Moody diagram

Moody, shows the variation of friction factor f with the governing parameters, viz. the Reynolds number of flow and the relative roughness $\left(\frac{\varepsilon}{D}\right)$, where '$\varepsilon$' – absolute/average roughness and D-diameter of pipe.

Used to determine friction factor for commercial pipes.

→ Please go to page no. 17.

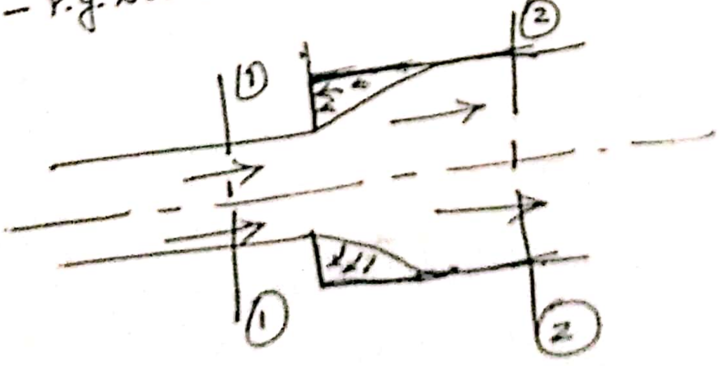
Minor losses:

Also known as minor energy (head) losses. These minor losses are due to change of velocity of the ~~following~~ flowing fluid in magnitude or direction. Minor losses are:

1. Loss of head due to sudden enlargement
2. Loss of head due to sudden contraction
3. Loss of head at the entrance to a pipe
4. Loss of head at the exit of a pipe.
5. Loss of head due to an obstruction in a pipe.
6. Loss of head due to bend in the pipe
7. Loss of head due to in various pipe fittings.

Loss of head due to sudden enlargement:

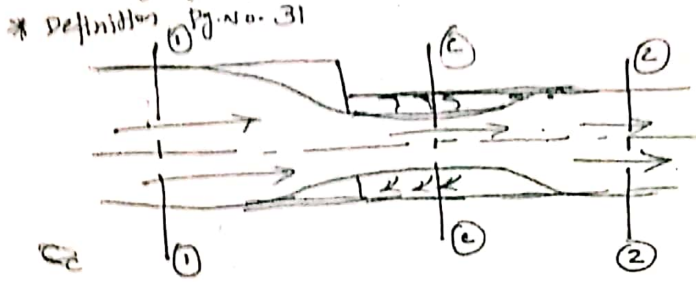
* Definition – P.g. No. 31



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

Loss of head due to sudden contraction

* Definition Pg.No. 31



$$h_c = 0.5\,\frac{V_2^2}{2g}$$

$$h_c = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1.0\right]^2$$

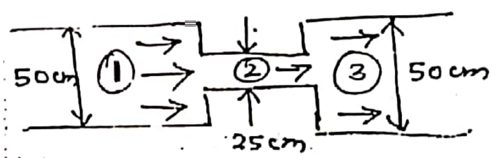
$C_c = \frac{a_c}{a_2}$ ← Co-efficient of Contraction

When a sudden contraction is introduced in a horizontal pipe line from 50 cm to 25 cm, the pressure changes from 10,500 kg/cm² to 6900 kg/m². Calculate the rate of flow. Assume Co-efficient of contraction of jet to be 0.65. Following this if there is a sudden enlargement from 25 cm to 50 cm and if the pressure at the 25 cm section is 6900 kg/m², what is the pressure at the 50 cm enlarged section.

Given data:

$d_1 = 50\text{ cm} = 0.5\text{ m} = d_3$

$d_2 = 25\text{ cm} = 0.25\text{ m}$



$p_1 = 10500\ \frac{kg}{cm^2} = 103.005\times10^3\ \frac{N}{m^2}$

$p_2 = 6900\ \frac{kg}{m^2} = 67.689\times10^3\ \frac{N}{m^2}$

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$C_c = 0.65$

$Q = ?$

$p_3 = ?$

Solution:

$$Q = a_1V_1 = a_2V_2 = a_3V_3 \quad \text{(By continuity equation)}$$

$$h_c = \frac{V_2^2}{2g}\left[\frac{1}{C_c} - 1.0\right]^2$$

$$= \frac{V_2^2}{2g}\left[\frac{1}{0.65} - 1\right]^2$$

$$= \frac{V_2^2}{2g}\left[0.54\right]^2 = 0.2899\,\frac{V_2^2}{2g}$$

(4b)

$$a_1 V_1 = a_2 V_2$$

$$V_1 = \frac{a_2 V_2}{a_1}$$

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

$$V_1 = \frac{0.25^2 \times V_2}{0.5^2} = 0.25 V_2$$

Now, applying Bernoulli's equation.

