Lecture Notes in Fluid Mechanics

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C H A P T E R 1

Fluid mechanics

Fluid mechanics is a science in study the fluid of liquids and gases in the cases of silence and movement and the forces acting on them can be divided materials found in nature into two branches.

A- Solid Matters.

B-Fluid Matters:

Fluid material is divided into two parts:

1- Liquid Matters.

2- Gaseous Matters.

Fluid mechanics include fluid materials such as water, air and other while unique science (Hydraulics) in the water as a liquid within the fluid material.

Hydrodynamics science is the study of the (Flow Fields) for materials may be not the viscosity or compression or correlation but may even be a few special the weight important and fluid called (Ideal fluid).

A fluid: is any substance that conforms the shape of its container and does not permanently resist distortion. Gases, liquids and vapors are considered to have the characteristic of fluids.

If a fluid affected by changes in pressure, it is called compressible fluid otherwise, it is called incompressible fluid [1].

1.1 Units

The basic dimensions in fluid mechanics are below:

Property	Symbol	SI Unit	English Unit
Force	F	N	Ib
Length	L	m, cm	Ft, in
Mass	M	Kg	Slug
Time	T	S, min, hr	S, min, hr
Temperature	t	C^o	F^o

1.2 Derived units

Some units are expressed in terms other units which are derived from fundamental units. They are known derived units and they are:

Quantity	symbol	SI unite
Area	A	m^2
Density	ρ	Kg/m^3
Force	F	N
Kinematic viscosity	U,v	m^2/sec
Liner velocity	u	m/sec
Acceleration	g	m/sec^2
Mass flow rate	m^o	Kg/sec
Power	p	N.m/sec= J/sec=W
Pressure	P	N/m^2=Pa
Shear stress	Ʈ	N/m^2=Pa
Surface tension	Ơ	N/m
Viscosity	µ	Kg/m.sec, Pa.sec
Specific Volume	V̓	m^3/N
Flow	Q	m^3/sec
Moment	M	N.m
Specific heat constant pressure	Cp	J/Kg.k^o
Specific heat constant volume	Cv	J/Kg.k^o
diameter	D	m
diameter cylinder	d	m
Energy	E	N.m
Force	F	N
Length	L	m
Mass	M,m	$N.sec^2/m$
Vapor pressure	Pv	N/m^2
Radius	r	m
Reynolds number	Re.	
Temperature	t	C^o
Second	T	sec
Volume	V	m^3
Weight	W	N

1.2.1 Greek symbols

Specific weight	ɣ	gamma	N/m^3
Viscosity	µ	mu	$N.sec/m^2$
Kinematic viscosity	U, v	nu	m^2/sec
Mass density	e	rho	$N.sec^2/m^4$
Surface tension	Ơ	sigma	N/m
Shear stress	Ʈ	tau	N/m^2
beta	β	beta	
alpha	α	alpha	

1.2.2 Conversion factor

Discharge or flow: 1 m^3/sec = 35.31 ft^3/sec.

Acceleration: 9.80665 m/sec^2 = 980 cm/sen^2= 32 ft/sec^2.

Volume: 1 m^3 = 1000 liter = 35.31 ft^3.

Temperature (T)

$F^o = 1.8C^o + 32$

$R^o = F^o + 460$

$K^o = C^o + 273^o$

Force: 1N = 0.2248 Ibf.

Velocity: 1 m/sec = 3.281 ft/sec.

Work: 1 N.m = 1 Joules.

Pressure: 1 KN/m^2 = 1Kpa = 0.145 Ib/in^2.

Vapor pressure: 1 atm = 1.013 x 10^5 N/m^2

(1mm) Hg = 0.0394 in H_g.

(1mm) H_2O = 9.807 pa.

Mass: 1 Kg = 1000gm = 0.068 slug.

Length: 1 mm = 0.0394 in; 1m = 3.281 ft. 1in = 0.0254 m

1Km = 0.62 mil; 1mil = 1609.3 m

Area: 1m^2 = 0.00155 in^2.

Power: N.m/sec = J/sec = Watt.

1KW = 1.341 HP = 737.5 Ib.ft/sec.

1 hp = 550 Ib.ft/sec.

Force: Newton = 0.2248 Ib.

Dynamic viscosityμ (mu) = N.sec/m^2 = Pa.sec = 10 poise =0.02 Lb.sec/ft^2.

Kinematic viscosity U (nu) L^2T.= m^2.sec = 10000 stokes (Cm^2/sec) = 10.7 ft^2/sec.

Mass (M)

Kg = 1000gm = 0.068 slug

Lean body mass Lbm = 454 gm

Ton = 1000 kg

Mass density (M/L^3) Kg/m^3 = 0.00194 $slug/ft^3$

Weighted density ɣ (W/L^3) = N.m3 = 0.006 Lbf/ ft^3.

Ex.1: What all units of the system quantity:

1- Force 2- Pressure 3- Work 4-Power 5- Mass density.

Solution:

1- Force:

Force = Mass X Acceleration ⇨ F = M x g ⇨ F= M x Length/ $time^2$.

2- pressure:

P = Force / area

3- Work:

W = F x Distance.

4- Power:

Power = $\frac{\text{work}}{\text{time}}$

5- mass density:

$\rho = \frac{\text{Mass}}{\text{Volume}}$

H.W: Find the units for viscosity, Sp.wt., pressure, mass, density.

1.3 Characteristics of flow and fluid property

1- mass density: or density [symbol: ρ (rho)]

It is ratio of mass of fluid to its volume.

$$\rho = \frac{\text{mass of fluid}}{\text{volume of fluid}} = \frac{m}{v} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The common units used of density are kg/m^3, g/cm^3, Ib/ft^3.

2- Weight density: or specific weight or: [symbol: (Sp. wt.)]
The ratio of weight of fluid to it is volume at standard temperature and pressure.

$$\text{Sp. Wt.} = \frac{\text{weight of fluid}}{\text{volume of fluid}} = \frac{w}{V} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The common units used of density are $\frac{N}{m^3}, \frac{dyne}{cm^3}, \frac{Ib}{ft^3}$.

The common weight density of water is 9.81 $\frac{KN}{m^3}$.

Can express the relationship between the density of the equation: ɣ = ρ . g

Resulting from the Newton equation: (F = M . g). The use of the force of attraction and accelerating (W= M. g) And dividing the parties to volume (W/V=M/V. g). We get (ɣ=ρ. g).

3- <u>Relative density:</u>

is the ratio between the density of the material and the density of water at 4C°, where the great water density under normal atmospheric pressure.

$$\text{Relative density} = \frac{\text{Density of the material}}{\text{The density of water}} \quad \text{……….…………(3)}$$

4- Specific volume: [symbol: V]

The ratio of volume of fluid to it is mass. It is the reverse of mass density.

$$V = \frac{\text{Volume of fluid}}{\text{Mass of fluid}} \quad \text{………………………………(4)}$$

The common units used of density are $\frac{m^3}{kg}, \frac{cm^3}{g}, \frac{ft^3}{Ib}$.

5- Compressibility

Is the portability size of the fluid to change the impact of external forces located the fluid. Liquid its portability (Incompressibility). Gas its portability compressibility to resize and reason is to the distances between the molecules of the fluid.

6- Viscosity: resistance is carried out by the layers of the fluid to the external force. That all of the fluid in nature has a viscosity resulting from fractions cohesion and momentum exchange between the different layers of the fluid rises and these fluids called fluid true or viscous fluid where the friction between the layers flow when and where you get two cases of the flow:

A-laminar flow: Does not occurs blending.

B -turbulent flow: Occurs rotational blending between the fluid layers.

Ideal fluid: No viscosity they are not found in nature, but a portion of the fluid viscosity is too small to the extent that it ignored in the calculations and the viscosity of the types:

1- Dynamic viscosity: [symbol: μ (mu)] Dynamic viscosity: know is the shear stress and speed slope $\frac{\text{Change vilocity}}{\text{Change distance}}(\frac{du}{dy})$.

$$\mu = \frac{\text{Shear strain}}{\text{Rate of shear strain}} = \frac{\tau}{\frac{du}{dy}} \quad \text{……………………….(5)}$$

$$\tau = \mu.\frac{du}{dy} \quad \text{…………………………………(6)}$$

shear strain: Is the force acting on a body fluid or solid in unit area of the body.

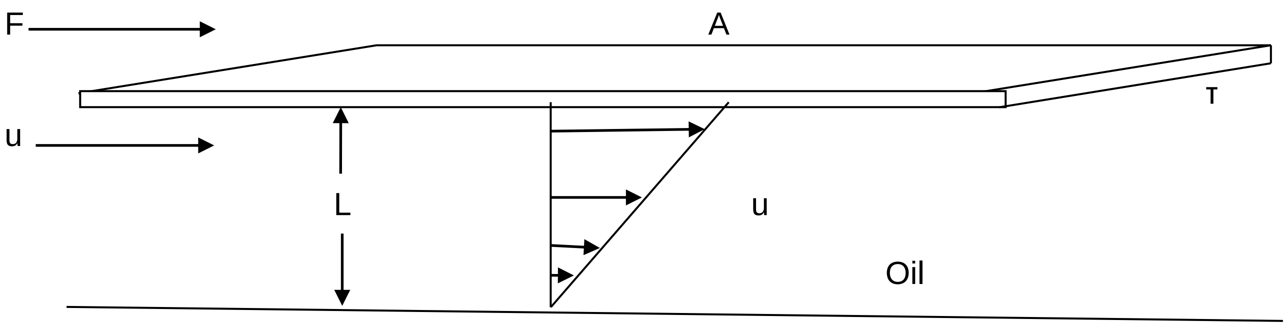
$$\text{Shearing strain } j = \frac{f}{A}, \quad \frac{\text{force}}{\text{area}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Viscosity of any fluid depends only on temperature. Vigorous and increases molecular mixing, thus the viscosity, increases. In case of a liquid, we find that increasing. Its temperature separates the molecules from each other, weakening. The attraction between them so the viscosity decreases.

Thus, the relation between temperature and the viscosity is shown in figure below.

The relation between shear stress & velocity gradient ($\frac{du}{dy}$).

Consider a, fluid confined between two plats as shown in, figure below. Which are situated at a very short distance (y) a part show in fig. the fluid motion is assumed to take place in a series of infinitely then layers, free to slide one over the other is no turbulence; the layer adjacent to the stationary plate is at rest while the layer adjacent to the moving plate has a velocity (u).



Where:

u: Velocity of the moving plate (varies linearly from at the stationary surface to maximum at the contact surface between the moving plate and oil).

A: Contact area between the moving plate and oil.

F: Applied force to the moving plate.

L: Thickness of oil layer.

This expression for the viscous stress was first proven by Newton equation of viscosity. Almost all fluids have a constant coefficient of proportionality and are referred to as Newtonian fluids and the fluids that do not follow this law are non- Newtonian fluids. The figure below shows these types of fluids.

2- Kinematic viscosity: [symbol: U (nu)]

The ratio of the dynamic viscosity to the fluid mass density.

$$U = \frac{\mu}{\rho} = \frac{M}{L.T} . \frac{L^3}{M} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

The common units used of kinematic viscosity are ($\frac{m^2}{sec}$, $\frac{cm^2}{sec}$, $\frac{ft^2}{sec}$, stoke).

$\frac{m^2}{sec}$ = 10 stoke.

1.4 Flow Characteristics

The term flow Characteristics refers to a quantity that may change from one point to another or from one space to another:

1- Shear stress: [symbol: τ (tau)]

It is the force per unit surface area that resists the sliding of the fluid layers.

The common units for shear stress are N/m^2 = Pa, $dyne/cm^2$.

2- Pressure: [symbol: P]

It is the force per unit cross sectional area normal to the force direction.

The common units used for pressure is N/m^2 = Pa, $dyne/cm^2$, atm, bar, psi,

The pressure difference between two points refers to (ΔP).

The pressure could be expressed as liquid height (or head).

Where: $P = \rho.g.h$ and $\Delta P = \rho.g.\Delta h$

h: is the liquid height or head, units (m, cm, and ft).

3- Velocity: [symbol: u]

is defined as average distance achieved for the time of units ($\frac{m}{sec}$).

4- Discharge or Flow rate: [symbol: Q]

Discharge is the volume of fluid transferred per unit time.

$Q = A.\ u$ where A: is the cross sectional area of the flow normal to the flow direction.

And the common units used for volumetric flow are m^3/sec, cm^3/sec, ft^3/sec.

5- Force: [symbol: F]

Is all that is produced or is tries to produce or stop or change movement. Units Newton, dyne. N = 100000 dyne.

