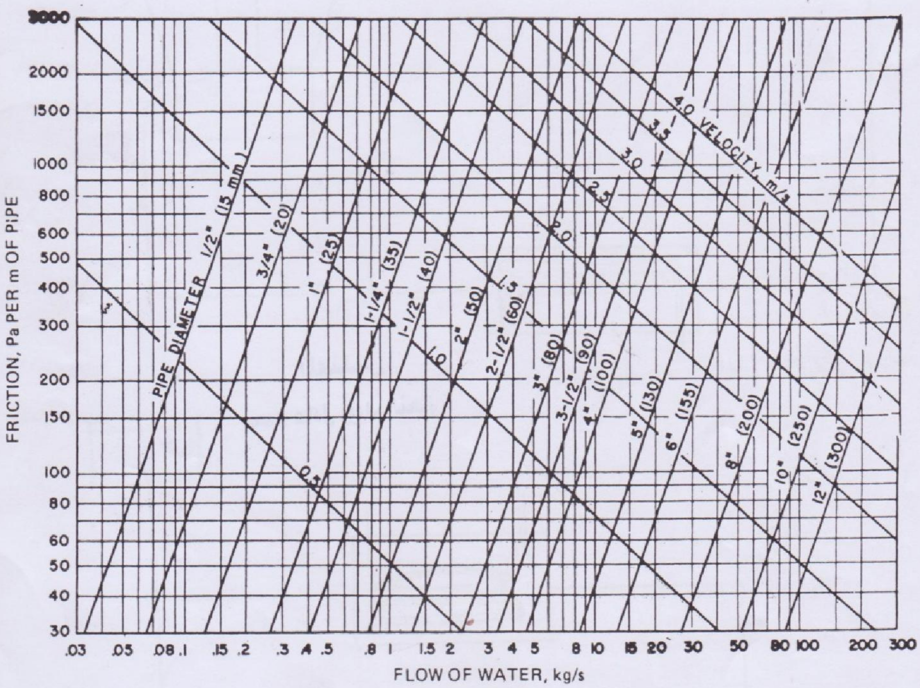
2) ΔP=Pd-Ps ⟾ 50=Pd-392.4 ⟾Pd=442.4kpa

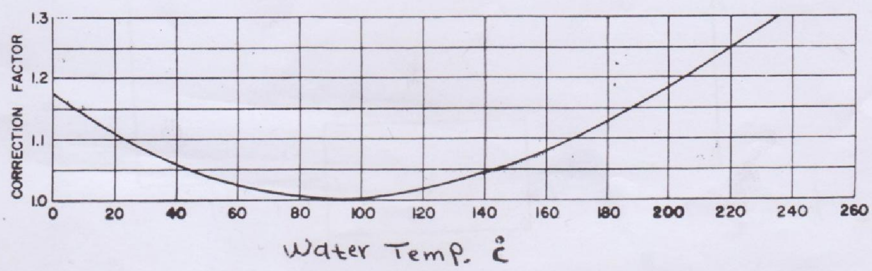
$$\text{Pressure due to } (1.5\text{mH2o}) = \rho \times g \times h_o = 1000 \times 9.81 \times 1.5 = 14715pa = 14.715kpa$$

Pressure gage reading = 442.4-14.715 = 427.685 kpa ≈ 427.7kpa

Water head ⟾ $P = \rho \times g \times h \Longmapsto 427.7 \times 1000 = 1000 \times 9.81 \times h \ \Longmapsto h = 43.598\text{mH2O}$

حجم الأنبوب عقدة (ملمتر)						
3/4 (20)	1 (25)	1 1/4 (35)	1 1/2 (40)	2 (50)	3 (80)	التركيب
						عكس
1.6	2.1	2.6	3.1	4.2	6.5	90°
1.1	1.5	1.8	2.2	2.9	4.5	45°
0.8	1.0	1.3	1.6	2.1	3.0	90° طويل
						تقسيم
2.8	3.8	4.7	5.6	7.5	13	100 °/. تحويل جانبي
6.3	8.3	10.4	12.5	16.7	25	50 °/. تحويل جانبي
14.3	18.7	23.4	28.1	37.5	56	33 °/. تحويل جانبي
25	33.3	41.6	49.8	66.7	100	25 °/. تحويل جانبي
						صمامات
18.7	25.0	33.8	36.8	50.0	66	كروي (مفتوح)
0.8	1.0	1.3	1.6	2.1	3.0	بوابي (مفتوح)
1.6	2.1	2.6	3.1	4.2	6.5	سداد (مفتوح)
3.6	4.2	5.2	6.2	8.3	12.5	زاوي (مفتوح)
0.6	0.8	1.0	1.3	1.7	2.5	مصفر
4.7	6.3	7.8	9.4	12.5	19	أو وحدة تدفئة





