HYDRAULICS

Hydraulics may be defined as the branch of engineering which deals with water at rest or in motion.

INTENSITY OF PRESSURE

When a liquid is contained in a vessel, it exerts force at all points on the sides and bottom of the container. This force per unit area is called intensity of pressure. If 'p' is the total force acting on the cross sectional area 'a' then intensity of pressure **p = P/a.**

The direction of this pressure is always at right angles to the surface, with which the fluid at rest, comes in contact.

PRESSURE HEAD

The vertical height of the free surface above any point in a liquid at rest is known as pressure head.

$$H = p/\gamma$$

$$\therefore P = \gamma h$$

This equation shows that the intensity of pressure at any point in a liquid is proportional to its depth from the liquid surface.

The pressure may be expressed as

1. *Force per unit area* --- **N/m^2**
2. *Height of the equivalent liquid column* --- **cm or m**

UNITS

The pressure is expressed in pascal (pa)

1 pascal = 1 N/m^2

1 M pa = 1 M N/mm^2

Find the intensity of pressure at a point 5m below the free surface of water

Solution:

Height of the liquid =5m

Sp. wt. Of liquid = 9.81 kN/m^3

Intensity of pressure = ?

Intensity of pressure , **P** **= γ h**

= 9.81 x 5 = 49.05 kN/m^2

= 49.05 kpa

Find the depth of a point below the water surface in a sea, where the pressure intensity is 1025 kN/m^2. Specific wt. Of sea water is 10.25 KN/m.

Solution:

Pressure intensity,p = 1025 kN/m^2

Sp. wt. Of sea water = 10.25 kN/m^3

Depth of sea water above the point, h =?

$$\mathbf{h = p/ \gamma}$$

$$= \frac{1025}{10.25}$$

$$= 100m$$

BERNOULLI'S THEOREM

It states that in a steady, ***irrotational flow of an incompressible fluid, the total energy at any point is constant.***

[The above statement is based on the assumption that there are no losses due to friction in pipe]

Mathematically; $\mathbf{Z + V^2 / 2g + p/ \gamma = Constant}$

Where **Z** = Potential energy

$\mathbf{V^2 / 2g}$ = Velocity energy

$\mathbf{p/\gamma}$ = Pressure energy

LOSSES OF HEAD IN PIPES

When a liquid is flowing in pipe, it loses energy or head due to friction of wall, change of cross section or obstruction in the flow. All such losses are expressed in terms of **velocity head**.

The following are losses which occur in a flowing fluid.

1. Loss of head due to friction

2. Loss of head due to sudden enlargement

3. Loss of head due to sudden contraction

4. Loss of head due to bends

5. Loss of head at entrance

6. Loss of head at exit.

LOSS OF HEAD DUE TO FRICTION

When the water is flowing in a pipe, it experiences some resistance to its motion. This reduces the velocity and ultimately the head of water available. The major loss is due to frictional resistance of the pipe only. Darcy's formula is used to calculate the loss of head in pipes due to friction; neglecting minor losses

$$H_f = \frac{4 f l v^2}{2gd}$$

Where

$f \rightarrow$ *frictional resistance*

$l \rightarrow$ *Length of pipe*

$f \rightarrow$ *frictional resistance*

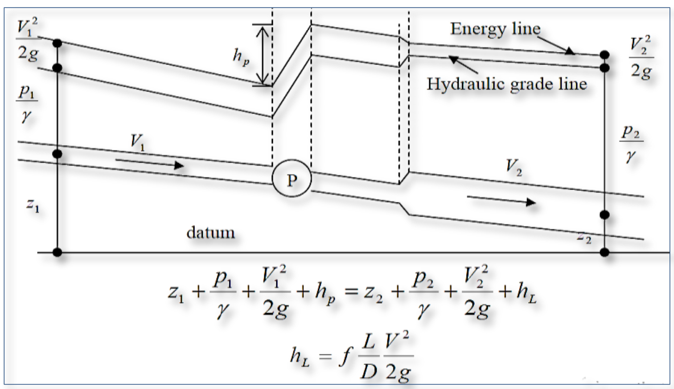
$v \rightarrow$ *velocity of water in the pipe*

