Lesson 21

EXTERNAL AND INTERNAL MOUTHPIECE

21.1 Mouthpiece

Mouthpiece is an extended form of orifice in which a tube or pipe is attached to the orifice. The length of pipe attached to the orifice is 2 to 3 times diameter of orifice (Fig. 21.1). A mouthpiece is used to measure discharge.

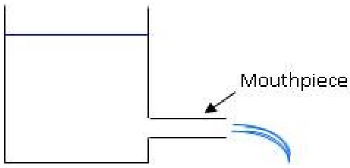


Fig. 21.1 Mouthpiece

21.2 Classification of Mouthpiece

Mouth piece can be classified as follows:

a. ***On basis of position***

i. Internal: Pipe is fixed inside the tank/vessel
ii. External: Pipe is fixed and projected outside the tank walls

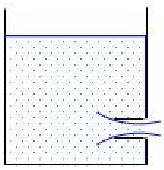
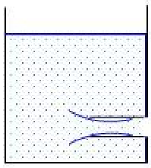
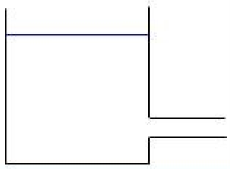
b. ***Flow pattern***

i. Running free: Water jet after contraction in mouthpiece does not touches pipe internal walls.
ii. Running full: Water jet after contraction in mouthpiece touches pipe internal walls.

c. ***Shape of mouthpiece***

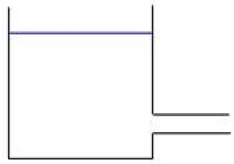
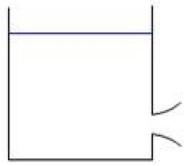
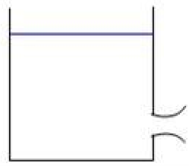
According to the shape of the mouthpiece cylindrical, converging, converging-diverging etc

Table 21.1 Classification of mouthpiece on basis of position

Classification	Type	Discharge	Diagram
1. Basis of position	a. Internal (Running free)	$Q = 0.5\ a\sqrt{2gh}$	
	b. Internal (Running full)	$Q = 0.707\ a\sqrt{2gh}$	
	c. External	$Q = 0.855\ a\sqrt{2gh}$	

***** a = Area of mouthpiece

Table 21.2 Classification of mouthpiece on basis of shape

Classification	Type	Discharge	Diagram
2. Basis of shape	a. Cylindrical	$Q = C_d\, a\sqrt{2gh}$	
	b. Convergent	$Q = C_d\, a\sqrt{2gh}$	
	c. Convergent-divergent	$Q = a_c\sqrt{2gh}$ Where $\frac{a_1}{a_c} = \sqrt{1 + \frac{H_a - H_c}{H}}$	

21.3 Flow Through an Internal Cylindrical Mouthpiece

Internal cylindrical mouthpiece is also known as Borda's mouthpiece.

21.3.1 Borda's mouthpiece running free

When the mouthpiece length is equal to its diameter, the liquid jet after contracting does not touch the sides of the tube. The mouth piece runs free i.e. without touching the tube.

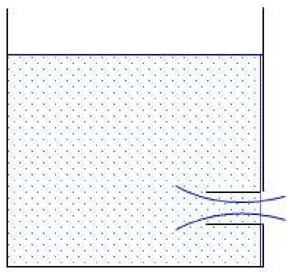


Fig. 21.2 Borda's mouthpiece running free

Pressure force on mouthpiece = pressure × area of mouthpiece = $\omega H \times \alpha$

Where,

ω = Weight density of liquid (ρg)

H = Height of liquid above the mouthpiece

α = Area of mouthpiece

α_c = Area at vena contracta

V = flow velocity

Mass of liquid flowing per sec = $\rho\, \alpha_c\, V$

We know,

Momentum = mass X velocity

Rate of change of momentum = mass of liquid flowing/sec × change of velocity

$= (\rho\ \alpha_c\ V) \times$ (final velocity−initial velocity)

Placing,

Initial Velocity = 0

Final Velocity = V

$= \rho\ \alpha_c V\ (V - 0)$

$= \rho\ \alpha_c\ V^2$

Since weight density $\omega = \rho g$

Rate of change of momentum $= \frac{\omega}{g} \alpha_c\ V^2$--------------------------(i)

Pressure force $= \omega\ H\ \alpha$ --(ii)

