Draft Tube

Def:

The draft tube is a pipe of gradually increasing area which connects the outlet of the runner to the tail race.

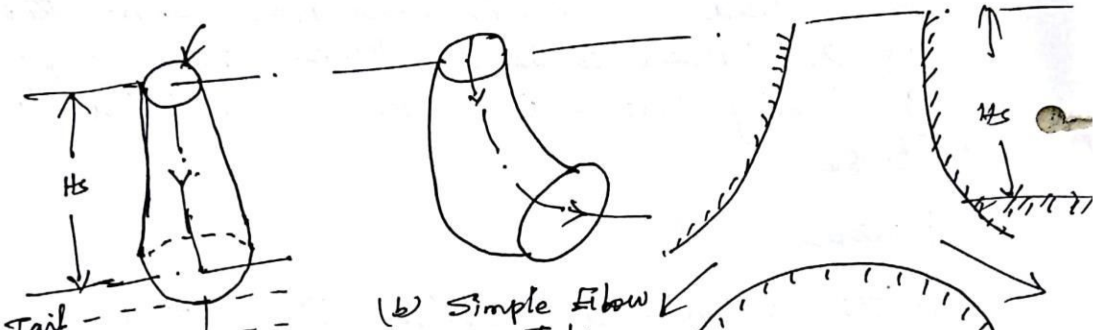
It is used for discharging water from the exit of the turbine to the tail race. This pipe of gradually increasing area is called a draft tube

Purpose:

1. It permits a negative head to be established at the outlet of the runner and thereby increase the net head on the turbine. The turbine may be placed above the tail race without any loss of net head and hence turbine may be inspected properly.
2. It converts a large proportion of the kinetic energy $\left(\frac{V_2^2}{2g}\right)$ rejected at the outlet of the turbine into useful pressure energy. Without the draft tube, the KE rejected at the outlet of the turbine will go waste to the tail race.

Types of Draft-Tubes:

1. Conical draft-tubes
2. Simple elbow tubes
3. Moody Spreading tubes
4. Elbow draft-tubes with circular inlet and rectangular outlet.



(a) Tail race

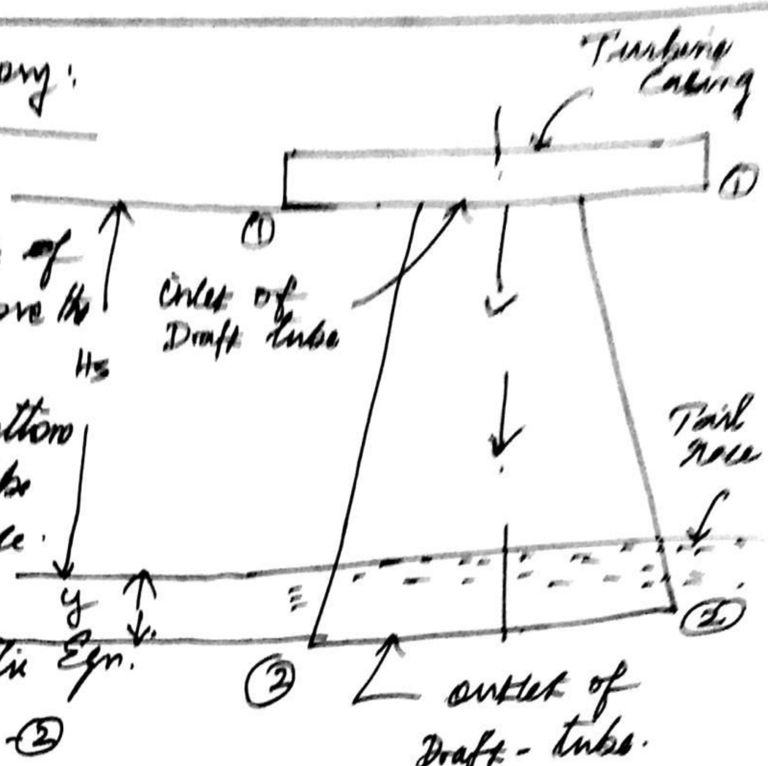
(b) Simple Elbow Tube

(c) Moody Spreading Tube

(d) Draft tube with circular inlet and Rectangular outlet

- Conical draft-tubes and Moody spreading draft-tubes are most efficient.
- Simple elbow tubes and elbow draft-tubes with circular inlet and rectangular outlets require less space as compared to other draft-tubes.