6- Time: [symbol: T, t] the Units is second.

7- Acceleration: [symbol: g] is the Rate of change of speed per unit time, the Units $\frac{m}{sec^2}$.

1.5 Dimensional analysis

Is an important means of modern science of Fluid Mechanics is a field of mathematics fields where deals with mathematics dimensions quantities.

The methods of dimensional analysis set out on the basis of Fourier for homogeneity dimensional known since 1822, which show that the equation that express normal relations between the quantities must be homogeneous and any that the dimensions of the left side are the same dimensions right side, used to check the examples mathematical through the dimensions of quantities required.

Analyses dimensional helps to know the way to get a lot of information from the experiences of a few.

In order to clarification the steps we take one sporting equations, but the expressive power equation on the surface in a liquid consonant.

$$F = \gamma . h . A \quad \text{……………………………………..(9)}$$

assume that the dimensions of the specific weight and height and area known and unknown dimensions of force.

The dimensions of the force made up of mass, length and time can be know from the equation.

$$F = M . L / T^2 \quad \text{……………………………………..(10)}$$

Dimensions (F) = Dimensions(ɣ). Dimensions(h). Dimensions(A).

$$M^1 . L^1 . T^{-2} = (ML^{-2}T^{-2}) . (L^1) . (L^2) \quad \text{……………………………..(11)}$$

Where the unknowns are (a, b, c).

If applied to the base of the homogeneity analysis ^ basic be conform on each side of the equation.

$$a = 1,\ b = -2 + 1 + 2 = 1,\ c = -2.$$

So, the Dimensions (F) Equals.

$$M^1 . L^1 . T^{-2} = ML/T^2$$

Equal to the force that can be the directly simplification and without mathematical operations, but what work above is the usual way to get dimensional information for any amount.

Another example of the solution assumes the force that can be received from the circular hole depends on the flow rate Q and average speed u and mass density of the liquid, but the relationship between the variables is not known with this simple defined about these variables can be written mathematical equation:

$$F \alpha (\rho, Q, u)$$

From the base of dimensional homogeneity shows that the quantities cannot be subtracted from each other or combine with each other because the dimensions are different, this rule determines the form of the equation be multiplied quantities raised to an unknown foundation can be expressed mathematically as:

$$F = C (\rho)^a (Q)^b (u)^c$$

Where C is a constant posttest, any existence cannot posttest analysis as:

$$ML/T^2 = C (M/L^3)^a (L^3/T)^b (L/T)^c$$

M: 1 = a

L: 1 = -3a + 3b + c

T: -2 = -b – c

Of the three equations

a = 1, b =1, c=1

Compensation again in the equation

$$F = C. \rho. Q. u \quad \text{……………………..……………..(12)}$$

Ex.2: How to derive the law of viscosity (μ): flow rate(Q) appropriate with the dynamic viscosity coefficient (μ) and the radius (r) of the tube and the ratio between the pressure change and the length of the tube, ΔP/L.

Solution:

$Q \alpha \mu. R.\Delta P/L$

$Q = K (\mu)^a (R)^b (\Delta P/L)^c$

Where (K) Is the constant of proportionality and its dimensionless.

$L^3/T = K (M/L.T)^a (L)^b (M/L^2T^2)^c$

L: 3 = - a + b – 2c

M: 0 = a + c

T: -1 = -a – 2c

a= -1, b = 4, c = 1.

$Q = K. (\mu)^{-1} (R)^4 (\Delta P/L)$

$Q = K.\ R^4.\ (\Delta P/L)/\mu$

$\mu = K.\ R^4.\ (\Delta P/L)/\ Q.$

Ex.3: Velocity fluid flow(u)appropriate with the tube(d) and dynamic viscosity(μ) and density(ρ) of the fluid Find the value of the (Re) constant use of dimensional analysis:

$u.\ \alpha,\ d,\ \mu,\ \rho.$

$L/T = Re.\ (L)^a\ (M/L.T)^b\ (M/L^3)^c.$

L: $1 = a - b - 3c$,   M: $0 = b + c$,   L: $-1 = -b$, $a= -1$, $b= 1$, $c= -1$.

$u=Re.\ (d^{-1})\ (\mu)\ (\rho)$, $u= Re.\ \mu / d.\ \rho$, $Re. = u\ .\ d.\ \rho / \mu.$

$Re. = (L/T)(\ L)(M/\ L^3) / (M/\ L.\ T).$

Ex.4: Find Law flow fluid velocity of hole for tank (u) appropriate with acceleration (g) and head hole (Z) use of dimensional analysis.

$u.\ \alpha\ g,\ Z.$

$u= K\ (g)^a\ (Z)^b$

$L/T = K\ (L/T^2)^a\ (L)^b$

L: $1 = a + b$

T: $-1 = -2\ a$

$a= 1/2$

$b= 1/2$

$u= k\sqrt{(g)(Z)}$.

C H A P T E R 2

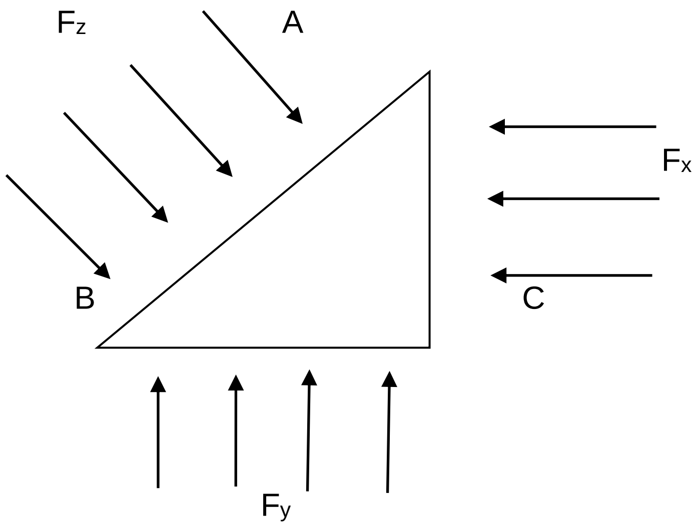
Static fluid

Is a state of the fluid at rest and there is no relative movement between the different layers, shall be velocity is zero and as a result have zero shear stress no matter how the viscosity of the fluid and the workforce static fluid pressure forces only.

The term pressure in the fluid to signify the force of the fluid pressure located on the unit area of the real surface.

$$P = \frac{F}{A} \quad \text{...(13)}$$

Amount of pressure is directed it is located on all sides to a point in the fluid, whether moving or static which is equal in all those points in the fluid static and proof of that can take a very small body of fluid in the form of a right-angled triangle.



P_x = Pressure that affects the fluid direction the horizontal.

P_y = Pressure that affects the fluid direction the Vertical.

P_z = Pressure that affects the fluid direction the slop (AB).

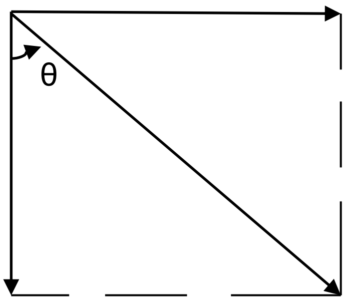
$$P = \frac{F}{A}$$

$$P_x = \frac{Fx}{AC}$$

F_x = Px . AC ……………………………(14)

F_z = Pz . AB ……………………………(15)

Since the fluid in the stagnant, and so could be the result of the forces acting direction the horizontal and vertical = zero.



Composite horizontal

A: Is the result of horizontal forces = zero.

Sinθ =Composite horizontal. F_z

Composite horizontal = F_z . Sinθ

Fz . Sinθ – Fx = 0

Fx = Fz . Sinθ ………..(16) Compensation equations (14) (15) in (16).

Px . AC = Pz . AB . Sinθ ..………(17) By reference to the triangle ABC.

Sinθ = $\frac{AC}{AB}$

AC = AB . Sinθ …………….(18) Compensation equal (18) in (17).

Px . AB . Sinθ = Pz . AB . Sinθ

Px = Pz ……………(19)

B: Is the result of vertical forces = Zero.

Cosθ = $\frac{\text{Composite vertical}}{\text{Fz}}$

Composite vertical = Cosθ . Fz

Forces to top = force to the bottom

Fy – Fz . Cosθ = 0

Fy = Fz . Cosθ ………….(20) Compensation equations (14) (15) in (20).

Py . BC = Pz . AB . Cosθ ……….(21) By reference to the triangle ABC.

$$\frac{BC}{AB} = \cos\theta$$

$BC = AB \cdot \cos\theta$ …………….(22) Compensation equal (22) in (21).

$$Py \cdot AB \cdot \cos\theta = Pz \cdot AB \cdot \cos\theta$$

$Py = Pz$ …………………………..(23) Equal equations (19) and (23).

$$Px = Py = Pz.$$

2.1 Atmospheric pressure - pressure and absolute standard

Atmospheric pressure - is the pressure that Directs air on the earth's surface as a result of weight, but this pressure changes with height and temperature and humidity, so it is a way to calculated different by calculating fluid pressure. And uses Barometer to measure atmospheric pressure and there are several types of metal Barometer and (Barometer Torricelli's).

2.2 Barometer Torricelli's

A tube length of 90 cm dictates the mercury and degeneration of in the basin of mercury decreases of mercury in the tube and then stop at a certain height has been the experience at sea level.

Vacuum or vapor pressure of water (according on temperature)

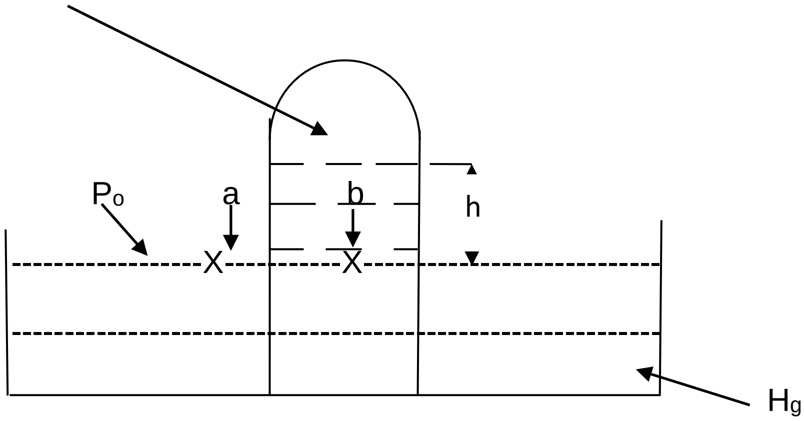


Fig. 1 Barometer mercury Torricelli's one horizontal level

$$P_a = P_b$$

$$P_a = P_o$$

$$P_b = \rho_{Hg} \cdot g \cdot h$$

$$P_o = \rho_{Hg} \cdot g \cdot h$$

This equation shows that the atmospheric pressure is the weight of a column of mercury equal length (760 cm), where the density of mercury (13.6 gm / cm ^{3}) and accelerate the (980 cm / sec^2).

$P_o = \rho_{Hg} . g . h$

P_o = 13.6 gm / cm ^{3} X 980 cm/sec^2 X 760 cm

P_o = 1.013 X 10^6 dyne/cm^2. =1.013 N/m2 (Pa) = 1 atm = 0.987 bar = 1 bar

= 33.9 Ft H_2O = 29.9 in Hg = 14.7 Psi (Ib/in^2).

2.3 Standard pressure and absolute pressure

Standard pressure is the pressure that can be measured by devices such as manometer pressure Borden gauge where atmospheric pressure is based. Standard pressure at a point in a liquid is the pressure of the fluid only without adding atmospheric pressure. If we add atmospheric pressure to standard pressure is considered absolute pressure.

Abs. Pressure = Gage Pressure + Atm. Pressure ……………….(24)

Note:

1- Gage pressure = Abs. Pressure – Atm. Pressure

2- Vacuum Pressure + Abs. Pressure = Atm. Pressure.

3- Vacuum Pressure = Negative pressure relative.

2.3.1 Pressure Gauges

1- Bourdon Gage:

Used to measure the standard pressure (relative) for air and gases confined as in the wheel cars and consists of a metal tube curved (A) and one end closed and relate screw (D) and other reach the source of the pressure causing pressure open slightly across the tube moves the cursor (C) shows the amount of compression.

2- Aneroid Gage:

Used to measure the absolute pressure is a mechanical device consists of a short cylinder empty (A) is surrounded by high light sensitive membrane (Diaphragm) (B) and related arm (D) which indicator is installed (C) and read zero when the index does not exist any pressure, so it measures the absolute pressure.