$d \rightarrow$ *diameter of pipe*

$H_f \rightarrow$ *loss of head due to friction*

$Q_L \rightarrow$ *discharge through pipe*

$$H_f = \frac{4 f l v^2}{2gd} = \frac{f l Q^2}{3 d^5}$$



LOSS OF HEAD DUE TO SUDDEN ENLARGEMENT

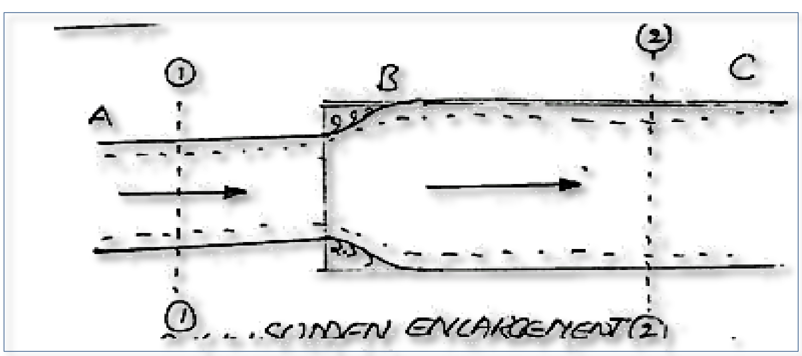


Fig : SUDDEN ENLARGEMENT

Consider a liquid flowing in a pipe **ABC**, having sudden enlargement at '**B**'. There is a loss of head due to this sudden enlargement as given below.

$$h_e = \frac{(V_1 - V_2)^2}{2g}$$

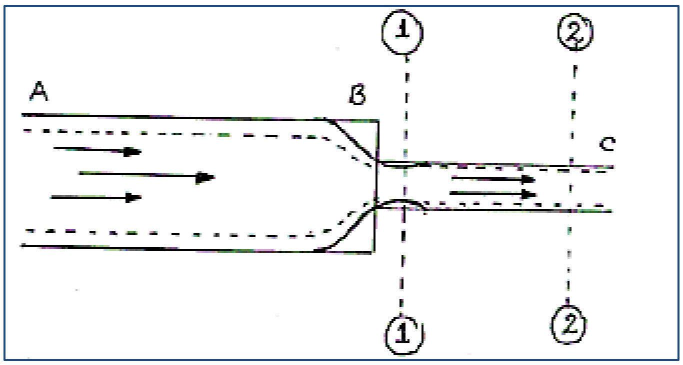
Where V_1 = Velocity of liquid at section 1 - 1

V_2 = Velocity of liquid at section 2 - 2

G = acceleration due to gravity

H_e = Loss head due to sudden enlargement

LOSS OF HEAD DUE TO SUDDEN CONTRACTION



Consider a liquid flowing in a pipe ABC, having sudden contraction at B, as shown in fig. When flowing through a narrow pipe, the liquid will get contracted at 1 - 1 forming ***vena contracta***. It is note that the loss of head due to sudden contraction is not due to the contraction itself but it is due to sudden enlargement which takes place after contraction

Loss of head due to sudden contraction

$$h_c = \frac{(V_1 - V_2)^2}{2g}$$

[$\therefore a_1 V_1 = a_2 V_2$]

$V_1 = V_2 / 0.62$

[$\therefore a_2 / a_1 = C_c$]

$$= \frac{[V_2 / 0.62 - V_2]^2}{2g}$$

$$= \frac{0.375 V_2^2}{2g} = \frac{K V_2^2}{2g}$$

Note :

1) The above equation is valid when C_c **= 0.62** , which actually depends upon type of Orifice.

2) The actual loss of head depends upon ratio d_1 / d_2.

LOSS OF HEAD DUE TO BENDS

When the direction of a length changes such as at the bends in a pipe line, some of the liquid energy is lost.

Loss of head due to bends = $k V^2 / 2 g$

Where

'**k**' *coefficient which depends upon angle and radius of bend*

k= *1 for* 90^0 *elbows*

V = Velocity of liquid in the pipe

g = acceleration due to gravity

LOSS OF HEAD AT THE ENTRANCE

The loss of head due to entrance in a pipe is actually a loss of head due to sudden contraction and depends upon the form of entrance.

Loss of head at entrance = $0.5 V^2 / 2 g$

Where

V = Velocity of liquid in the pipe

g = acceleration due to gravity

LOSS OF HEAD DUE TO EXIT

The loss of head due to exit in a pipe is actually a loss due to energy of head of flowing liquid by virtue of its motion.

Loss of head at exit by experimentally = $V^2 / 2 g$

Where

V = Velocity of liquid in the pipe

g = acceleration due to gravity

Find the loss of the head due to friction in a pipe of 1000mm diameter and 2.0 km long. The velocity of water in the pipe is 2m/sec. Take coeff. of friction as 0.005

Solution:

Diameter of pipe, d = 1000mm = 10m

Length of pipe, l = 2.0 km = 2000m

Velocity of water, v = 2m/sec

Coeff of friction, f = 0.005

Loss of head, h_f =?

$$h_f = \frac{4 f l v^2}{2gd} = \frac{4 \times 0.005 \times 2000 \times 2^2}{2 \times 9.81 \times 1.0} = 8.15 \text{ m}$$

A pipe of 80mm in diameter is suddenly enlarged to 160mm diameter. Find the loss of head due to sudden enlargement if the velocity of water in 80mm diameter section is 5m/sec.