Draft tube Theory:



Hs – vertical height of draft tube above the tail race.

y – Distance of bottom of draft-tube from tail race.

Apply Bernoulli Eqn. from ① - ① to ② - ②

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + (H_s + y) = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + 0 + h_f \quad \text{—(i)}$$

But $\frac{P_2}{\rho g}$ = Atmospheric Pressure head + y

$$= \frac{P_a}{\rho g} + y$$

Substituting this value of $\frac{P_2}{\rho g}$ in eqn (i)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + (H_s + y) = \frac{P_a}{\rho g} + y + \frac{V_2^2}{2g} + h_f$$

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + H_s = \frac{P_a}{\rho g} + \frac{V_2^2}{2g} + h_f$$

$$\frac{P_1}{\rho g} = \frac{P_a}{\rho g} + \frac{V_2^2}{2g} + h_f - \frac{V_1^2}{2g} - H_s$$

$$= \frac{P_a}{\rho g} - H_s - \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g} - h_f\right) \quad (ii)$$

in Equation (ii) $\frac{P_1}{\rho g}$ is less than atmospheric Pressure

Efficiency of Draft-tube.

The efficiency of a draft-tube is defined as the ratio of actual conversion of kinetic head into pressure head in the draft tube to the kinetic head at the inlet to the draft-tube. Mathematically

$$\eta_d = \frac{\text{Actual conversion of kinetic head into pressure head}}{\text{Kinetic head at the inlet of draft tube}}$$

V_1 – Velocity of water at inlet of draft tube.

V_2 – Velocity of water at outlet of draft tube and

h_f – Loss of head in the draft tube

Theoretical conversion of kinetic head into Pressure head in draft tube $\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right)$

Actual conversion of kinetic head into Pressure head $= \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) - h_f$

$$\boxed{\eta_d = \frac{\left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) - h_f}{\left(\frac{V_1^2}{2g}\right)}}$$

PERFORMANCE OF TURBINE.

The Concept of unit quantities and Specific quantities are required.

- The behaviour of a Turbine is Predicted working under different Conditions
- Comparison is made between the Performance of turbines of Same type but different Sizes.
- The performance of turbine is Compared with different types.

Performance under unit head - unit quantities:

Unit quantities refer to the turbine Parameters which are obtained for a particular turbine operated under a unit head.

For estimating unit quantities, it is assumed that the efficiency of the turbine remains unchanged.

The velocity triangles under the actual working head and any other assumed head are to be Similar.

Let, the ~~performance~~ parameters under a head H,

V = Absolute velocity
V_r = Relative velocity
V_f = Flow velocity
u = peripheral velocity

V′, V_r', V_f' and u′ are corresponding value under another head H′. Since the magnitude of absolute velocity varies in proportion to $\sqrt{H}$. The following relations hold good.

$$\frac{u}{u'} = \frac{V_f}{V_f'} = \frac{V_r}{V_r'} = \frac{V}{V'} = \frac{\sqrt{H}}{\sqrt{H'}} \quad \text{--- (1)}$$

From the above relation, the following three important unit quantities are to be derived under unit head.

(i) Unit Speed (N_u)

Unit speed is the speed of a turbine when working under a unit head (1m).

We know that $u = \omega r = \omega \frac{D}{2} = \frac{2\pi N}{60} \times \frac{D}{2}$

$$\therefore u \propto N$$

Since, the diameter D is constant for a given turbine. By combining this relation with equation (1)

$$\frac{N}{N'} = \frac{u}{u'} = \frac{\sqrt{H}}{\sqrt{H'}}$$

When $H' = 1m$ and $N' =$ Unit speed N_u.

$$\frac{N}{N_u} = \sqrt{H}$$

Unit speed $N_u = \frac{N}{\sqrt{H}}$

(2) Unit discharge (Q_u)

It is the theoretical discharge of a turbine when working under a unit head.

