FLOW THROUGH PIPES

FLUID MECHANICS

CONTENTS

INTRODUCTION

Pipe is a passage with a closed perimeter through which the fluid flows under pressure.

The fluid flowing in the pipe is always subjected to resistance due to shear forces b/w fluid particles & surface of pipe.

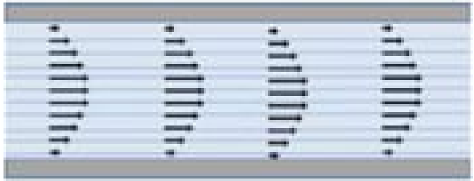
It is also known as Frictional resistance.

HEAD LOSSES THROUGH PIPE

It depends upon the type of flow. It may be either laminar or turbulent.

Laminar flow:

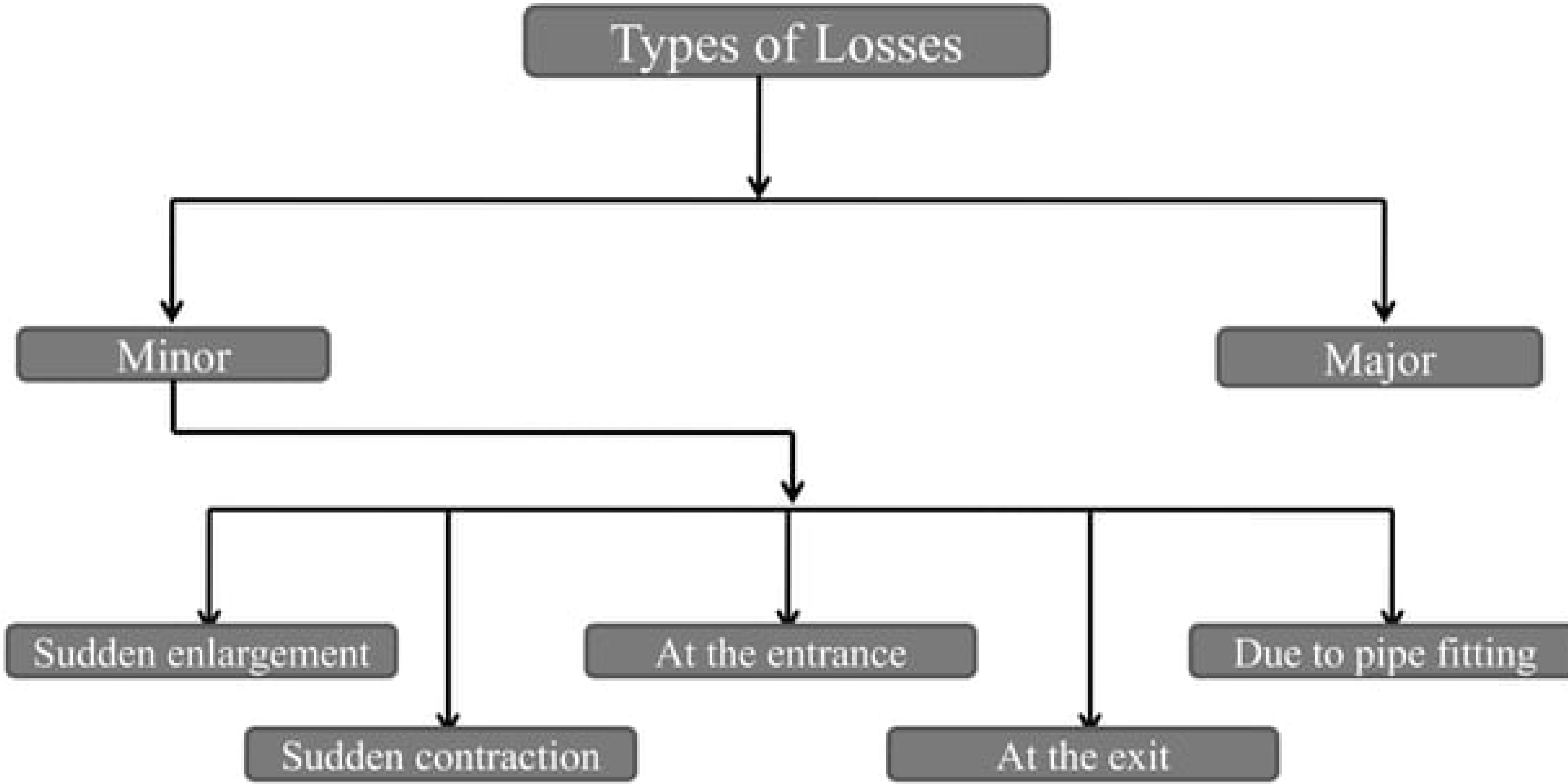
It is the type of flow of fluid in which fluid travels smoothly or in regular paths.