Chapter five

Airconditonning systems and air filtration

5-1 Airconditonning systems/ The decision to selection the A/C system:-

1- The satisfaction of occupants.

2- Fillness of the system for space.

3- The economic consideration.

5-2Types of Heating, ventilating and Air-conditioning (H.V.A.C) system:-

5-2-1 All –air system.

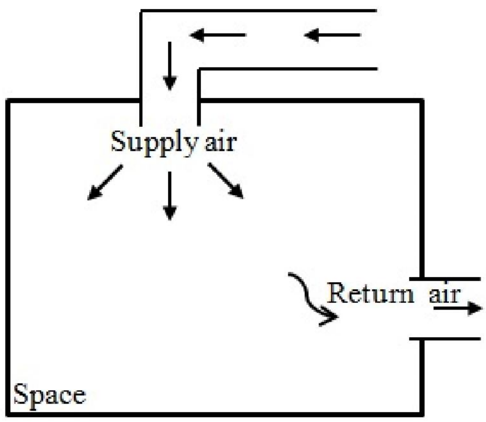


Figure 5-1 all air system

5-2-2 All – water system

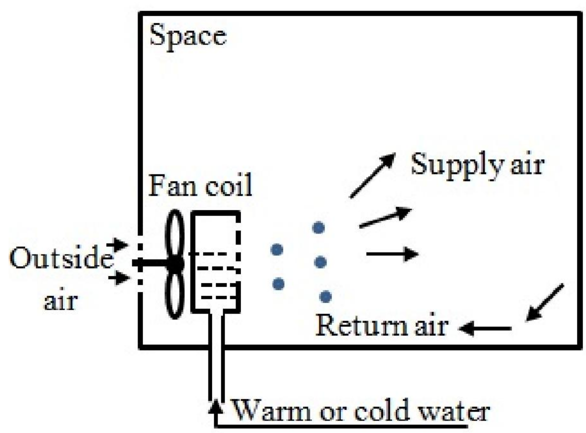


Figure 5-2 all water system

5-2-3 Air –water system

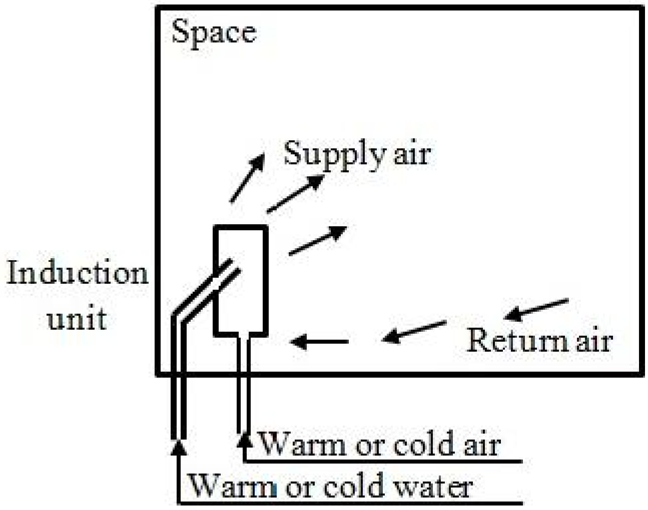


Figure 5-3 air- water system

5-2-4 Multiple unit or unitary system [Direct expansion system]

A self-contained compact unit with the conditioned space consisting of minimum elements Include:-

5-2-4-1 Window type

5-2-4-2 Split unit :-

a- Wall type fan coil unit

b- Floor/ceiling fan coil unit

c- Cassette fan coil unit

d- Free standing decorative unit

E- low/medium/high static duct air handling unit

f- Top discharge condensing units

5-2-4-3 Packaged air-conditioner

5-3 Cleaning of Air (Filtration)

5-3-1 Operating characteristics:-

There are three operating characteristics that distingusih the various types of air cleaners . These are:-

1-Efficiency

2- Air flow resistance

3- The dust holding capacity

5-3-2 Contaminants:-

Atmospheric contaminants Fall into four classes:- Solid , liquid , gaseous and organic.