For any turbine $Q = A V_f = \frac{\pi}{4} D^2 V_f$

$$\therefore Q \propto V_f$$

Combining this relation with equation (1)

$$\frac{Q}{Q'} = \frac{V_f}{V_f'} = \frac{\sqrt{H}}{\sqrt{H'}} \quad \left[\because V = C_v \sqrt{2gH}\right]$$

When $H' = 1m$ and $Q' =$ Unit Discharge (Q_u)

$$\frac{Q}{Q_u} = \sqrt{H}$$

Unit Speed $Q_u = \frac{Q}{\sqrt{H}}$

(3) Unit Power

It is the theoretical power of a turbine when working under a unit head.

for any turbine power $P = \rho Q H$

$$P \propto V_f \propto \sqrt{H} \quad (\because Q \propto V_f \ \& \ Q \propto \sqrt{H})$$

Thus $P \propto H\sqrt{H}$

$$P \propto H^{3/2}$$

$$\frac{P}{P'} = \frac{H^{3/2}}{H'^{3/2}}$$

When $H' = 1m$

and $P' =$ Unit power (P_u)

$$\frac{P}{P_u} = H^{3/2}$$

$$P_u = \frac{P}{H^{3/2}}$$

Specific Speed (N_s)

Homologus units are required in governing dimensionless groups to use scaled models in designing turbomachines, based geometric similitude.

Similarity Rules: For pump 1 and pump 2 from the same geometric family are operating at homologous points are analysed.

Specific speed is the speed of a geometric similarity turbine (i.e turbine identical in shape, dimensions, blade angles and gate openings etc) which will develop unit power when working under a unit head.

The specific speed is used in comparing the different types of turbines as every

$$P = K \frac{H^{5/2}}{N^2}$$

where K = Constant of Proportionality

if P = 1KW, Head H = 1m, N = Speific Speed N_s

$$1 = K \frac{1}{N_s^2}$$

$$K = N_s^2$$

Substituting the value of K in the equation P.

$$P = N_s^2 \frac{H^{5/2}}{N^2}$$

$$N_s^2 = \frac{PN^2}{H^{5/2}}$$

Speific Speed

$$\boxed{N_s = \frac{N\sqrt{P}}{H^{5/4}}}$$

Specific Speed plays an important role in the Selection of the type of turbine..

By knowing the speific speed of the turbine, the performance of the turbine can also be predicted.

The type of turbine for different Speific Speed is given below.

Sl. No	Speific Speed	Type of turbine
1.	10 to 30	Pelton turbine with Single Jet
2.	17 to 50	Pelton turbine with two Jets
3.	24 to 70	→ with 4 Jets
4.	70 to 257	→ Francis Turbine
5.	257 to 858	→ Kaplan Turbine.

type of turbine has different specific speed
In S.I units unit power is taken as one kW and unit head as one meter

Power available at the turbine shaft $P = wQH \times \eta_0$

Since η_0 and w are constant $P \propto QH$ —(1)

The tangential velocity, absolute velocity, flow velocity and the head are related as

$$u \propto V_f$$
$$\propto V \propto \sqrt{H} \quad \text{—(2)}$$

Now $Q = A V_f = \frac{\pi}{4} D^2 V_f$

$$Q \propto D^2 V_f$$
$$Q \propto D^2 \sqrt{H} \quad (\text{from eqn.(2) } V \propto \sqrt{H})$$

also $u = \frac{\pi D N}{60}$

$$D \propto \frac{u}{N}$$
$$D \propto \frac{\sqrt{H}}{N} \quad (\because \text{ from equation (2) } u \propto \sqrt{H})$$

$$Q \propto \left(\frac{\sqrt{H}}{N}\right)^2 \cdot \sqrt{H} \propto \frac{H}{N^2} \sqrt{H} \propto \frac{H^{3/2}}{N^2}$$

Substituting this value in equation (1)

$$P \propto \frac{H^{3/2}}{N^2} \times H \propto \frac{H^{5/2}}{N^2}$$
$$P = K \frac{H^{5/2}}{N^2}$$

The Following points are worthwhile for noting

- Specific speed is proportional to the speed of rotation. Evidently, the high speed Kaplan turbine is expected to have high specific speed than pelton wheel.