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + h_c$$

$z_1 = z_2$ (horizontal pipe)

$$\frac{103.005 \times 10^3}{1000 \times 9.81} + \frac{(0.25 V_2)^2}{2 \times 9.81} = \frac{67.689 \times 10^3}{1000 \times 9.81} + \frac{V_2^2}{2 \times 9.81} + \frac{0.2899 V_2^2}{2 \times 9.81}$$

$$10.5 + 3.186 \times 10^{-3} V_2^2 = 6.9 + 0.051 V_2^2 + 0.0148 V_2^2$$

$$10.5 - 6.9 = 0.0626 V_2^2$$

$$V_2 = \sqrt{\frac{3.6}{0.0626}} = 7.583 \frac{m}{s}$$

$$\therefore Q = a_2 V_2 = \frac{\pi}{4} d_2^2 \times V_2$$

$$= \frac{\pi}{4} \times 0.25^2 \times 7.583$$

$$= 0.372 \frac{m^3}{s} = 372.25 \frac{\text{litres}}{s}$$

Team 5

Similarly, applying Bernoulli's equation for section (2) and (3).

$$\frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 = \frac{p_3}{\rho g} + \frac{V_3^2}{2g} + z_3 + h_e$$

$z_2 = z_3 = 0$ and

$$V_3 = \frac{Q}{a_3} = \frac{0.372}{\frac{\pi}{4} \times 0.5^2} = 1.895 \frac{m}{s}$$

(2b)

$$h_e = \frac{(V_2 - V_3)^2}{2g}$$

$$= \frac{(7.583 - 1.895)^2}{2 \times 9.81}$$

$$= 1.649 \text{ m}$$

Now,

$$\frac{67.\overset{6}{_\wedge}89 \times 10^3}{1000 \times 9.81} + \frac{(7.583)^2}{2 \times 9.81} = \frac{p_3}{1000 \times 9.81} + \frac{(1.895)^2}{2 \times 9.81} + 1.649$$

$$6.9 + 2.931 = \frac{p_3}{9810} + 0.183 + 1.649$$

$$p_3 = 7.999 \times 9810$$

$$= 78.47 \times 10^3 \ \frac{N}{m^2}$$

$$\therefore p_3 = 78.47 \ \frac{kN}{m^2}$$

Team 2

Loss of head at the entrance ('inlet') of a pipe:

This is the loss of energy which occurs when a liquid enters a pipe which is connected to a large tank or reservoir.

This loss is similar to that of loss of head due to sudden contraction.

$$\boxed{h_i = 0.5 \frac{V^2}{2g}}$$

Loss of head at the exit ('outlet') of pipe:

This is due to the velocity of liquid at outlet of the pipe which is ~~dissipated either~~ in the ~~form of a free jet (if outlet of the pipe is free) or it is lost in~~ connected to ~~the~~ tank or reservoir (if the outlet of the pipe is connected to the tank or reservoir.)

D.N. SREEHARAN
M.E., (Ph.D)
Assistant Professor/Mechanical Engg
SVS College of Engg., Cbe-109

$$\boxed{h_o = \frac{V^2}{2g}}$$

Loss of head due to an obstruction in a pipe:

Whenever there is an obstruction in a pipe, the loss of energy takes place due to reduction of the area of the cross-section of the pipe at the place where obstruction is present.

There is a sudden enlargement of the area of flow beyond the obstruction due to which loss of head takes place.

$$\boxed{h_{ob} = \frac{V^2}{2g}\left(\frac{A}{C_c(A-a)} - 1\right)^2}$$

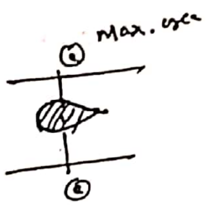
A - Area of pipe
a - Max. area of obstruction

Loss of head due to bend in pipe:

When there is any bend in a pipe, the velocity of flow changes, due to which the separation of the flow from the boundary and also formation of eddies takes place. Thus the energy is lost.

$$\boxed{h_b = \frac{KV^2}{2g}}$$

K - Co-efficient of bend (which depends on
(i) Angle of bend
(ii) Radius of curvature of bend
(iii) Diameter of pipe.