Turbulent flow:

It is the type of flow of fluid in which fluid undergoes irregular fluctuations and mixings.

TYPES OF LOSSES

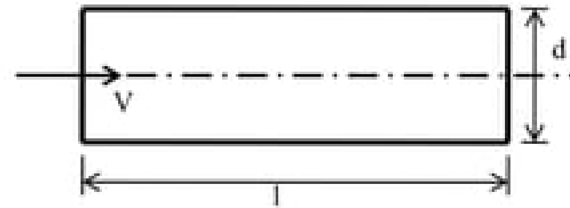


Major loss

→ Loss of head due to friction is termed as major loss.

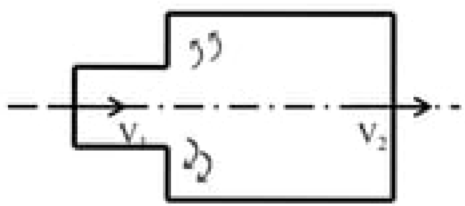
→ It depends on the velocity of flow, dia. of pipe & roughness.

→ It is denoted as h_f.



$h_f = flv^2/(2gd)$

Minor loss



$h_e = (v_1 - v_2)^2/(2g)$

→ It is due to distribution in the flow pattern.

i)Loss due to sudden enlargement:-

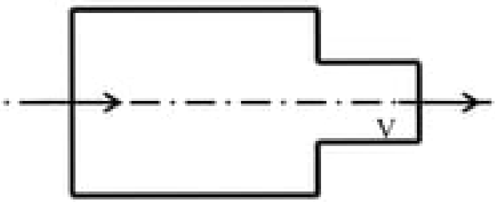
→ It is due to sudden enlargement of pipe.

→ It is denoted by h_e.

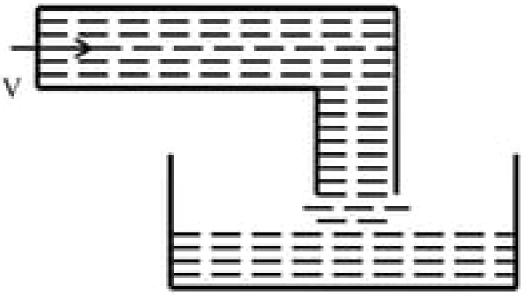
ii)Loss due to sudden contraction:-

→ It is due to sudden contraction of pipe.

→ It is denoted by h_c.



$h_c = [(1/Cc)-1]^2 \times v^2/(2g)$



$h_{ex} = v^2/(2g)$

iii)Loss at the exit:-

→ It is head loss at the exit of the pipe.

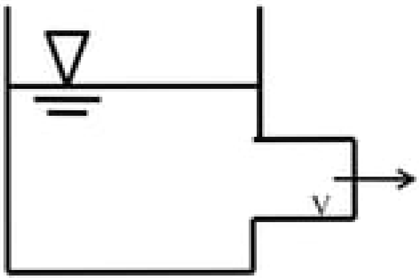
→ It is denoted by h_{ex}.

iv)Loss due to pipe fittings:-

→ It is due to pipe fittings like elbows, valves etc.

→ It is denoted by h_b.