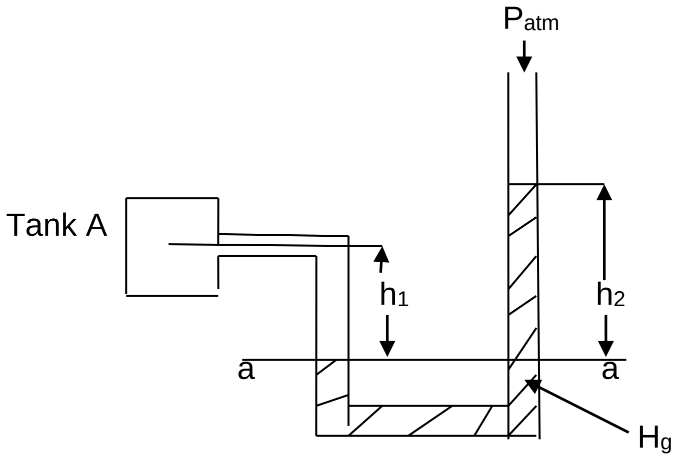
3- Open Manometer:

Is a tube-shaped transparent uses the height of the liquid surface in the tank open and if the tank is closed and under particular pressure fluid then measure the height of the liquid surface in Manometer plus rising output of the pressure off the liquid.

Used manometer also to measure the pressure in the water pipes and fluids the ongoing and it must be contact angle in the pipe (90◦) and Manometer openings should be flush with the inner tube to get the correct reading. It may be the pressure in the pipe or tank High, improves the use of heavy liquid such as mercury, for example in Manometer to avoid excessive for Manometer [2].

Ex.5: Measured pressure fluid tank by manometer simple open and be shaped (U) and connect tank containing fluid to be measured pressure is being fluid in the tube and touching mercury in manometer and the advantage of mercury high and specific weight is calculated pressure after it gets balance level liquid ends of manometer and at (a - a).

Solution:



$P = \frac{F}{A} = \frac{W}{A} = \frac{M.g}{A}$

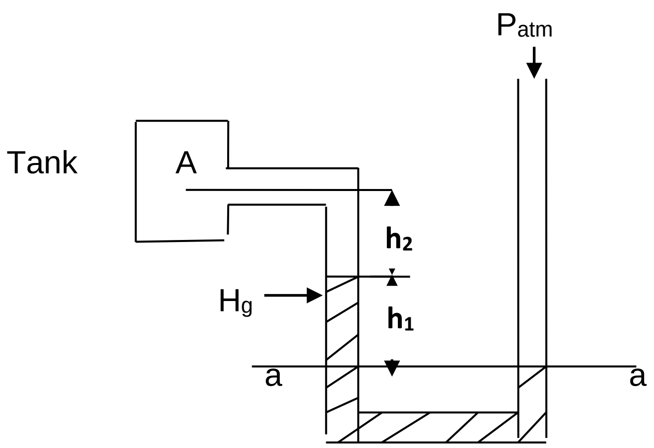
$P = \frac{\frac{M}{V}.V.g}{A} = \frac{\rho.A.h\,g}{A}$

$P = \rho . g . h$ Since the pressure at a level equal (a-a)

$P_A + \rho_A . gh_1 = P_{atm} + \rho_{Hg} . gh_2$

$P_A = P_{atm} + \rho_{Hg} . gh_2 - \rho_A . gh_1$

Ex.6: Monometer normal simple open pressure when (A) less than atmospheric pressure (unstable).



Solution:

At the level of (a-a) equal pressure.

$P_A = P_{atm} - \rho_A .gh_1 - \rho_{Hg}. gh_2$

$P_A + \rho_A .gh_1 + \rho_{Hg} . gh_2 = P_{atm}$

2.3.3 Differential manometer
A transparent tube character (U) of up between tubes or 2 tank to measure the pressure difference between two points and use heavier or lighter fluids of the fluid in the tubes or 2 tank.

Ex.7: Measure the pressure difference between the two reservoirs by differential monometer.
Equal pressure at the level of (a-a)

$P_A + \rho_A . gh_3 + \rho_{Hg} . gh_2 = P_B + \rho_B . gh_1$

$P_B - P_A = \rho_A . gh_3 + \rho_{Hg}. gh_2 - \rho_B . gh_1$

2.3.4 Italics Monometer exact
Is a very accurate capillary tube italics angle (α) and be more efficient to measure the pressure of the very few of vertical monometer because slop pipeline and thus become (α) the distance that rises heavy liquid bigger and be reading of monometer explained.

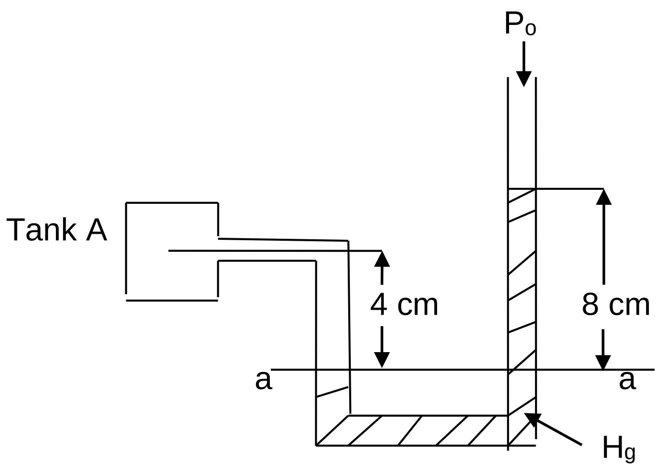
$$Sin\alpha = h/h$$

$$h. = h\ Sin\alpha \quad \text{……………………………………}(25)$$

$$\Delta P = P_1 - P_2 = \rho . g . h \quad \text{……………..…………..…….}(26)$$

$$\Delta P = \rho . g . h . Sin\alpha \quad \text{………………………………..}(27)$$

Ex.8: Monometer normal as in the figure used to measure the pressure in the tank that contains a liquid density (0.8 gm/cm[3]), find the pressure in the tank units (N/m^2), (Pa), and units (mH_2O).



Solution:

At the level of (a-a) equal pressure.

$P_A + \rho_A \cdot gh = P_o + \rho_{Hg} \cdot gh$

$P_A = P_o + \rho_{Hg} \cdot gh - \rho_A \cdot gh$

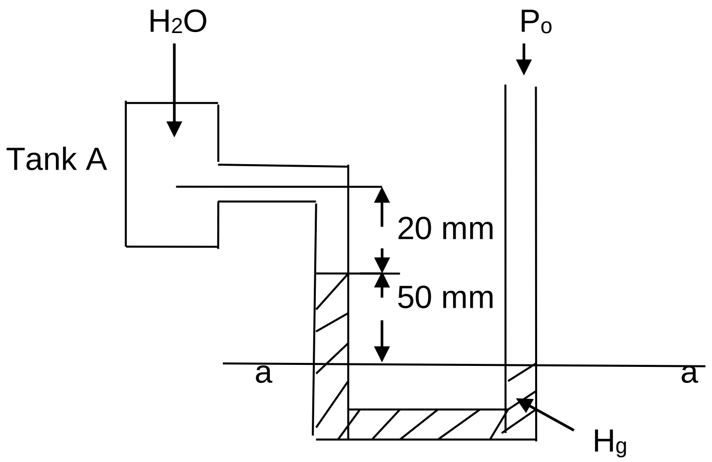
$P_A = 1.013 \times 10^5 \frac{N}{m^2} + 13600 \frac{Kg}{m^3} \times 9.8 \frac{m}{sec^2} \times 0.08\ m - 800\ \frac{Kg}{m^3} \times 9.8\ \frac{m}{sec^2} \times 0.04\ m.$

$P_A = 11.164 \times 10^4 \frac{N}{m^2}$ (Pa).

$11.164 \times 10^4 \frac{N}{m^2} = \rho_{Hg} \cdot gh\ = 11.164 \times 10^4 = 1000\ \frac{Kg}{m^3} \times 9.8\ \frac{m}{sec^2} \times h$

$h_{H2O} = 11.4\ mH_2O.$

Ex.9: Simple monometer containing mercury was used to measure the pressure in the tank (A), which contains water either side of Monometer open to the normal atmospheric pressure. Find the value of the pressure inside the tank units ($\frac{N}{m^2}$).



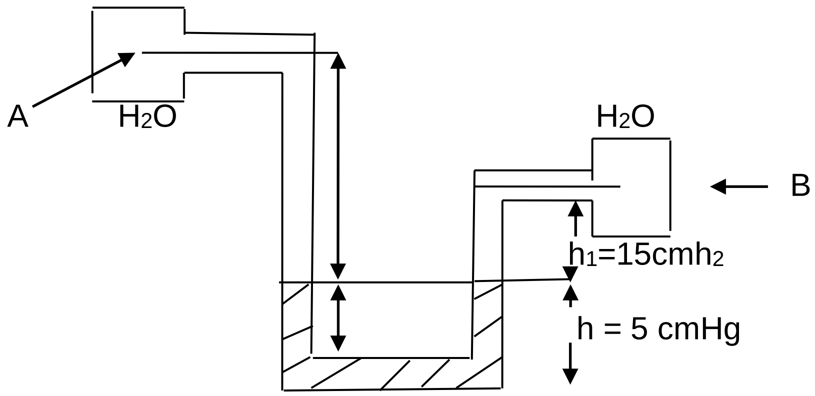
At the level of (a-a) equal pressure:

$P_A + 1000\ \frac{Kg}{m^3} \times 9.8\ \frac{m}{sec^2} \times 0.02\ m + 13600 \times 9.8 \times 0.05 = 1.013 \times 10^5 \frac{N}{m^2}$

$P_A = 9.4 \times 10^4 \frac{N}{m^2}$

Ex.10: Find the pressure in the tank (A) note that the pressure in the tank (B=100 cmH_2O) as in figure.

Tank A=B



Solution:

At the level of (a-a) equal pressure.

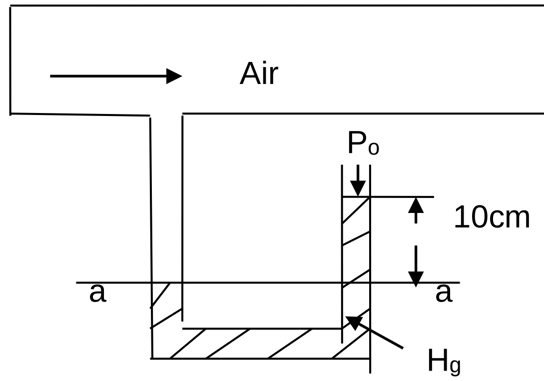
$P_A + \rho_{H2O} . gh_1 = PB + \rho_{H2O} . gh + \rho_{Hg} . gh$

$P_A = P_B + \rho_{H2O} . gh_2 + \rho_{Hg} . gh - \rho_{H2O} . gh_1$

$P_A = 1 X 1000 X 9.8 + 1000 X 0.05 + 13600 X 9.8 X 0.05 – 1000 X 9.8 X 0.15$

$P_A = 1.55 X 10$ (Pa).

Ex.11: Calculate the real pressure air through a tube is being standard pressure (10cmH_2O) read Parameter (730 mmHg).



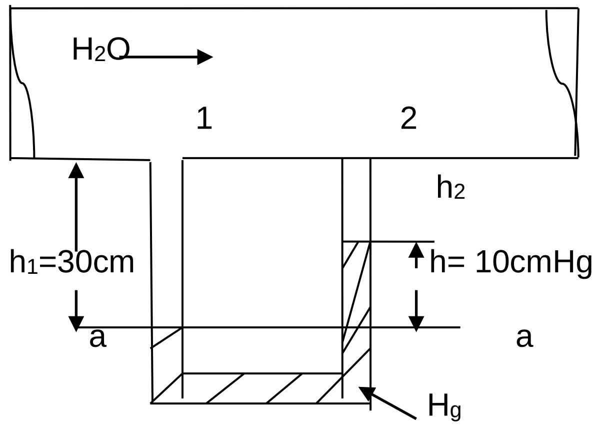
Solution:

$P_{air} = P_o + \rho_{Hg} . gh$

$P_{air} = 73 X 980 X 13.6 + 1 X 980 X 10.$

$P_{air} = 9.83 X 10^5$ dyne/cm^2.

Ex.12: Calculate water pressure difference ($P_2 – P_1$) between the two points (1, 2) by monometer linked between the two points and filled with mercury as in below figure.