Rate of change of momentum = Pressure force

Equating equation (i) and (ii)

$\omega\ H\ \alpha = \frac{\omega}{g} \alpha_c\ V^2$ --(iii)

Torricelli's equation $V = C_v\sqrt{2gH}$ --------------------------(iv)

From equation (iii) and (iv)

$$\omega\ H\ \alpha = \frac{\omega}{g}\alpha_c\left(C_v\sqrt{2gH}\right)^2$$

Simplifying,

$$\frac{\alpha_c}{\alpha} = \frac{1}{2C_v^2}$$

In case of no loss of head $C_v = 1.0$ --------------------------(v)

$$\frac{\alpha_c}{\alpha} = \frac{1}{2C_v^2} = 0.5$$

Since,

$$C_c = \frac{\alpha_c}{\alpha}$$

$C_c = 0.5$-------------------------(vi)

$C_d = C_c \times C_v$ -------------------------(vii)

From equ (v), (vi) and (vii)

$C_d = C_c \times C_v = 0.5 \times 1 = 0.5$

Discharge $Q = C_d\ \alpha\ \sqrt{2gH}$

Or,

Discharge $Q = 0.5\ \alpha\ \sqrt{2gH}$

21.3.2 Borda's mouthpiece running full

Internal cylindrical mouthpiece is also known as Borda's mouthpiece. Mouthpiece tube is about 3 times its diameter, the liquid jet after contraction in the tube touches the internal walls of the tube. Such a condition is known as mouthpiece running full (Fig. 21.3).

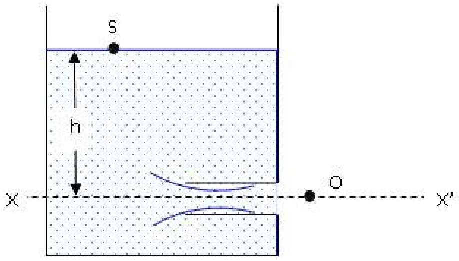


Fig. 21.3 Borda's mouthpiece running full

Considering XX' as datum line

	At point S	At point O
Potential head or height from datum line	h	0
Pressure	P_s	P_o
Velocity	V_s	V

Applying Bernoulli's theorem to the free liquid surface at point S and the outlet of mouthpiece O,

$$\frac{P_s}{w} + \text{h} + \frac{V_s^2}{2g} = \frac{P_o}{w} + 0 + \frac{V^2}{2g} + head\ loss \qquad \dots(i)$$

$V_s = 0$ as $V_s << V$ and V_s is very small $\qquad \dots(ii)$

$P_\alpha = P_o =$ atmospheric pressure $\qquad \dots(iii)$

$$Head\ loss = \frac{(V_c - V)^2}{2g} \qquad \dots(iv)$$

Placing values of (ii), (iii) & (iv) in equation (i)

$$h = \frac{V^2}{2g} + \frac{(V_c - V)^2}{2g}$$

$$h = \frac{V^2}{2g} + \frac{V^2}{2g}\left(\frac{V_c}{V} - 1\right)^2$$

$$\dots(v)$$

From equation of continuity

$V_c\, a_c = V\, a$

$$\frac{V_c}{V} = \frac{\alpha}{\alpha_c}$$

$$\frac{\alpha}{\alpha_c} = \frac{1}{C_c} = \frac{1}{0.5}$$

Thus,

$$\frac{V_c}{V} = \frac{1}{0.5}$$

From equ v

$$h = \frac{V^2}{2g} + \frac{V^2}{2g}\left(\frac{1}{0.5} - 1\right)^2 = 2\frac{V^2}{2g}$$

Or,

$$h = 2\frac{V^2}{2g}$$

Placing $V = C_v\sqrt{2gH}$ from Torricelli's theorem in the above equation,

$$h = 2 \times \frac{\left(C_v \times \sqrt{2gH}\right)^2}{2g}$$

$$h = 2C_v^2 h$$

$Cofficient\ of\ velocity\ C_v = \frac{1}{\sqrt{2}} = 0.707$

Coefficient of contraction $C_C = 1$

[Since the area of jet at exit equals the area of the mouthpiece]

$$C_d = C_c C_v = 1 \times 0.707 = 0.707$$

Discharge through a Borda's mouthpiece running full,

$$Q = C_d \alpha \sqrt{2gH}$$

$Q = 0.707 \alpha \sqrt{2gH}$