$h_b = K[v^2/(2g)]$



$h_{en} = 0.5[v^2/(2g)]$

v)Loss at entrance :-

→ It is head loss at the entrance of the pipe.

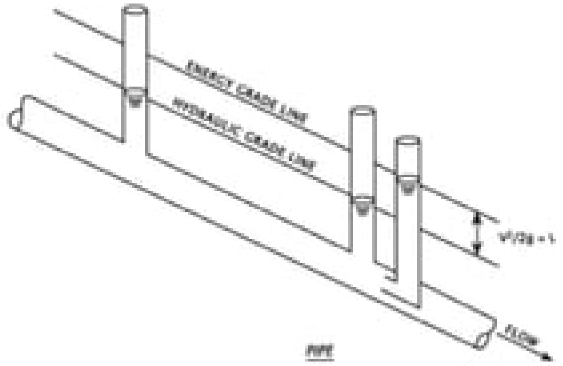
→ It is denoted by h_{en}.

Hydraulic Grade Line

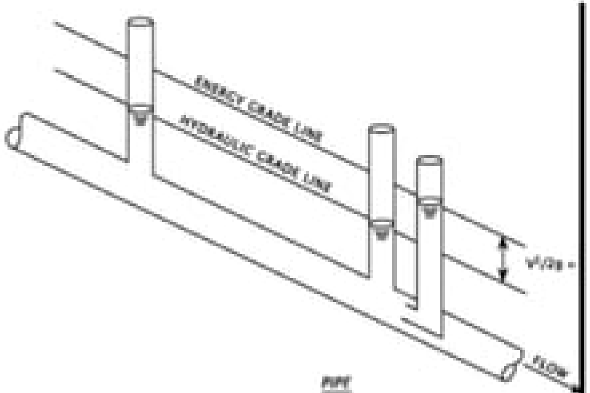
→It is the line joining all the liquid levels in piezometers.

→It is the sum of pressure head & datum head $[(P/\gamma)+z]$.

→Slope of HGL is called as hydraulic gradient.



Total Energy Line



→It is graphical representation of total head at various points along pipe.

→It is the sum of pressure head, velocity head & datum head. $[(P/\gamma)+(v^2/2g)+z]$.

→If datum is 0 then energy grade line is TEL.

PIPES IN SERIES

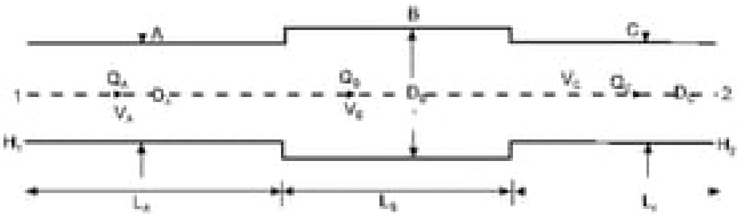
→ **If a pipeline is joined to one or more pipelines in continuation, these are said to constitute pipes in series.**

→ **The discharge through the each pipe is same,**

$$Q_1 = Q_2 = Q_3 = \ldots$$

or

$$A_1V_1 = A_2V_2 = A_3V_3$$



→ **If minor losses are negligible, then the total loss of head is,**

$$H = h_{f1} + h_{f2} + h_{f3}$$

$$H = (f_1 l_1 V_1^2/2gd_1) + (f_2 l_2 V_2^2/2gd_2) + (f_3 l_3 V_3^2/2gd_3)$$

$$H = (f_1 l_1 Q^2/12.1d_1^5) + (f_2 l_2 Q_2^2/12.1d_2^5) + (f_3 l_3 Q_3^2/12.1d_3^5)$$