1- Dusts:-these are solid particles.

2- Fumes: - these also are solid particles but formed in different way from dusts.

3- Smokes: - smokes may be regarded as small solid partieles

4- Mists and fogs: - They are both air borne droplets which are liquid at normal temperature and pressure.

5- Vapors and gases: - They are substances which are in the gaseous phase at normal temperature and pressure.

6- Organic particles: - The commonest of these are bacteria, pollen, the spores of fungi and viruses.

5-3-3Air filters types:-

5-3-3-1 viscous filters:

a- cell type

b- automatic type

5-3-3-2 Dry filters

a- cell type

b- Automatic type

5-3-3-3 Electric filters (figure 5-4)

5-3-3-4 Wet filters (figure 5-5)

5-3-3-5 Centrifugal collectors (figure 5-6)

5-3-3-6 Adsorption filters

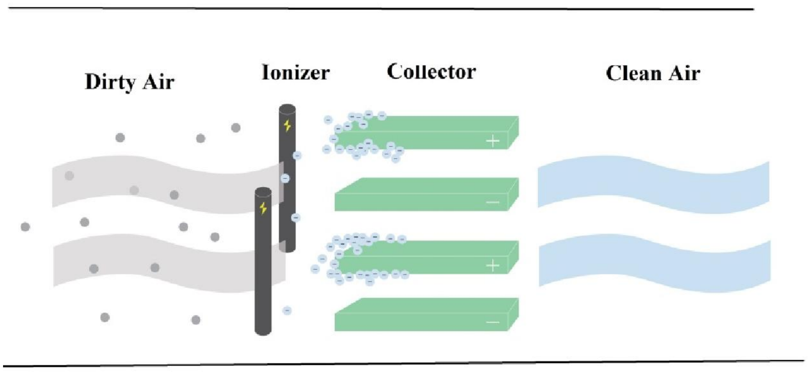


Figure 5- 4 Electrical air filters

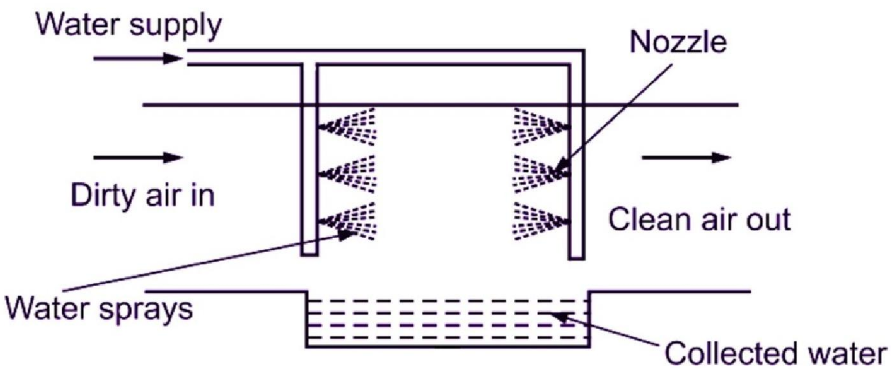


Figure 5- 5 wet air filters

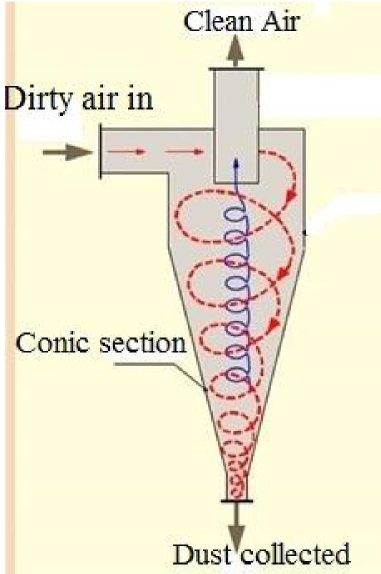


Figure 5-6 Centrifugal collectors air filter