Loss of head in various pipe fittings:

The loss of head in the various pipe fittings such as valves, couplings, etc

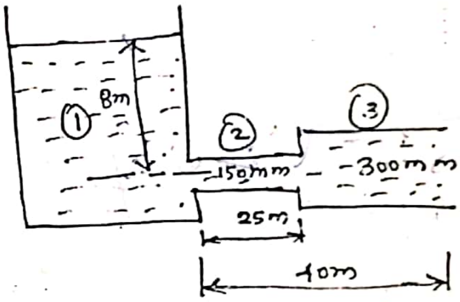
$$\boxed{h_p = \frac{KV^2}{2g}}$$

K - Co-efficient of pipe fitting

A horizontal pipe line 40 m long is connected to a water tank at one end and discharges freely into the atmosphere at the other end. For the first 25m of its length from the tank, the pipe is 150 mm diameter and its diameter is suddenly enlarged to 300 mm. The height of water level in the tank is 8 m above the centre of the pipe. Considering all loses of head which occur, determine the rate of flow. Take f' = 0.01 for both sections of the pipe.

B.N.SREEHARAN
M.E., (Ph.D)
Assistant Professor / Mechanical Engg.
SVS College of Engg., Cbe-109

Given data:



$L_1 = 40m$

$L_2 = 25m$

$L_3 = 40 - 25 = 15m$

$d_2 = 150mm = 0.15m$

$d_3 = 300mm = 0.3m$

$h = 8m$

$f' = 0.01$

$Q = ?$

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Solution:

Applying Bernoulli's theorem at (1) & (2)

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + \text{all losses}$$

$$0 + 0 + 8 = \frac{p_2^{\,0}}{\rho g} + \frac{V_2^2}{2g} + 0 + \text{all losses}$$

$$\boxed{8 = \frac{V_2^2}{2g} + h_i + h_{f_2} + h_e + h_{f_3}} \rightarrow (1)$$

$H = \frac{V^2}{2g} + \Sigma$ all loss.

From continuity equation

$$a_2 V_2 = a_3 V_3$$

$$V_2 = \frac{a_3 V_3}{a_2}$$

$$V_2 = \frac{\frac{\pi}{4} d_3^2 \times V_3}{\frac{\pi}{4} d_2^2} = \frac{0.3^2 \times V_3}{0.15^2} = 4V_3$$

$$h_i = 0.5\,\frac{V_2^2}{2g}$$

$$= 0.5\,\frac{(4V_3)^2}{2\times 9.81} = 0.408\,V_3^2$$

Therfor since

$$h_{f_2} = \frac{4f'LV_2^2}{2gd} = \frac{4\times 0.01\times 25\times(4V_3)^2}{2\times 9.81\times 0.15}$$

$$= 5.437\,V_3^2$$

$$h_e = \frac{(V_2 - V_3)^2}{2g} = \frac{(4V_3 - V_3)^2}{2\times 9.81} = 0.4587\,V_3^2$$

$$h_{f_3} = \frac{4f'L\,V_3^2}{2gd} = \frac{4\times 0.01\times 15\times V_3^2}{2\times 9.81\times 0.3} = 0.102\,V_3^2$$

Substituting above in (1)

$$8 = 0.816\,V_3^2 + 0.408\,V_3^2 + 5.437\,V_3^2 + 0.4587\,V_3^2 + 0.102\,V_3^2$$

$$V_3^2 = \frac{8}{\cancel{7.221}\ 6.887} = \sqrt{1.1078} = 1.052\ \frac{m}{s}$$

$$V_3 = \sqrt{1.1084}$$

$$V_3 = 1.041\ \frac{m}{s}$$

$$\therefore Q = a_3V_3$$

$$= \frac{\pi}{4} d_3^2 \times \cancel{1.041}\ 1.052 = \frac{\pi}{4}\times(0.3)^2\times \cancel{1.041}\ 1.052 = 0.074\ \frac{m^3}{s}$$

$$= 73.58\ \frac{\text{litres}}{s}$$

$$8 = 6.887\,V_3^2$$

$$V_3 = \sqrt{\frac{8}{6.887}} = \sqrt{1.03} = 1.019\ \frac{m}{s}$$

$$\therefore Q = a_3V_3 = \frac{\pi}{4}\,0.3^2\times 1.019 = 0.072 = 72.03\ \frac{\text{litres}}{s}$$

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Definition for loss of head due to sudden enlargement:

Due to sudden change of diameter of the pipe, the liquid flowing from the smaller pipe is not able to follow the abrupt change of the boundary. Thus the flow separates from the boundary and turbulent eddies are formed. The loss of head (or energy) takes place due to the formation of these eddies.