PIPES IN PARALLEL

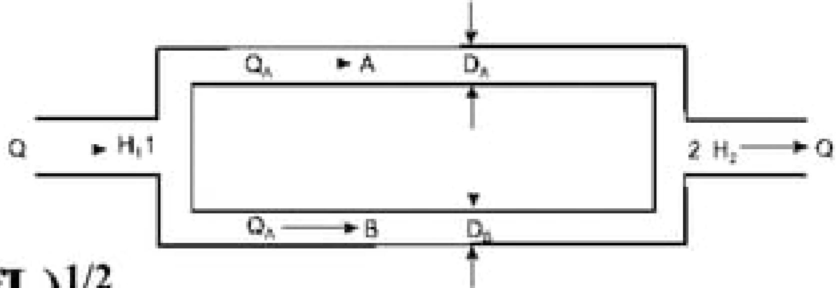
→ **When a man pipeline divided into two or more parallel pipes it is known as pipes in parallel.**

→ **The discharge through the each pipe is,**

$$Q = Q_1 + Q_2 + Q_3 + \ldots$$

and

$$h_f = h_{f1} = h_{f2} = \ldots$$



We know that $Q = (12.1 d^5 h_f / fL)^{1/2}$

→ **Substituting this value in Q,**

$$Q = Q_1 + Q_2 + Q_3 + \ldots$$

$$(12.1 d_e^5 h_{fe} / f_e L_e)^{1/2} = (12.1 d_1^5 h_{f1} / f_1 L_1)^{1/2} + (12.1 d_2^5 h_{f2} / f_2 L_2)^{1/2} + (12.1 d_3^5 h_{f3} / f_3 L_3)^{1/2}$$

$$(d_e^5 / f_e L_e)^{1/2} = (d_1^5 / f_1 L_1)^{1/2} + (d_2^5 / f_2 L_2)^{1/2} + (d_3^5 / f_3 L_3)^{1/2}$$

SYPHON

- SYPHON IS LONG BENT PIPE WHICH IS USED TO CONVEY LIQUID FROM A RESERVOIR AT A HIGHER ELEVATION WHEN THE TWO ARE SEPARATED BY A HIGH LEVEL GROUND OR HILL.
- THE HIGHEST POINT OF THE SYPHON I.E. A POINT ABOVE FREE SURFACE OF RESERVOIR IS KNOWN AS SUMMIT.
- THE PORTION OF SYPHON WHICH IS CONNECTED WITH SOURCE RESERVOIR IS CALLED INLET LEG AND THE OUTPUT RESERVOIR IS CALLED OUTLET LEG.
- THE FLOW THROUGH THE SYPHON IS ONLY POSSIBLE IF THE PRESSURE AT THE SUMMIT IS BELOW ATMOSPHERIC PRESSURE.
- HOWEVER PRESSURE AT SUMMIT SHOULD NOT FALL BELOW THE SATURATION PRESSURE OF THE LIQUID OTHERWISE VAPOR WILL START FORMING, CAUSING THE CAVITATION IN SYPHON AND FLOW OF WATER WILL BE OBSTRUCTED.
- APPLYING BERNOULLI'S THEOREM BETWEEN INLET LEG AND SUMMIT WE COME UP WITH,

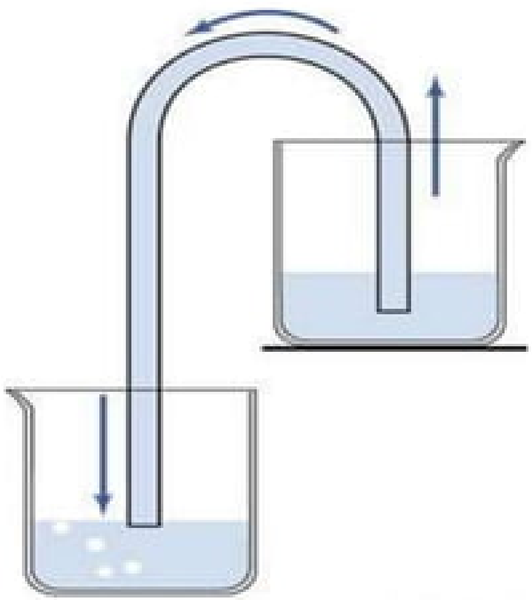
$$l_i = \frac{g \ x \ D \ [hatm \ - hs \ - hi \ - \frac{v^2}{2g}]}{2fv^2}$$

❖ **Applying Bernoulli's equation between inlet leg and outlet leg we come up with,**

$$Z_A - ZB = hf = \frac{4flv^2}{D \; x \; 2g}$$

The syphon is generally used to

i. Carry water from one reservoir to another which is separated by hill or bridge.
ii. Emptying the liquid tank which is not having any outlet.
iii. Emptying water channel not provided with any outlet slice.