- Specific speed is inversely proportional to head. Obviously, the high speed pelton wheel has a low value of specific speed Kaplan turbine which operates at low heads.

Discussion:

What is the importance of a draft tube in a Francis turbine . Discuss different types of draft tubes.

Ans. It is a pipe, which connects the turbine and outlet or tail race, through which the water exhausted from the runner, flows to the outlet channel.

It also act as a water conduit.

Draft tube has the following important function:

1. It makes the installation possible above the tail race level without the loss of head.

2. Water velocity at runner outlet is very, high. By using draft tube the velocity can be lowered. Loss of kinetic energy is converted into pressure energy.

3. Draft tube prevents the splashing of water coming out of the runner.

Different types of draft tubes used are:

(1) Conical draft tubes

(2) Simple elbow tubes

(3) Moody spreading tubes

(4) Elbow with circular inlet and rectangular outlet.

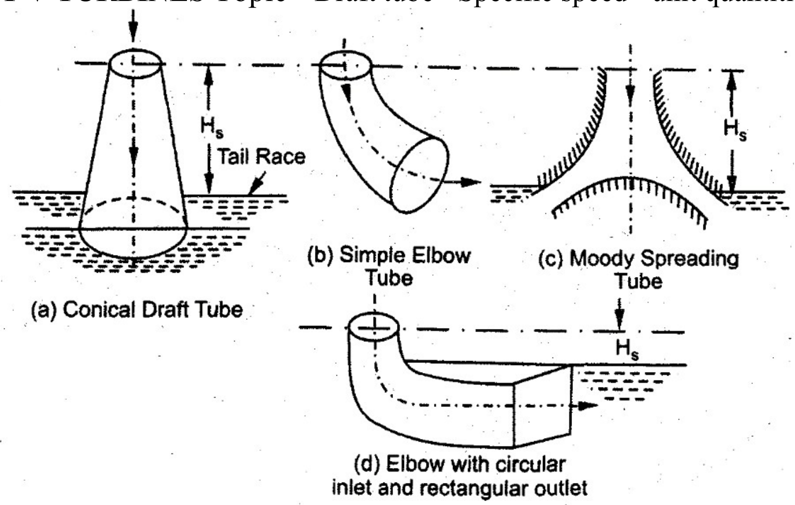


Fig. Types of draft tubes

(1) Conical Draft Tubes—This is known as tapered draft tube and used in all reaction turbines where conditions permit. It is preferred for low specific speed and Francis turbine. The maximum cone angle is 8° (a = 40°). The hydraulic efficiency is 90%.

(2) Simple Elbow Tubes-The elbow type draft tube is often preferred in most of the power plants. If the tube is large in diameter; 'it may be necessary to make the horizontal portion of some other section. A common form of section used is over or rectangular. It has low efficiency around 60%.

(3) Moody Spreading Tubes-This tube is used to reduce the whirling action of discharge water when turbine runs at high speed under low head conditions. The draft tube has efficiency around 85%.

(4) Elbow with circular inlet and rectangular outlet—This tube has circular cross-section at inlet and rectangular section at outlet. The change from circular section to rectangular section take place in the bend from vertical leg to the horizontal leg. The efficiency is about 85%.

Define draft tube efficiency. Give mathematical expression.

Ans. The efficiency of the draft tube is defined as the ratio of actual conversion of kinetic head into pressure head in the draft tube to the kinetic head at the inlet of the draft tube.

Mathematically,
$$\eta_d = \frac{\text{Actual conversion of K.H into P.H.}}{\text{K.H at inlet of draft tube}} = \frac{\left(\frac{v_1^2}{2g} - \frac{v_2^2}{2g}\right) - h_f}{\left(\frac{v_1^2}{2g}\right)}$$

Q .17. Why the draft tube is not used for Pelton turbine?

Ans. In case of pelton turbine all the K. E. is lost and draft tube is not used because the pressure value is just the atmospheric so there is no requirement of draft tube.