Solution:

Diameter of pipe, before enlargement d_1 = 80mm = 0.08m

Diameter of pipe, after enlargement d_2 = 160mm = 0.16m

Velocity of water in pipe, before enlargement, v_1 = 5m/sec

Velocity of water in pipe, after enlargement, v_2 =?

By continuity equation, $\mathbf{a_1 V_1 = a_2 V_2}$

$$V_2 = \frac{a_1 V_1}{a_2} = \frac{\frac{\pi \times d_1^2}{4} \times V_1}{\frac{\pi \times d_2^2}{4}}$$

$$V_2 = \frac{d_1^2 \times V_1}{d_{22}}$$

$$= \frac{0.08^2 \times 5}{0.16^2} = 1.24 \text{ m/sec}$$

∴ Loss of head due to sudden enlargement

$$h_e = \frac{(V_1 - V_2)^2}{2g} = \frac{(5 - 1.25)^2}{2 \times 9.81} = 0.717\text{m}$$

A pipe of 25mm diameter is conveying water with a velocity of 2m/sec. Find the loss of head at entrance and exit.

Solution:

Diameter of pipe , d = 25mm = 0.025m

Valocity of water , V = 2m/sec

Loss of head entrance = ?

Loss of head entrance = 0.5 V^2 / 2g

$$= \frac{0.5 \times 2^2}{2 \times 9.81} = 0.102 \text{ m}$$

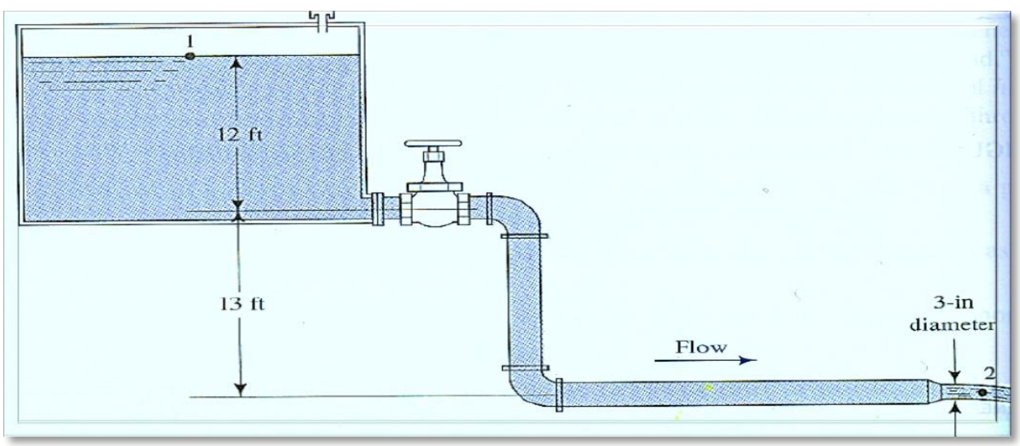
Loss of head entrance = V^2 / 2g

$$= \frac{2^2}{2 \times 9.81} = 0.204 \text{ m}$$

WATER HAMMER

When the water flowing in a long pipe is suddenly brought to rest by closing the valve or by any similar cause, there will be a sudden rise in pressure due to momentum of the moving water being destroyed. This cause a wave of high pressure transmitted along the pipe, which creates noise known as ***knocking***. ***This phenomenon of sudden rise of pressure in the pipe is known as water hammer or hammer blow.***

Find the total head losses due to friction, valves, bends etc. Given –Water moving in the system, Q = 1.20 ft^3/s.



Solution: Apply the **General Energy Equation** for pts 1 and 2,

$$p_1/\gamma + z_1 + v_1^2/2g - h_L = p_2/\gamma + z_2 + v_2^2/2g$$

Cancel out the terms –

$$p_1/\gamma + z_1 + v_1^2/2g - h_L = p_2/\gamma + z_2 + v_2^2/2g$$

And we get –

$$h_L = (z_1 - z_2) - v_2^2/2g$$

$(z_1 - z_2) = 25$ ft

Area of 3 inch dia pipe = 0.0491 ft^2

v_2 = 1.20 / 0.0491 = 24.4 ft/s

h_L = 25 – $(24.4)^2$/2*32.2 = **15.75 ft**