Definition for loss of head due to sudden contraction:

The liquid flows from large pipe to smaller pipe, the area of flow goes on decreasing and becomes minimum at vena contracta. After vena-contracta, a sudden enlargement of the area takes place. The loss of head due to sudden contraction is actually due to sudden enlargement from Vena-contracta to smaller pipe.

Determine the difference in the elevations between the water surfaces in the two tanks which are connected by a horizontal pipe of diameter 300 mm and length 400 m. The rate of flow of water through the pipe is 300 litres/s. Consider all loses and take the value of $f' = 0.008$.

Given data:

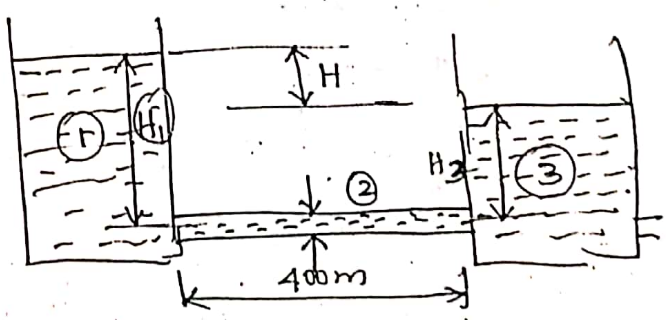
$d = 300mm = 0.3m$

$L = 400\,m$

$Q = 300 \frac{\text{litres}}{s} = \frac{300 \times 10^{-3}}{(0.3)} \frac{m^3}{s}$

$f' = 0.008$

$H = ?$



Solution:

$H = H_1 - H_3 = ?$

$H_1 = H_3 + h_i + h_f + h_o$

$H_1 - H_3 = h_i + h_f + h_o$

$h_i = 0.5 \frac{V^2}{2g}$

$$Q = aV = a_2 V_2$$

$$0.3 = \frac{\pi}{4} \times 0.3^2 \times V_2$$

$$V_2 = \frac{0.3 \times 4}{\pi \times 0.3^2} = 4.244 \ \frac{m}{s}$$

$$\therefore h_i = \frac{0.5\,(4.244)^2}{2 \times 9.81} = 0.459 \ m$$

$$h_f = \frac{4 f' L \times V^2}{2gd} = \frac{4 \times 0.008 \times 400 \times 4.244^2}{2 \times 9.81 \times 0.3}$$

$$= 39.17 \ m$$

$$h_o = \frac{V^2}{2g} = \frac{4.244^2}{2 \times 9.81} = 0.918 \ m$$

$$\therefore H_1 - H_3 = 41.01 \ m$$

⟶ Go to P.g. No. '16'

For the problem no. 54 draw the hydraulic gradient and total energy line.

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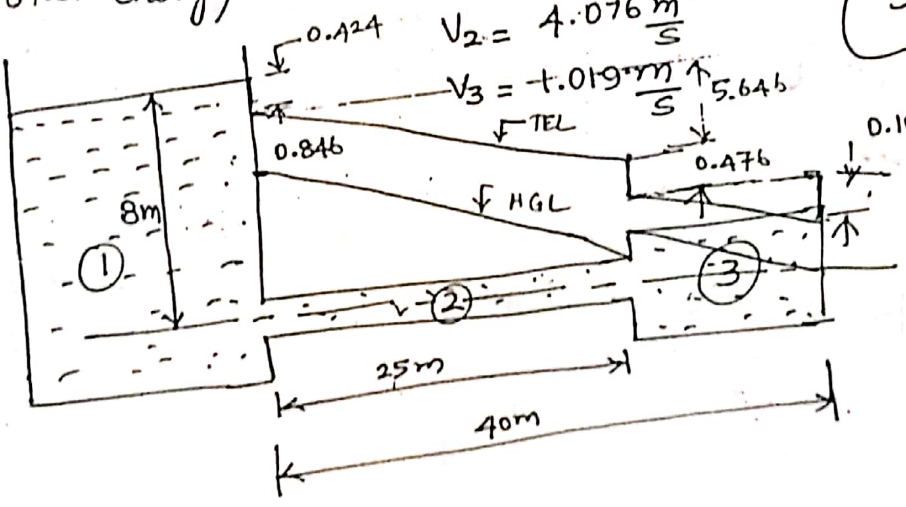

Solution:

$$h_i = 0.408 V_3^2 = 0.408 \times (1.019)^2 = 0.424 \ m$$

$$h_{f2} = 5.437 V_3^2 = 5.646 m$$

$$h_e = 0.458 V_3^2 = 0.476 \ m$$

$$h_{f3} = 0.102 V_3^2 = 0.105 \ m$$

$$\frac{V_2^2}{2g} = 0.8467 m$$