Solution:

$P_2 + \rho_{H2O} . gh_1 = P_1 + \rho_{H2O} . gh_2 + \rho_{Hg} . gh$

$P_2 – P_1 = \rho_{H2O} . gh_2 + \rho_{Hg} . gh - \rho_{H2O} . gh_1$

$P_2 – P_1 = 1 X 980 X 20 + 13.6 X 980 X 10 – 1 X 980 X 30$

$P_2 – P_1 = 1.23 X 10^5$ dyne/ cm^2.

C H A P T E R 3

Fluid flow

In this chapter we take the movement of fluids and the forces that affect them and cause the flow, and depends on the laws of fluid dynamic, is:

1. Conservation of Mass: the law of conservation of mass (continuity equation represents).

2. Conservation of Energy: Energy Conservation Act (representing the Bernoulli equation).

Law of conservation of mass (mass not perish not born out of nowhere) This represents the flow of fluid in the pipe or the wind etc..

3.1 Conservation of Mass

Mass Flow rate (m^o): is quantity fluid flow through the unit time through the tube section or surface.
The unit of mass flow rate in (SI) unit (Kg/sec), (g/sec).
Flow rate depends on the density and speed of the fluid passing the tube section, whenever the velocity or density or sectional area of the pipe increased flow rate.
The flow rate of the fluid = velocity X density X sectional area of the pipe [3].

$$m^o = \rho \cdot u \cdot A \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(28)$$

Since the circular tube section, the cross-section area equal to the square radius:

$$A = \frac{\pi}{4} \cdot d^2$$

$$m^o = \rho \cdot u \cdot \left(\frac{\pi}{4} \cdot d^2\right)$$

Ex.13: Find mass flow rate water in units (kg/min) flowing in a pipe diameter of 10 cm and velocity 1 ($\frac{\text{m}}{\text{sec}}$).
$m^o = \rho \cdot u \cdot A$
$m^o = 1000 \frac{\text{Kg}}{\text{m}^3} \text{ X } 1 \frac{\text{m}}{\text{sec}} \text{ X } \frac{\pi}{4}\left(\frac{10}{100}\right)^2$
$m^o = 7{,}85 \frac{\text{Kg}}{\text{sec}} = 471 \frac{\text{Kg}}{\text{min}}$

3.1.1 Flow rate (Q)

Is the volume of the fluid through the unity of time and used in the case of more fluid because the density of the liquid nearly constant with temperature change and pressure, units (SI) ($\frac{\text{m}^3}{\text{sec}}$),($\frac{\text{lit}}{\text{hr}}$), ($\frac{\text{Cm}^3}{\text{sec}}$) and English ($\frac{\text{Gal}}{\text{hr}}$), (British gallon = 4.546 Liter), English gallon = 3.78 Liter.

Q = Flow velocity X sectional area of the pipe.

Q = u . A

Ex.14: Calculate the flow rate crude oil through a tube diameter of 8 cm velocity 2 ($\frac{\text{m}}{\text{sec}}$), units ($\frac{\text{m}^3}{\text{hr}}$), and ($\frac{\text{Lit}}{\text{hr}}$).

Q = u . A

$Q = 2\frac{m}{sec} \text{ X } \frac{3600sec}{hr} \text{ X } \frac{\pi}{4} \text{X } (\frac{8}{100})^2 \text{ m}^2$

$Q = 36.2 \frac{m^3}{hr}$

$Q = 36.2 \frac{m^3}{hr} \text{X}1000 \frac{lit}{\text{m}^3} = 36.2 \text{ X } 10^3 \frac{lit}{\text{hr}}$.

3.2 Continuity equation of liquid flow

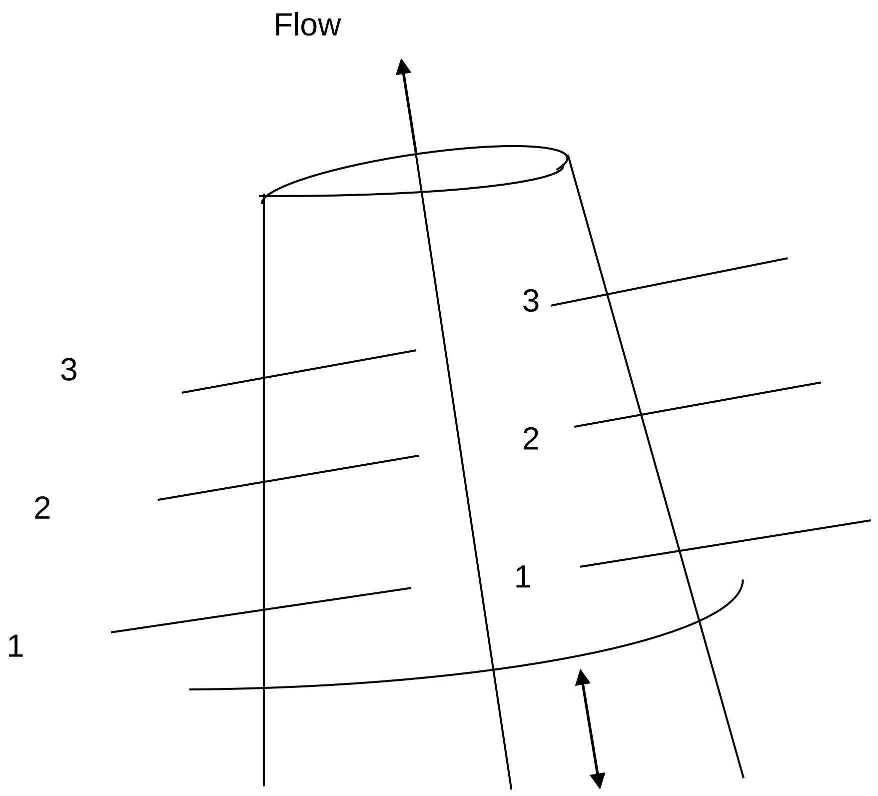


Fig. 2 Shows a variable diameter tube through which the liquid being one.

Tube change diameter 1-1 area A_1 and velocity liquid u_1 and 2-2 area A_2 and velocity liquid u_2.

And 3-3 area A_3 and velocity liquid u_3.

Mass flow rate through unit time in 1-1 $m^o = \rho_1 . u_1 . A_1$.

Mass flow rate through unit time in 2-2 $m^o = \rho_2 . u_2 . A_2$.

Mass flow rate through unit time in 2-2 $m^o = \rho_3 . u_3 . A_3$.

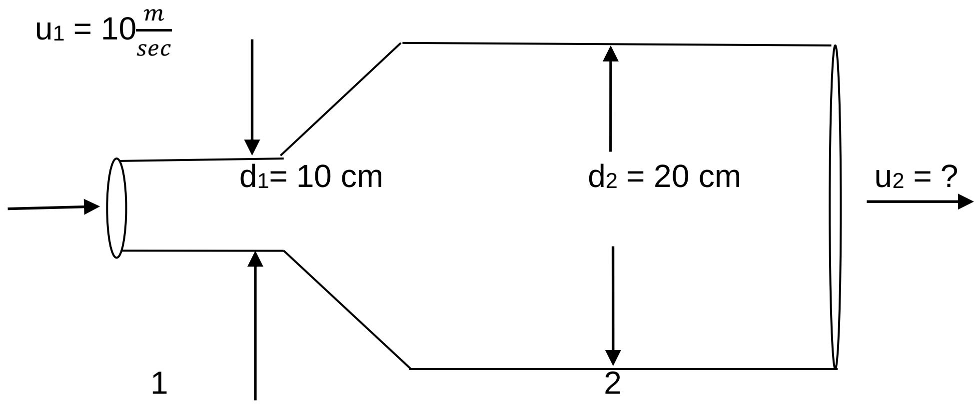
Quantity liquid through unit time for three section equal

$m^o{}_1 = m^o{}_2 = m^o{}_3$

$\rho_1 . u_1 . A_1 = \rho_2 . u_2 . A_2 = \rho_3 . u_3 . A_3$.

$\rho_1 = \rho_2 = \rho_3$.

Ex.15: Calculate mass flow rate of water in tube diameter, velocity ($10\frac{m}{sec}$), and find velocity in change tube diameter to 20 cm?



Solution:

$A_1 = \frac{\pi}{4}(d_1)^2 = \frac{\pi}{4}(10)^2 = 78.54\ cm^2$.

$u_1 = 10\frac{m}{sec} = 1000\frac{Cm}{sec}$

$m^o = \rho_1 . u_1 . A_1$

$m^o = 1\ \frac{gm}{Cm^3}\ X\ 1000\ \frac{Cm}{sec}\ X\ 78.54\ cm^2$.

$m^o = 78.5\ \frac{Kg}{sec}$

$A_2 = \frac{\pi}{4}(d_2)^2 = \frac{\pi}{4}(20)^2 = 314.16\ cm^2$.

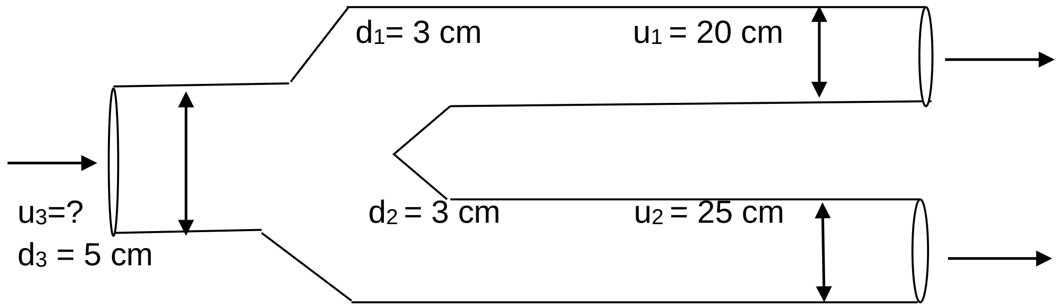
$u_1 . A_1 = u_2 . A_2$

$u_2 = \frac{u_1 . A_1}{A_2}$

$u_2 = \frac{78.54X1000}{314.16} = 250\ \frac{Cm}{sec} = 2.5\ \frac{m}{sec}$.

Note: Increased the diameter of the pipe lower the velocity.

Ex.16: Liquid passing in two pipe diameters (3 cm) of the pipe inlet in the third pipe diameter (5 cm) and liquid velocity in first pipe (20 cm/sec) and in two pipe (25 cm), find liquid velocity in third pipe?



.

Solution:

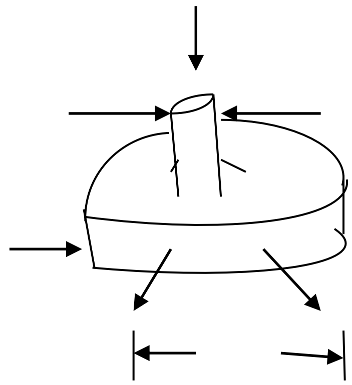
$u_3 . A_3 = u_2 . A_2 + u_1 + A_1$

$u_3 . \frac{\pi}{4}(d_3)^2 = u_2 . (\frac{\pi}{4}(d_2)^2) + u_1 . \frac{\pi}{4}(d_1)^2$

$u_3 . \frac{\pi}{4}(5)^2 = 25cm/sec \ X \ \frac{\pi}{4}(3)^2 cm + 20 \ cm/sec \ X \ \frac{\pi}{4}(3)^2$

u_3 = 9/25 (20 + 25) = 16.2 m/sec.

(A) Flow velocity of the air outside of the two Cylinder diffuser as in Figure shown if the pipe diameter at the entrance (2 cm) and the diameter of both discs (20 cm) and the distance between them (0.5 cm) and flow velocity in the Pipe entrance (5 m / sec).
(B) Flow rate in the diffuser.



Solution:
Continuity equation

$u_1.A_1 = u_2.A_2$

$u_2 = \frac{u1.A1}{A2} d_2$ =0.5 cm $\quad u_2$

$A_1 = \frac{\pi}{4} X \ (d_1^2) = \frac{\pi}{4} X \ (0.02^2) = 0.000314 \ m^2 \ d_2$

Area of the cylinder = Perimeter rule X Height. (Diffuser)

$A_2 = \pi. d_2. L = \pi \ X \ 0.2 \ X \ 0.005 = 0.000314 \ m^2$.