Condition of maximum power :

Power transmitted will be maximum when $\frac{dp}{dv} = 0$ and we will come up with,

$$\therefore h_f = \frac{H}{3}$$

It is the condition for maximum transmission of power as loss of friction head is one third of the total head.

Efficiency of power transmission :

$$\alpha = \frac{Power\ available\ at\ outlet\ of\ pipe}{Power\ available\ at\ inlet\ of\ the\ the\ pipe}$$

Therefore, $\alpha = \frac{H-hf}{H}$

Thus the maximum efficiency will be obtained when $h_f = \frac{H}{3}$

$$\therefore \alpha_{\max} = 66.67\%$$

POWER TRANSMISSION THROUGH PIPE

- Power can be transmitted by liquid which is flowing through pipes.
- Power transmission through pipes is commonly used to convey water from a high level reservoir to turbine house and in operation of hydraulic equipments such as hydraulic press, crane jack , etc.
- The power transmitted depends upon the weight of liquid flowing through pipe and total head available at end of pipe.
- Thus, Power transmitted through pipe

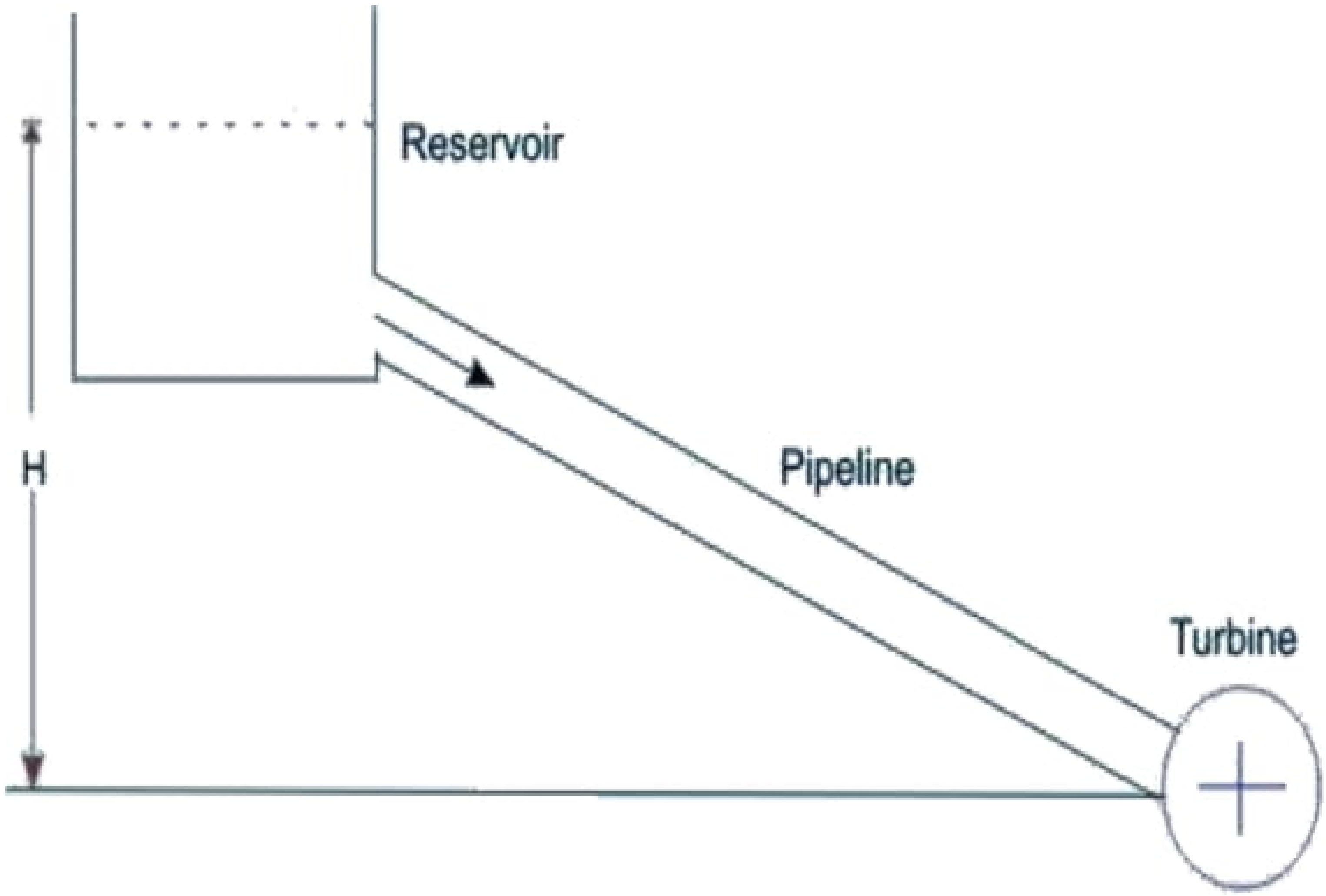
$$P = weight\ of\ water\ flow\ through\ pipe\ x\ Head\ available\ at\ outlet\ of\ pipe$$