$u_2 = 5 \ X \ \frac{0.000314}{0.00314} = 50 \ \frac{m}{sec}$

To calculate the flow rate:

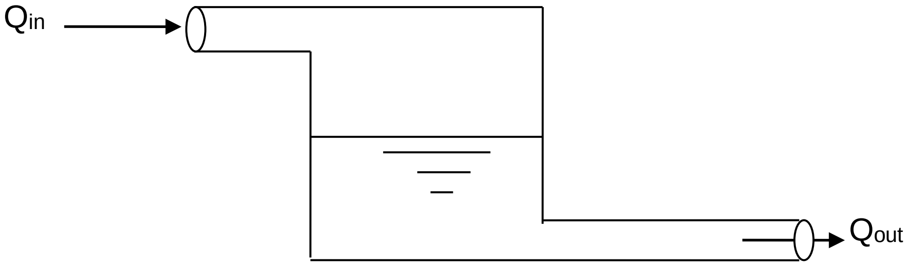
$Q = u_1. A_1$

$Q = 5 \ X \ 0.000314 = 0.00157 \ \frac{m^3}{sec}$.

Ex.17: Tank contains (100 m^3), the fluid passes through the tank with rate (200 m^3 / hr) and goes out at a rate (15 m^3 / hr) Calculate the time required to fill the tank, if the tank was full to half at the beginning.

Solution:

Rate of increase of the liquid in the tank = the rate entering the liquid inside the tank - the rate of exit liquid out of the tank.



$\Delta Q = Q_{in} - Q_{out}$

$20\,\frac{m^3}{hr} - 15\,\frac{m^3}{hr} = 5\,\frac{m^3}{hr}.$

Since the tank is filled to the at the beginning half.

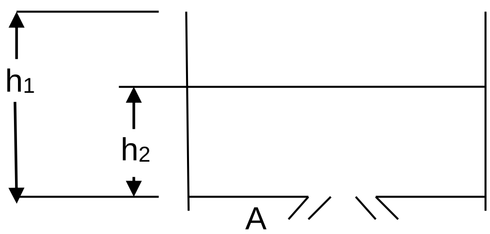
$\frac{100}{2} = 50\ m^3$

The time required to fill the tank is:

$\frac{50 m^3}{5\frac{m^3}{hr}} = 10\ hr.$

Variable flow rate with time:

$t = \frac{2A_b}{A} X \frac{\sqrt{h_1} - \sqrt{h_2}}{\sqrt{2g}}$



A_b = Base area of the tank.

A = Sectional area hole the bottom of the tank.

h_1 = Height of the liquid at the beginning.

h_2 = Height of the liquid after the passage of time (t).

g = Acceleration.

Ex.18: Calculate the time required to discharge the liquid from the tank through an slot in the bottom base if the ratio of the base of the tank area to area slot (1:600) and the height of the liquid in the tank at the beginning (10 cm).

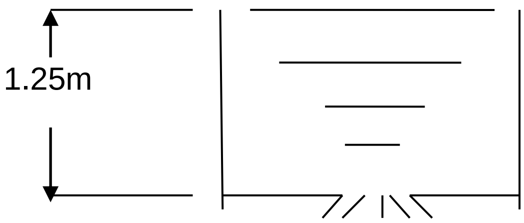
<u>Solution:</u>

$$t = \frac{2A_b}{A} X \frac{\sqrt{h_1} - \sqrt{h_2}}{\sqrt{2g}}$$

$$t = \frac{2 X 600}{1} X \frac{\sqrt{10}}{\sqrt{2} X 9.8}$$

t = 855.98 sec.

Ex.19: Swimming pool length (10 m) and width (6 m) and the height of the water in which (1.25 m), find time crisis to empty the basin if water is flowing through the hole from the base of basin area (0.023 m 2).



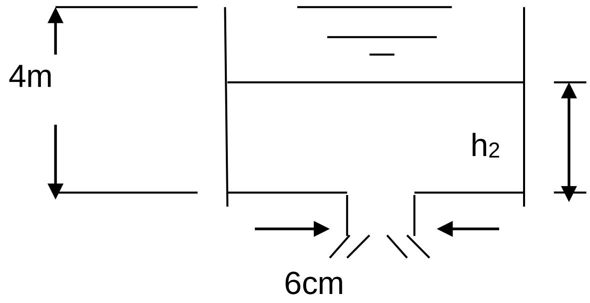
Solution:

$$t = \frac{2A_b}{A} X \frac{\sqrt{h_1} - \sqrt{h_2}}{\sqrt{2g}}$$

$$t = \frac{2 X 60}{0.023} X \frac{\sqrt{1.23}}{\sqrt{2} X 9.8}$$

t = 21.6 min.

Ex.20: Tank cross-sectional area $1m^2$ contains water height of 4m, find the height of the water after two minutes if the water was flowing from a hole in the base of the tank diameter of 6 cm and find a low in the level of the surface of the water in the tank.



Solution:

$A = \frac{\pi}{4} X (\frac{6}{100})^2 = 0.028\ m^2$

t = 2 min = 120 sec.

$t = \frac{2A_b}{A} X \frac{\sqrt{h_1} - \sqrt{h_2}}{\sqrt{2g}}$

$t = \frac{2 X 1}{0.028} X \frac{\sqrt{4} - \sqrt{h_2}}{\sqrt{2} X 9.8}$

$h_2 = 1.44$ m.

$\Delta h = 4 - 1.44 = 2.56$ m. Low of the water level.

3.3 The flow of gases

3.3.1 Continuity equation for gas

To find a relation between the velocity of gas flow in the tube variable diameter two sections.

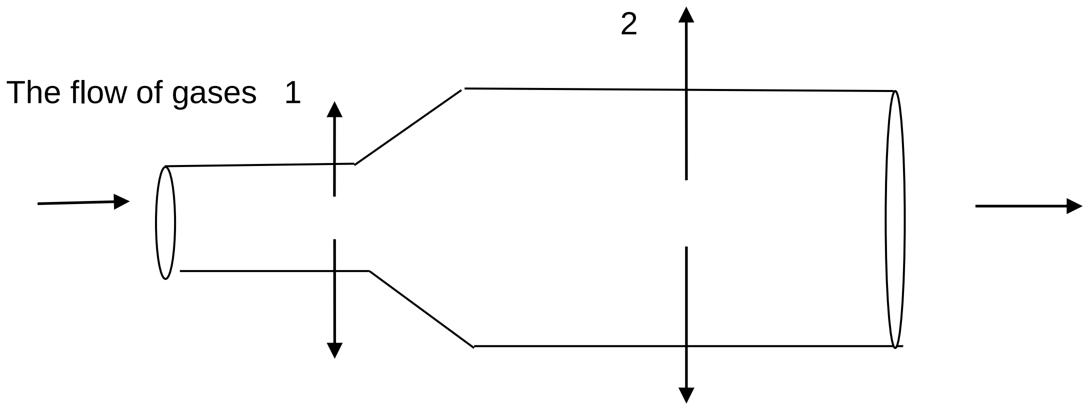


Fig. 3 Form shows a variable diameter tube through which gas being.

Assume that:

In Section one 1-1	In Section two 2-2
ρ_1 Gas density. **P_1** Gas pressure. **T_1** Absolute temperature. **A_1** Sectional area tube. **u_1** Velocity Gas.	**P_2** Gas density. **P_2** Gas pressure. **T_2** Absolute temperature. **A_2** Sectional area tube. **u_2** Velocity Gas.

Using the general law of gases:

Pressure first . The first volume = Number of moles . General constant gas . Absolute temperature first.

$$P_1 . V_1 = n . R . T_1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(29)$$

$$\text{Number of moles} = \frac{\text{weight}}{\text{Molecular weight}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(30)$$

$$P_1 . V_1 = \frac{M}{Mwt} . R . T_1$$

$$P_1 . Mwt = \frac{M}{V_1} . R . T_1 .$$

$$P_1 . Mwt = \rho . R . T_1 .$$

$$\rho_1 = P_1 . \frac{Mwt}{R . T_1} \quad \ldots\ldots\ldots\ldots(31)$$

$$\rho_2 = P_2 . \frac{Mwt}{R . T_2} \quad \ldots\ldots\ldots\ldots(32)$$

Since the continuity equation of fluid equal to

$$Q_1 = Q_2$$

$$\rho_1 . u_1 . A_1 = \rho_2 . u_2 . A_2$$

From equation (31) (32) in (33) we get:

$$P_1 . \frac{Mwt}{R . T_1} . u_1 . A_1 = \frac{Mwt}{R . T_2} . u_2 . A_2 \quad \ldots\ldots\ldots\ldots(33)$$

$$\frac{P_1}{P_2} . \frac{T_2}{T_1} = \frac{u_2}{u_1} . \frac{A_2}{A_1}$$

$$\frac{u_2}{u_1} = \frac{P_1}{P_2} . \frac{T_2}{T_1} . \frac{A_1}{A_2}$$

Ex.21: Find the ratio between my velocity gas pipe variable diameter if the pipe diameter in the first section (2m) and when the second section (3m) and pressure in the first section (90 N/m^2) In the second section (40 N/m^2), either the temperature in the first section was (200 ◦F) and the second section (150 ◦F).

<u>Solution:</u>

$$\frac{u_2}{u_1} = \frac{P_1}{P_2} \cdot \frac{T_2}{T_1} \cdot \frac{A_1}{A_2}$$

$$\frac{u_2}{u_1} = \frac{90}{40} \cdot \frac{150+460}{200+460} \cdot \frac{\frac{\pi}{4} X\, 2^2}{\frac{\pi}{4} X\, 3^2}$$

$$\frac{u_2}{u_1} = \frac{61}{66} = 87.46$$

3.3.2 Fluid energy (Conservation of energy)

Energy cannot perish but transformed from one form to another equation that we get by using this law called energy or Bernoulli equation, take different forms depending on the type and the fluid flow and dimensions used in the analysis.

Types of energies that lead to the movement of fluids. Energy generally known as the susceptibility to achievement work and divided into:

1 - Potential energy (E_z): This type of energy is produced often from the effect of the power of gravity, for example, we find that the water stored in tanks high even have adequate capacity for flow in pipelines for distribution, and downhill car from the top of the slope to the bottom without running the engine powered underlying Depends on body mass and height for a certain level [4].

$$E_z = M \cdot g \cdot Z \quad \text{.......................................(34)}$$

2 - Energy Pressure (E_p): Energy is those owned liquid molecules as a result of pressure If the mass of the fluid pressure (P), and density (ρ).

$$E_p = \frac{P \cdot M}{\rho} = P \cdot V$$

V = volume of the fluid directed pressure admitted to the system to get work.

3. Kinetic energy: Kinetic energy: is energy consisting of body mass (M) movement depends on the velocity (u).

$$E_h = \frac{1}{2} M.\, u^2 \quad \text{.......................................(35)}$$

All energies measured in units of (force * Distance), (N. M) and is called the Joule. The total energies of fluid particles in motion equal to the potential energy and kinetic energy and pressure energy.

$$\text{Total energy (E)} = M.\,g.\,z + \frac{1}{2} M.\,u^2 + \frac{P\,.\,M}{\rho} \quad \text{.....................(36)}$$

To find overall height resulting from the movement of molecules divide equation (M. g) we get:

Overall height = height of the potential energy (shipment height) + height of the kinetic energy (speed shipment) + height of the energy pressure (pressure shipment).

$$\text{Total head (H)} = Z + \frac{1}{2g} u^2 + \frac{P}{\rho.g} \quad \text{..............................(37)}$$

3.4 Energy equation

3.4.1 Bernoulli's equation

Energy equation or equation energy conservation which to calculate flow velocity, pressure or Height or losses friction, etc., and will derive this equation assuming flow constant fluids non compressibility, and ideally any flow without friction, when transmission unit mass of the fluid of point (1) to the point (2) as shown in the figure below:

Work product of a turbine work given by the pump

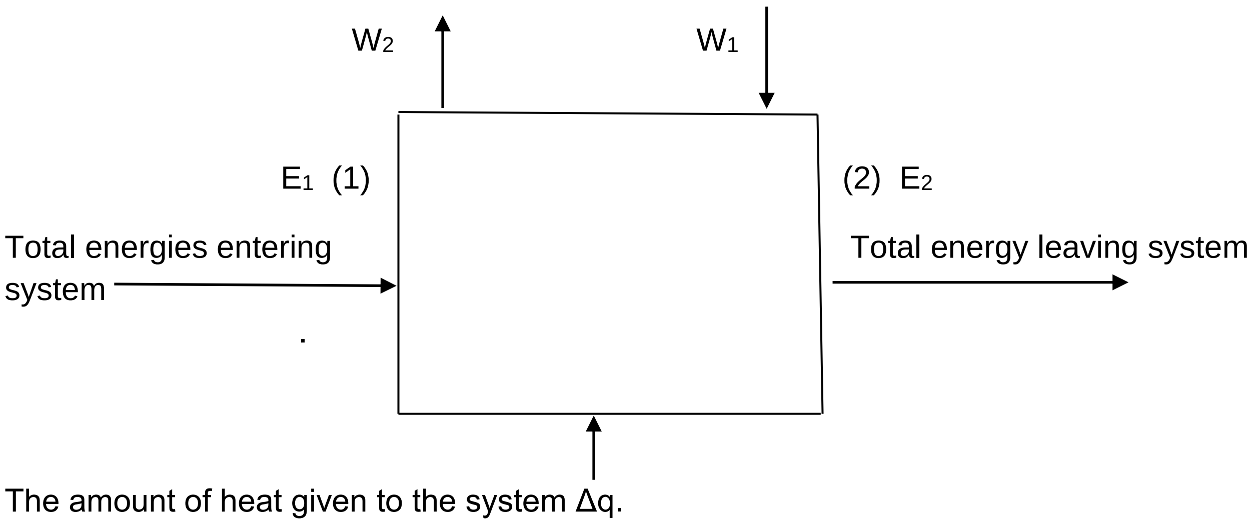


Fig. 4 Heat balance of the system

Δq = The amount of heat added or lost.
W_1 = Work accomplished on a fluid pump or compressor.
W_2 =The amount of work that has been accomplished the fluid at the surrounding or when there is a turbine or energy loss as a result of friction.