$$= W\ x\ [H\ - hf]$$

$$= mg\ x\ [H\ - hf]$$

$$= \rho.A.V.g\ x\ [H\ - hf]$$

$$\therefore \mathrm{P} = \rho.g.\frac{\Pi D^2}{4}.V\ x\ [H\ - \frac{4flv^2}{D\ x\ 2g}]\ \ \mathrm{W}$$


Reservoir
H
Pipeline
Turbine

FLOW THROUGH NOZZLE AT END OF PIPE

- The function of nozzle is to convert total energy of liquid into kinetic energy.
- Nozzle is used where higher velocity of liquid is required as in pelton wheel, for fire fighting, mining power developments, etc.
- Since water is flowing continuously through pipe and nozzle we can apply law of continuity,

$$\therefore Q = AV = av \rightarrow V = \frac{a}{A}.v$$

- Head at inlet of nozzle = $H - hf$ (neglecting minor losses)
- Head at outlet of nozzle = kinetic head = $\frac{v^2}{2g}$
- According to Bernoulli's equation head at inlet = head at outlet (neglecting losses)

$$\therefore H - hf = \frac{v^2}{2g}$$

$$H - \frac{4flv^2}{D \times 2g} = \frac{v^2}{2g} \quad \text{but } V = \frac{a}{A}.v$$