When the work of balancing energy entering and energy outside to system we get:
Total energies entering = total energies leaving (the law of conservation of energy).

Inlet = outlet

$$E_1 + \Delta q + W_1 = W_2 + E_2$$

$$E_2 - E_1 = \Delta q + W_1 + W_2$$

Since the fluid is ideal (no friction)
There are no Add and there is no drag of the temperature of the system. ($\Delta q = 0$)
There is no pump or compressor. $W_1 = 0$

$$E_2 - E_1 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (38)$$

Where (E_1) (E_2) are Total of the energies of the molecules of the fluid at the point (38) and (36) are entering the system and leaving the system and which have been collected at one equation:

$$E = M.\ g.\ z + \frac{1}{2} M.\ u^2 + \frac{P\ .\ M}{\rho}$$

Substitute equation (2) in (1) we get:

$$[M.\ g.\ z_2 + \frac{1}{2} M.\ u_2^2 + \frac{P_2\ .\ M}{\rho}] - [M.\ g.\ z_1 + \frac{1}{2} M.\ u_1^2 + \frac{P_1\ .\ M}{\rho}] = 0$$

And dividing the equation (M. g) we get:

$$[Z_2 + \frac{1}{2g}\ .\ u_2^2 + \frac{P_2}{\rho g}] - [Z_1 + \frac{1}{2g}\ .\ u_1^2 + \frac{P_1}{\rho g}] = 0$$

$$Z_1 + \frac{u_1^2}{2g} + \frac{P_1}{\rho g} = Z_2 + \frac{u_2^2}{2g} + \frac{P_2}{\rho g}$$

$$\text{Or} \quad [\Delta Z + \frac{\Delta u^2}{2g} + \frac{\Delta P}{\rho g}] = 0$$

This equation is called the Bernoulli equation.

ΔZ = Height product (Height shipment).

$\frac{\Delta u^2}{2g}$ = Velocity height, (shipment velocity).

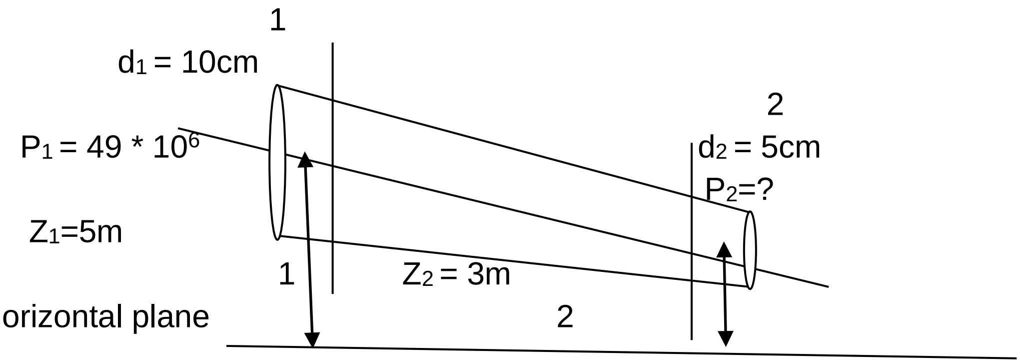
$\frac{\Delta P}{\rho g}$ = Pressure head, (shipment Pressure).

3.4.2 Limitation of Bernoulli's equation

1 - the speed of each liquid molecules cross-section tube be regular.
2 - not the effect of external forces, except for the effect of gravity on the liquid.
3 - not part of the energy loss during the flow of the liquid.
4 - If the flow of fluid through a curved path when it should be calculated the loss of energy as a result of centrifugal forces, and this is when using the Bernoulli equation [5].

Application examples of the Bernoulli equation:

Ex.22: Water flowing through a tube changing diameter of (10 cm) high (5 m) of the horizontal plane to diameter (5 cm) high (3 m) of the same level where the pressure at the first section ($49 * 10^6$) and flow velocity when the first section 1 m / sec Calculate pressure at the second section?



Solution:

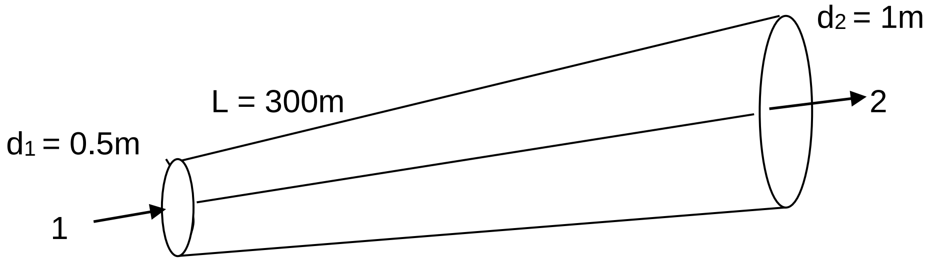
The continuity equation $u_1 . A_1 = u_2 . A_2$

$$u_2 = \frac{u1.A1}{A2} = \frac{\frac{\pi}{4} X\ (10)^2\ X\ 100}{\frac{\pi}{4} X\ (5)^2} = 400\ \frac{cm}{sec} = 4\ \frac{m}{sec}$$

$$Z_1 + \frac{u_1^2}{2g} + \frac{P_1}{\rho g} = Z_2 + \frac{u_2^2}{2g} + \frac{P_2}{\rho g}$$

$$5m + \frac{1^2}{2\ X\ 9.8} + \frac{49\ X\ 10^6}{1000\ X\ 9.8} = 3m + \frac{4^2}{2X\ 9.8} + \frac{P_1}{1000\ X\ 9.8} \qquad P_2 = 9\ X\ 10^6 \frac{N}{m^2}$$

Ex.23: Tube length (300 m) inclination (1/100) and a diameter varies from (1m) to (0.5 m) flowing through the water rate (5400 l / min) and the pressure was passage by the second (0.7 kg/cm^2) very pressure passage by the first. Note that (0.7 kg / cm^2) represents pressure divided by units acceleration, (p/g).



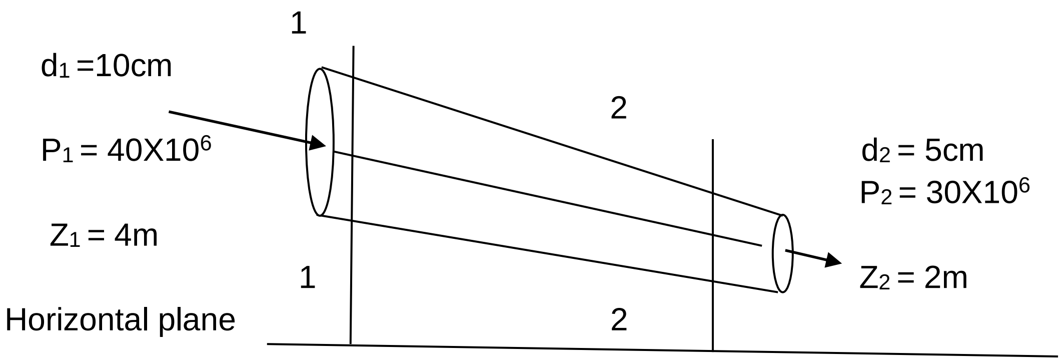
Solution:

$h_1 = 0 = Z_1\ Z_2 = 300\ X\ \frac{1}{100} = 3$ m.

$A_1 = \frac{\pi}{4}(0.5)^2 = 0.19\ m^2$

$A_2 = \frac{\pi}{4}(1)^2 = 0.78\ m^2$

Ex.24: Water flows through a pipe diameter varies from (10 cm) high (4 m) to diameter (5cm) high (2m) If the pressure on the first section (40 X 106) and when the second section (30 X 10^6 N/m^2), Find velocity at the first section.



Solution:

The continuity equation $u_1 . A_1 = u_2 . A_2$

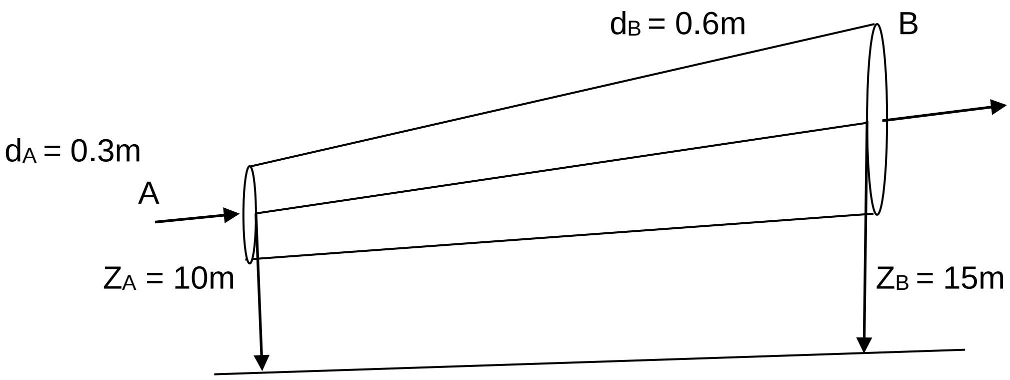
$$u_2 = \frac{u1.A1}{A2} = \frac{\frac{\pi}{4}X\,(10)^2}{\frac{\pi}{4}X\,(5)^2} = 4u_1$$

$$Z_1 + \frac{u_1^2}{2g} + \frac{P_1}{\rho g} = Z_2 + \frac{u_2^2}{2g} + \frac{P_2}{\rho g}$$

$$4 + \frac{{u_1}^2}{2\,X\,9.8} + \frac{40\,X\,10^6}{1000\,X\,9.8} = 2 + \frac{16u_1^2}{2X\,9.8} + \frac{30X10^6}{1000\,X\,9.8}$$

$$u_1 = 29.9\,\frac{m}{sec}$$

Ex.25: Water flowing through the passages (A) (B) rate (0.4 m^3/s), if pressure of the water column in the section (4 meters of water) and diameter of the pipe at (A) (0.3 m) and high (10 m) from the horizontal plane and diameter at (0.6 m) and high (15 m) Find the pressure of the water column at (B).



The horizontal plane

$$Q_A = u_A.\,A_A = u_A = \frac{Q}{A_A}$$

$$u_A = \frac{0.4}{\frac{\pi}{4}0.3^2} = 5.7\,\frac{m}{sec}$$

$$u_B = \frac{0.4}{\frac{\pi}{4}0.6^2} = 1.4\,\frac{m}{sec}$$

$$Z_A + \frac{u_A^2}{2g} + \frac{P_A}{\rho g} = Z_B + \frac{u_B^2}{2g} + \frac{P_B}{\rho g}$$

$$10 + \frac{5.7^2}{2 \text{ X } 9.8} + \frac{\rho g h_A}{1000 \text{ X } 9.8} = 15 + \frac{1.4^2}{2\text{X } 9.8} + \frac{P_B}{1000 \text{ X } 9.8}$$

$\frac{P_B}{\rho g}$ = 0.6 mH_2O P_B = 5880 $\frac{N^2}{m}$

3.4.3 Bernoulli's equation applications

The basic equation of Bernoulli equation has many applications in fluid movement and the most important of these applications:

1- Venturi meter.
2- Orifice meter.
3- Pitot tube.
4- Measuring the velocity of the liquid flow of a circular hole in the tank.
5- Bernoulli's equation when there is a pump.

3.4.3.1 Venturi meter

Used to measure the flow rate of the liquid which consists of the following parts:

a - Convergent cone:

Is a short pipeline starts from the tube diameter associated with (d_1) and take its walls convergent to the small diameter (d_2).

b - Throat

The walls are parallel and have a diameter equal to (d_2) and constant.

3 - Divergent cone

Is the last part of the measure you take walls divergent the diameter (d_2) to diameter (d_1), have a length of about (3-4) weaken length of the cone of convergence, when the flow of fluid through the scale of the first section (d_1) to the second section (d_2) during the convergence cone, As a result accelerate the liquid increases flow velocity at (d_2) and this increase quickly lead to a decrease in pressure, there is fixed ratio are relying upon between (d_1/d_2) and preferably be (1/3) (1/2) until you get to read a set of column manometer not get other problems, after the arrival of the liquid to the last section (cone spacing) less speed and pressure and increases rapidly when decries the lead to break the course of this fluid works spacing along the cone (3-4) times the length of the cone of convergence as well as to reduce the loss due to friction [6].

To find a formula to measure the flow rate in this measure apply Bernoulli's equation when the colon (1) (2) in the scale in its horizontal so that it is equal height ($Z_1 = Z_2$) we get:

$$Z_1 + \frac{u_1^2}{2g} + \frac{P_1}{\rho g} = Z_2 + \frac{u_2^2}{2g} + \frac{P_2}{\rho g}$$

$$\frac{P_1 - P_2}{\rho g} = \frac{u_2^2 - u_1^2}{2g}$$

$$\frac{2}{\rho g}(P_1 - P_2) = u_2^2 - u_1^2$$

$$u_1 . A_1 = u_2 . A_2$$

$$u_2 = \frac{A_1}{A_2} . u_1$$

$$u_2 = \frac{\frac{\pi}{4}d_1^2}{\frac{\pi}{4}d_2^2} \,.\, u_1 = u_2 = \frac{d_1^2}{d_2^2} \,.\, u_1$$

$$u_2^2 = \frac{d_1^4}{d_2^4} \,.\, u_1^2$$

$$\frac{2}{\rho g}(P_1 - P_2) = \frac{d_1^4}{d_2^4} \,.\, u_1^2 - u_1^2$$

$$\frac{2}{\rho g}(P_1 - P_2) = u_1^2\left(\frac{d_1^4}{d_2^4}-1\right)$$

$$u_1 = \sqrt{\frac{2(P_{1-P_2})}{\rho(\frac{d_1^4}{d_2^4}-1)}} \quad ....(39)$$

Velocity fluid flow through the venture measure.
Theoretical flow rate fluid

$$Q_{theo} = u_1.\ A_1 \quad ....(40)$$

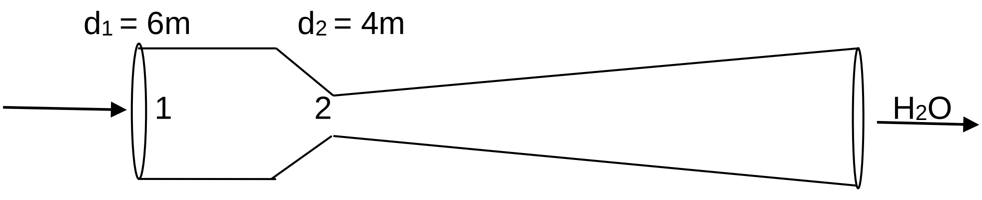
$$Q_{theo} = \sqrt{\frac{2(P_{1-P_2})}{\rho(\frac{d_1^4}{d_2^4}-1)}}.\ A_1 \quad ....(41)$$

Practical flow rate = theoretical flow rate * Constant Gauge.

$$Q_{act} = Q_{theo} = \sqrt{\frac{2(P_{1-P_2})}{\rho(\frac{d_1^4}{d_2^4}-1)}}.\ A_1.\ C \quad ....(42)$$

Coefficient Venture scale depends on the ratio and the quality of flow (Limners - transitional - turbulent) and between the value of (0.94 - 0.96 - 1.0).

Ex.26: Calculate the theoretical flow rate of water outside of the measure venture as in Figure:



$$\frac{P_{1-}\ P_2}{g} = \frac{3kg}{m^2}$$

$u_1.\ A_1 = u_2.\ A_2$

$u_2 = \frac{A_1}{A_2} \,.\, u_1$

$u_2 = \frac{\frac{\pi}{4}d_1^2}{\frac{\pi}{4}d_2^2} \,.\, u_1$

$u_2 = \frac{36}{16}.\ u_1$

$Z_1 = Z_2$

$\frac{P_1 - P_2}{g} = \frac{u_2^2 - u_1^2}{2g}$

$\frac{3\,\frac{kg}{m^2}}{1000\frac{kg}{m^3}} = \frac{1}{2x9.8}(\frac{36^2}{16^2}.\ u_1^2 - u_2^2)$

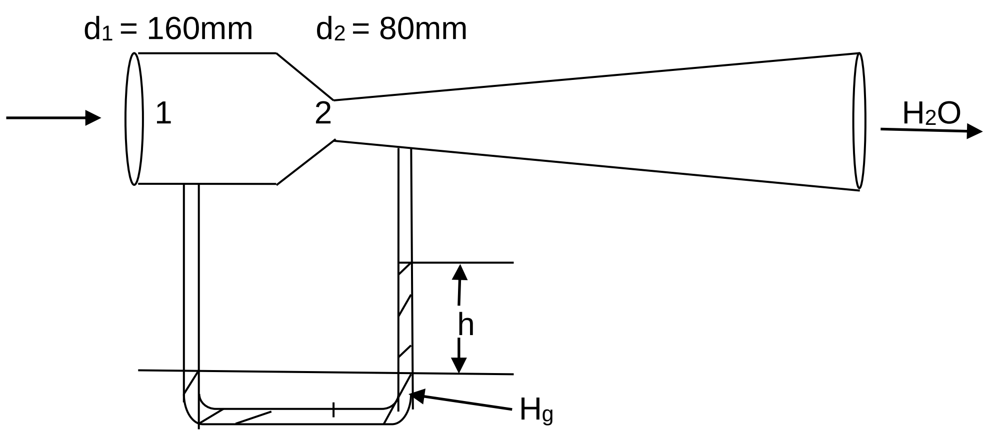
$u_1 = 0.12\ \frac{m}{sec}$

$Q_{theo} = u_1.\ A_1$

$Q_{theo} = \frac{\pi}{4}(6)^2\ X\ 0.12$

$Q_{theo} = 3.4\ \frac{m^3}{sec}$

Ex.27: Calculate the height of a column of mercury in manometer linked measure Venturi horizontal the situation which diameter entrance (160 mm) diameter necked (80 mm) and being through which oil and weight Specific (0.8) knowing that constant measure (C = 1) and the rate of oil flow practical (50 liters /seconds).



$A_1 = \frac{\pi}{4}d_1^2 = \frac{\pi}{4}\ (\frac{160}{10})^2 = 201.06\ cm^2$

$A_2 = \frac{\pi}{4}d_1^2 = \frac{\pi}{4}\ (\frac{80}{10})^2 = 50.26\ cm^2$

$Q_{act} = 50\ \frac{lit}{sec} X\ \frac{1}{1000}\frac{m^3}{lit}\ X\ \frac{(100cm)^3}{m^3} = 50\ X10^3\ \frac{cm^3}{lit}$

$Q_{act} = C.Q_{theo}$

$Q_{theo} = C.A\ \sqrt{\frac{2\triangle P}{\rho[\left(\frac{A_1^2}{A_2^2}\right)-1]}}$

$50\ X10^3 = 1\ X\ 201.06\ \sqrt{\frac{2\triangle P}{0.8[\left(\frac{201.06^2}{50.26^2}\right)-1]}}$

$\triangle P = 3.7\ X\ 10^5\ \frac{dyne}{cm^2}$

$\triangle P = \rho_{Hg}.g.h$

$h = \frac{3.7\ X\ 10^5}{13.6\frac{g}{cm^3} X\ 980\ cm/sec^2} = 27.8\ cm\ Hg$

3.4.3.2 Orifice meter

Advantage of this measure accuracy and simplicity and ease of installation and maintenance and low cost, which is a plate with a small hole at its center, is placed in the course of the fluid and the hole narrow lead to an increase in the velocity of the fluid (according to the equation of continuity), leading to reduced pressure (according to equation Bernoulli) and is measuring pressure by manometers the links between the two points (1) and (2) to obtain the final the equation of continuity same the derivation measure of Venturi by applying Bernoulli's equation and the continuity equation:

$$Q_{act} = C.A\sqrt{\frac{2\triangle P}{\rho[\left(\frac{D_1^4}{D_2^4}\right)-1]}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(43)$$

Value of the constant is different in this measure, ranging from 0.61 - 0.62, and sometimes to 0.65 depending on the type and flow according to the ratio $\frac{D_2}{D_1}$.

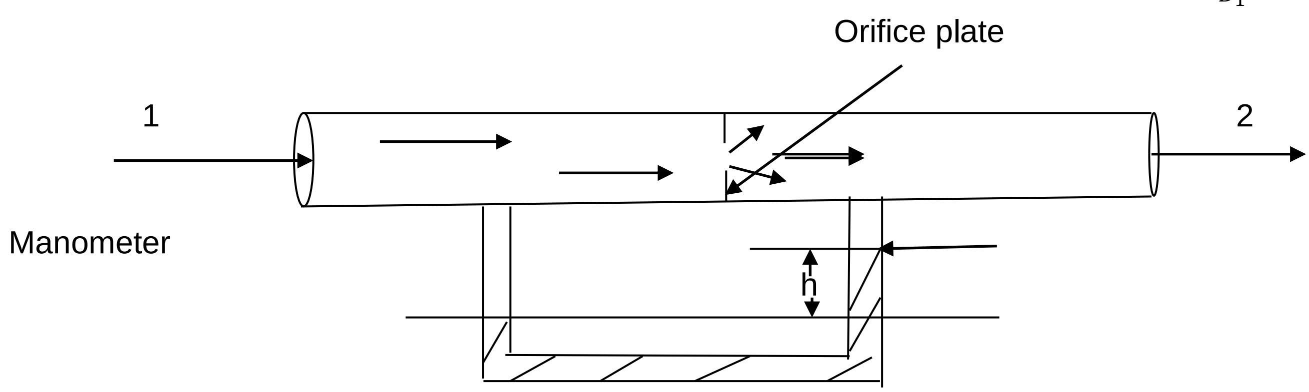


Fig. 5 The shape of the shows parts measure of orifice

Ex.27: Calculate the flow rate of oil the practical (density 0.8 g/cm^3) through a tube diameter (20 cm) contains on Orifice plate diameter (10cm) (C=0.64) the read manometer (10 mmHg).

$d_1 = 20$ cm $\quad d_2 = 10$cm $\quad P_1-P_2 = \rho gh \quad$ C=0.64

$$Q_{act} = C.A\sqrt{\frac{2\triangle P}{\rho[\left(\frac{D_1^4}{D_2^4}\right)-1]}}$$

$$Q_{act} = 0.64 \text{ X } \pi/4(20)^2 \text{ X}\sqrt{\frac{2(13.6 \text{ X } 980 \text{ X } 10)}{0.8[\left(\frac{20^4}{10^4}\right)-1]}}$$

$Q_{act} = 9461$ cm^3/sec

3.4.3.3 Pitot tube

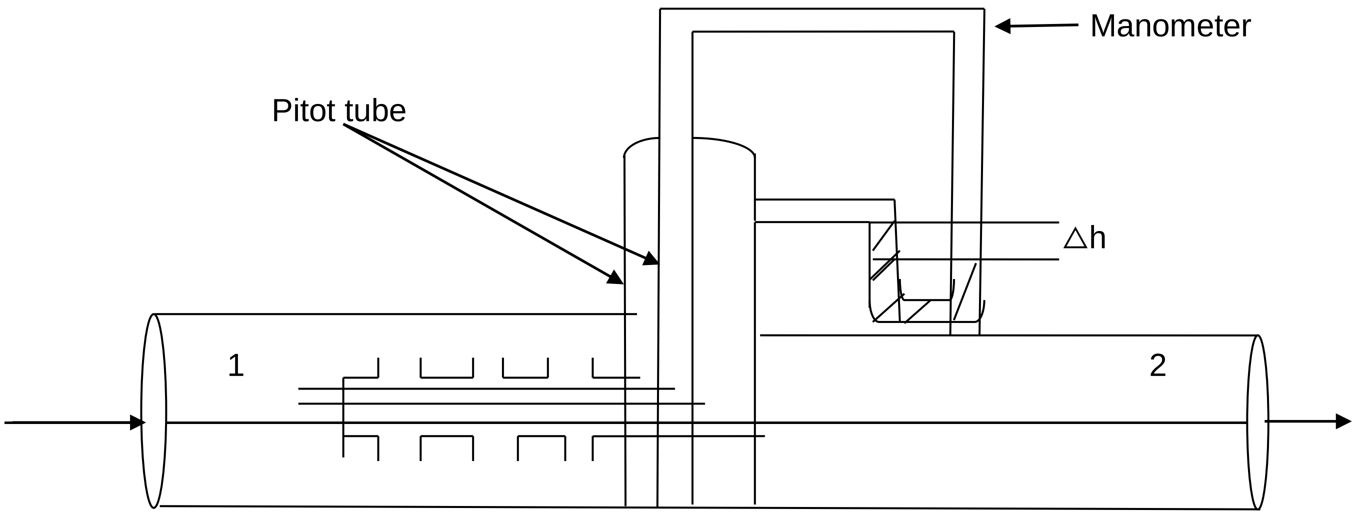


Fig. 6 The shape of the shows parts Pitot tube

This tube is used to measure the velocity and flow rate of liquids and gases and consists of two tubes a joint center and set the direction parallel to the flow of the fluid in the tube to be measuring the velocity and the flow rate.