- Solving this, we can ultimately come up with,

$$v = \left(\frac{2gH}{1 + \frac{4fla^2}{D \times A^2}}\right)^{1/2}$$

∴ Discharge through nozzle

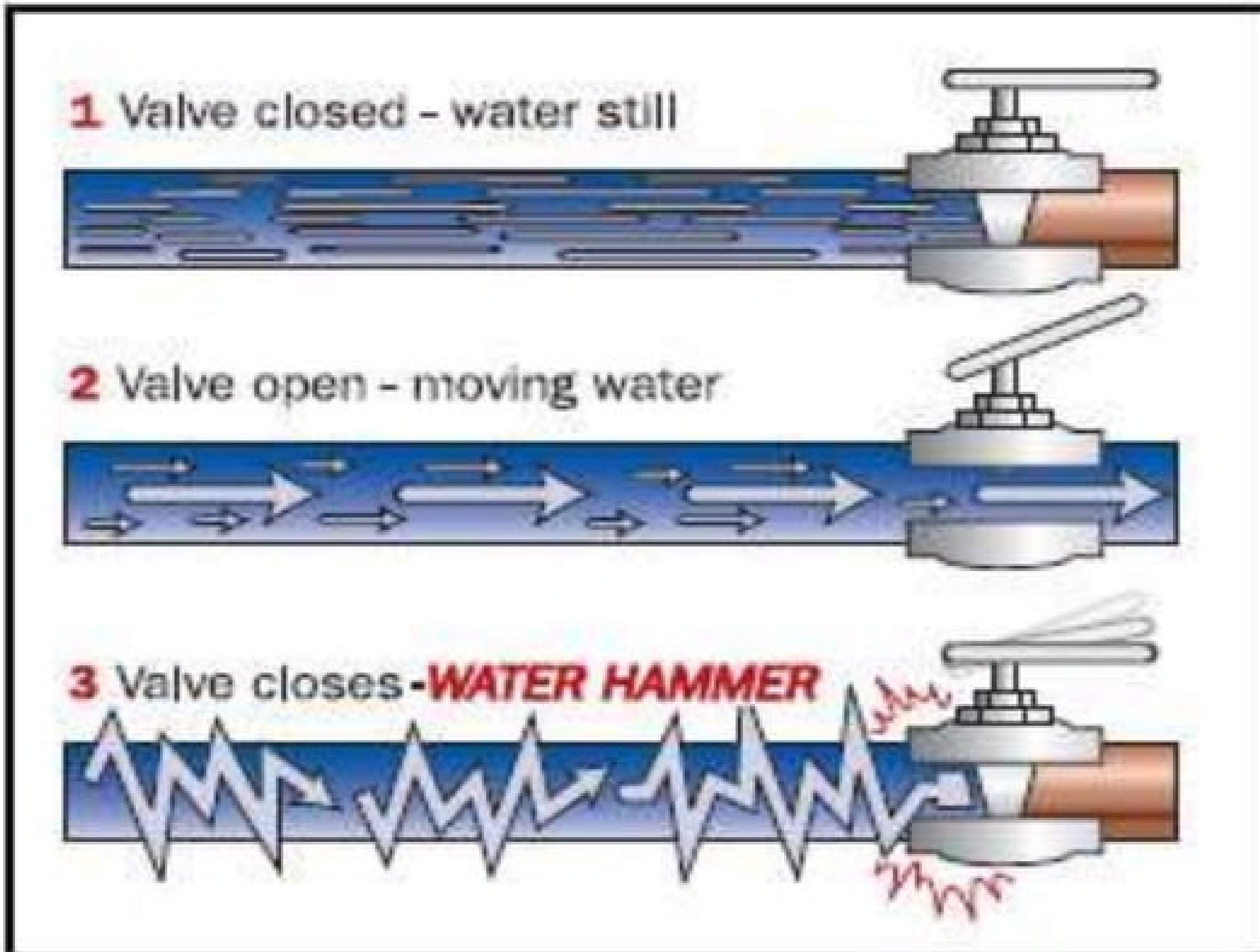
$$Q = A.V = a.v = a \times \left(\frac{2gH}{1 + \frac{4fla^2}{D \times A^2}}\right)^{1/2}$$

- The condition for transmission of power through nozzle is similar to that of pipe i.e. $h_f = \frac{H}{3}$.

WATER HAMMER IN PIPES

- Water while flowing in pipe possesses momentum due to some velocity of water.
- If the flowing water is suddenly brought to rest by closing the valve, its momentum is destroyed ,which causes a very high pressure waves.
- This high pressure waves will be transmitted along the pipe with a velocity equal to the velocity of sound wave, and it may create noise which is called knocking.
- Also this wave of high pressure has the effect of hammering action on the walls of the pipe and thus is known as water hammer.
- There are three cases of water hammer depending upon the time taken in closing valve and they are as follows :

1. Water hammer when valve is closed gradually closed
2. Water hammer when the valve is suddenly closed and pipe is rigid
3. Water hammer when the valve is suddenly closed and elastic pipe.


1 Valve closed - water still
2 Valve open - moving water
3 Valve closes-WATER HAMMER