A. Internal tube transfers the internal pressure confrontational.
B. External tube transfers' static pressure.

difference between tow pressure the moving to manometer where reading height to calculate the pressure either use Pitot tube, few in the industry and limited and therefore cannot be used for fluids containing solids and the Reading rate of manometer is very few so the value is not accurate. so used to measure the velocity of the flow of gases. For the final equation we apply the Bernoulli equation (1) and (2).

$$Z_1 + \frac{u_1^2}{2g} + \frac{P_1}{\rho g} = Z_2 + \frac{u_2^2}{2g} + \frac{P_2}{\rho g}$$

$Z_1 = Z_2$ Point (1) is a point of stillness for liquid

$$u_1 = 0$$

$$\frac{P_1 - P_2}{\rho g} = \frac{u_2^2}{2g}$$

$$u_2 = \sqrt{\frac{2(P_1 - P_2)}{\rho}}$$

This equation is used to measure the velocity of the flow rate gas by Pitot tube, and to calculate the flow rate theoretical = velocity X area Section of the tube [7].

$$Q_{theo} = u_2.A_2$$

$$Q_{theo} = A_2 \text{ X } \sqrt{\frac{2(P_{1-P_2})}{\rho}}$$

$$Q_{theo} = Q_{act}$$

$$C = 1$$

Ex.28: Pitot Tube is used to measure the velocity of the flow of kerosene density (0.8 g/cm^3) The read manometer (5 cmHg). Calculate the velocity $u_2 = \sqrt{\frac{2(P_{1-P_2})}{\rho}}$, $u_2 = \sqrt{\frac{2(5 \text{ X } 13.6 \text{ X } 980)}{0.8}}$ = 182.5 cm/sec.

C H A P T E R 4

Real fluid flow and pressure loss in pipes

4.1 Reynolds number (Re)

Reynolds Number of a flowing fluid obtained by dividing the inertia force of the fluid (velocity X diameter) into the kinematic viscosity (viscous force per unit length).

$$Re = \frac{u.d}{\nu} = \frac{\rho.u.d}{\mu} \quad \text{.....................................(44)}$$

Where:
d =diameter of flow section (m).
ν = kinematic viscosity ($\frac{m^3}{sec}$).
ρ= Mass density of fluid ($\frac{kg}{m^3}$).
μ = dynamic velocity of fluid ($\frac{N.sec}{m^2}$). or (Pa. sec).

4.1.1 Types of flow

A. Laminar flow

This type of flow when the flow rate is slowly and velocity at any fixed point does not change with time.

B. Turbulent flow

This type of flow when the flow rate is high and the speed at any point variable with time and equal to the velocity [8].

Note:
We can find the flow of the fluid laminar flow or turbulent flow or transitional flow according to Reynolds number, we depend on the following:

1- Laminar flow: $Re \leq 2000$.
2- Transitional flow: $2000<Re<3000$.
3- Turbulent flow: $Re\geq3000$.

Ex.29: Determine the type of flow in a pipe with a diameter of (25.4mm) containing with relative density (0.9) and dynamic viscosity (0.1Pa.sec) at a velocity (3 $\frac{m}{sec}$)?

$Re = \frac{\rho.u.d}{\mu}$

$Re \ \frac{3X0.0254X900}{0.1}$

Re = 685.6. Re < 2000The flow is laminar.

Ex.30: Calculate the largest discharge of water moving through a tube diameter (115 mm) and dynamic viscosity water (1.15X10$^{-6}\frac{m^2}{sec}$).

Re = $\frac{u.d}{\nu}$= 2000 = $\frac{u\ X\ 0.115}{1.15\ X\ 10^{-6}}$

u = 0.02 $\frac{m}{sec}$

Q = u . A

Q = 0.02 X $\frac{\pi}{4}$ (0.115)^2 = 2.07 X 10$^{-4}\frac{m^3}{sec}$ = 0.207 $\frac{lit}{sec}$

4.2 Pressure loss

Pressure loss and friction coefficient, the relationship between Reynolds number and friction coefficient.

When fluids flow through pipes they lose part of their energy because of the resistance encountered as a result of friction that occurs between the internal pipe wall and fluid and the greater the roughness of the walls of the pipe the more resistance occurs and can be used by the following equations can be used to calculate the loss in energy:

$$Re = \frac{\rho.u.d}{\mu}$$

When the flow is laminar. i.e. (2000), the following equation applied to calculate the energyloss as a result of viscosity only.

$$h_f = \frac{128.Q.L.\mu}{\pi.d^{4}.\rho.g} \quad \text{.....................................(45)}$$

Where:

h_f = energy losses (m).

Q = flow rate ($\frac{m^3}{sec}$).

L = length pipe (m).

μ = dynamic viscosity ($\frac{kg}{m.\ sec}$).

Ex.31: Find the friction loss in a pipe with a diameter of 25.4mm and 300m length containing with relative density 0.9 and dynamic viscosity 0.1Pa.sec at a velocity 3 $\frac{m}{sec}$:

Re = $\frac{\rho.u.d}{\mu}$

Re= $\frac{3X0.0254X900}{0.1}$

Re = 685.6. Re < 2000 The flow is laminar.

$h_f = \frac{128.Q.L.\mu}{\pi.d^{4}.\rho.g}$ Q = u. A

Q = 3 X $\frac{\pi}{4}$ ($\frac{25.4}{1000}$)^2

Q = 0.00152 $\frac{m^3}{sec}$

$h_f = \frac{128\ X\ 0.00152\ X\ 300\ X\ 0.1}{\pi\ X \frac{25.4}{1000}^4\ X\ 900\ X 9.8}$

h_f = 509.1 m.

But if the flow is turbulent. i.e. that (Re≥3000), the following equation (Darcy equation) is used:

$h_f = F.\ \frac{L}{d}.\frac{u^2}{2g}$

where:

F = friction factor.

u = velocity fluid ($\frac{m}{sec}$).

Ex.32: A crude oil with density 860 $\frac{kg}{m^3}$ and dynamic viscosity (0.0086 $\frac{kg}{m.sec}$), flows through a pipe of steel iron with a (200mm) diameter and (300m) length, and at a discharge (0.126$\frac{m^3}{sec}$) (F = 0.0235). Calculate the friction losses.

$Q = u_1.\ A_1$

$u_1 = \frac{Q}{A_1}$

$Q = \frac{0.126}{\frac{\pi}{4}0.2^2}$

$Q = 4.01\ \frac{m}{sec}$

$Re = \frac{\rho.u.d}{\mu} = \frac{860\ X\ 4.01\ X\ 0.2}{0.0086} = 80200$ The flow is turbulent

$h_f = F\ \frac{L}{d}\frac{u^2}{2g} 0.0235\ X\ \frac{300}{0.2} X\ \frac{4.01^2}{2X9.8}$ $h_f = 28.92$ m

C H A P T E R 5

Pipes and valves

5.1 Pipe

Pipe is one of the transfer of liquids and gases. In chemical plants must transfer a lot of liquids and gases, so it cannot dispense pipes, in addition to the solid material can be transferred dust. General Pipe systems consist of a cylindrical pipe of circular section, where it has compared to piped box-section [9].

Provides the correct conditions in the cylinders with the following circular section:

1 - Less than the thermal Stream loss.

2 - high resistance.

3 - In an economic Production.

Before the construction of pipeline systems should provide the following:

1 - Type of material to be transferred to this system.

2 - The amount of material.

3 - Pressure in the system.

4 - Temperature.

5.1.1 Pipe industries

Pipe Industries used in the transfer of crude oil are steel pipes made of open hard steel like electric steel furnaces.

5.1.2 Mainstream continuity equation

$$Q = u. A$$

$$Q = \frac{m}{\rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (46)$$

Q = Volumetric mainstream transferred material.

m = The amount of material transferred per unit time.

ρ = Density transferred material.

A = Section of the pipeline area.

u = Average speed the mainstream.

$$A = \frac{\pi}{4} (d_r)^2$$

Must determine commonly the speed of the mainstream used to transfer crude oil:

(u) = 0.5 – 2 $\frac{m}{sec}$

Water and the like (u) = 1 – 3$\frac{m}{sec}$

Air and gas (u) = 10 – 30$\frac{m}{sec}$

Steam (u) = 20 – 70$\frac{m}{sec}$

Thus, the tube diameter can be calculated (d_r) according to the following relation:

$$d_r = \sqrt{\frac{4 . Q}{\pi . u}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(47)$$

d_r = Internal diameter of the pipe arithmetically.

When you select the actual diameter of the pipe should be added a certain value called El Amana factor (according to a special table) where you must take into account the ratio of sediments in the Internal tube and the actual internal diameter of the pipe is called the nominal dimension of the pipe and knowledge of the nominal dimension of each pipe can determine the outer diameter of the pipe. In the following table, for example:

Table 1 External diameter and nominal dimensions of cast iron and steel pipes.

Cast irons		Steel pipe	
External diameter (d_e) mm	Nominal dimension (d) mm	External diameter (d_a) mm	Nominal dimension (d) mm
56	40	10.2	6
66	50	13.5	8
82	65	17.2	10
48	80	21.3	15
118	100	26.9	20
144	125	33.7	25
170	150	72.4	32
222	200	48.3	40
274	250	60.3	50
378	350	88.9	80
429	400	139.7	125
532	500	165.1	150

Ex.33: Pipe transfer of kerosene was designed flow rate of kerosene (12 $\frac{\text{cm}^3}{\text{sec}}$) and the velocity of the passage of kerosene in the tube (1.5 $\frac{\text{cm}}{\text{sec}}$) Calculate the outer diameter of the tube and the tube of steel.

$d_r = \sqrt{\frac{4 .Q}{\pi .u}}$

$d_r = \sqrt{\frac{4\ X\ 12}{\pi\ X\ 1.5}}$ = 3.56 cm

d_r = 35.6 mm

Nominal dimension from the table = 40

External diameter(d_e) from the table = 48.3 mm.

5.3 Types of pipes for the metal inside in its industry

1- Steel pipe: high-pressure-resistant and have a good ability to form and can be transferred effect weak materials such as water and air.
2- Cost irons: of those pipes are made in the case of underground transport because it has the ability to resist corrosion, and this kind be heavy and expensive at the same time, the transfer of materials used acidic, and it is difficult to form these tubes.
3- Plastic pipe: often used PVC pipe and be corrosion resistant and easy to operate when heated and can be welded as well as paste them. Because of the high resistance to corrosion fit used for the transport of gases severe reaction. Adverse impact resistance, mechanical low temperatures [10].

5.4 Valves

Valves by which is controlled by opening and closing the gates, as well as to control the flow of liquids and gases in the Pipe.

5.4.1 The most important purposes of valves

1- Allow total and total stop of the flow.
2- Amend flow.
3- Prevent flow in the adverse the trend.
4- Safety valve.

5.4.2 Type of valves

1- Gate valve.
2- Plug valve.
3- Diaphragm valve.
4- Ball valve
5- Globe valve.
6- Butterfly valve.
7- Check valve.
8- Safety valve.

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