DEPARTMENT OF AEROSPACE ENGINEERING

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Course	:	**23AST202 – Fluid Mechanics for Aerospace**			

UNIT V – TURBINES

EFFICIENCIES OF A TURBINE

1. Hydraulic Efficiency (η_h):

$$\eta_h = \frac{Power\ delivered\ to\ runner}{Power\ supplied\ at\ inlet} = \frac{R.P}{W.P}$$

Where, R.P. = Runner Power

W.P. = Water Power

$$R.P. = \frac{W}{g}\frac{\left[V_{w_1} \pm V_{w_2}\right] \times u}{1000}\ kW$$

$$W.P. = \frac{W \times H}{1000}\ kW$$

Where,

W= Weight of water striking the vanes of the turbine per second

$= \rho g \times Q$ in which Q = Volume of water/s,

V_{w_1} = Velocity of whirl at inlet,

V_{w_2} = Velocity of whirl at outlet,

u = Tangential velocity of vane,

u_1 = Tangential velocity of vane at inlet for radial vane,

u_2 = Tangential velocity of vane at outlet for radial vane,

H = Net head on the turbine.

2. Mechanical Efficiency (η_m):

$$\eta_m = \frac{Power\ at\ the\ shaft\ of\ the\ turbine}{Power\ delivered\ by\ water\ to\ the\ runner} = \frac{S.P}{R.P}$$

Where, R.P. = Runner Power

S.P. = Shaft Power

3. Volumetric Efficiency (η_v):

$$\eta_v = \frac{Volume\ of\ water\ actually\ striking\ the\ runner}{Volume\ of\ water\ supplied\ to\ the\ turbine}$$

4. Overall Efficiency (η_0):

$$\eta_0 = \frac{Power\ available\ at\ the\ shaft\ of\ the\ turbine}{Power\ supplied\ at\ the\ inlet\ of\ the\ turbine} = \frac{S.P}{W.P}$$

Where, W.P. = Water Power

S.P. = Shaft Power

$\eta_0 = \eta_m \times \eta_h$

Water power in kW = $\frac{\rho \times g \times Q \times H}{1000}$

$$\eta_0 = \frac{P}{\frac{\rho \times g \times Q \times H}{1000}}$$

PERFORMANCE CHARACTERISTIC CURVES OF TURBINES

- Hydraulic Turbines gives their best performance when they are operated at certain conditions of head, discharge, speed and output power.
- Model turbines are tested under different conditions of head, discharge, speed, power, efficiency. Results are plotted in the form of curves and are known as **performance characteristic curves.**
- For convenience, curves are plotted in terms of unit quantities.

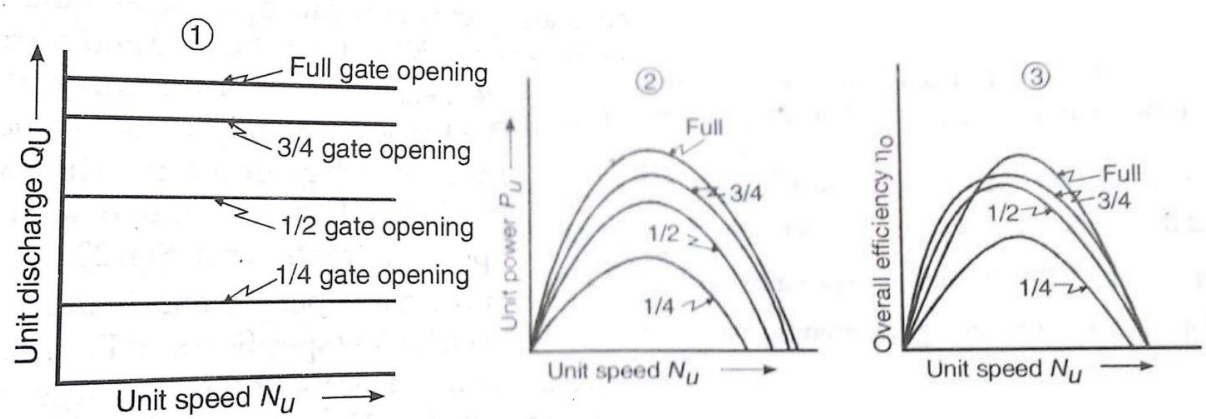
Types of PC curves

- Main Characteristic curves / Constant head curves
- Operating characteristic curves / Constant Speed curves
- Constant efficiency curves (Muschel Curves)

Main Characteristic curves/ Constant head curves

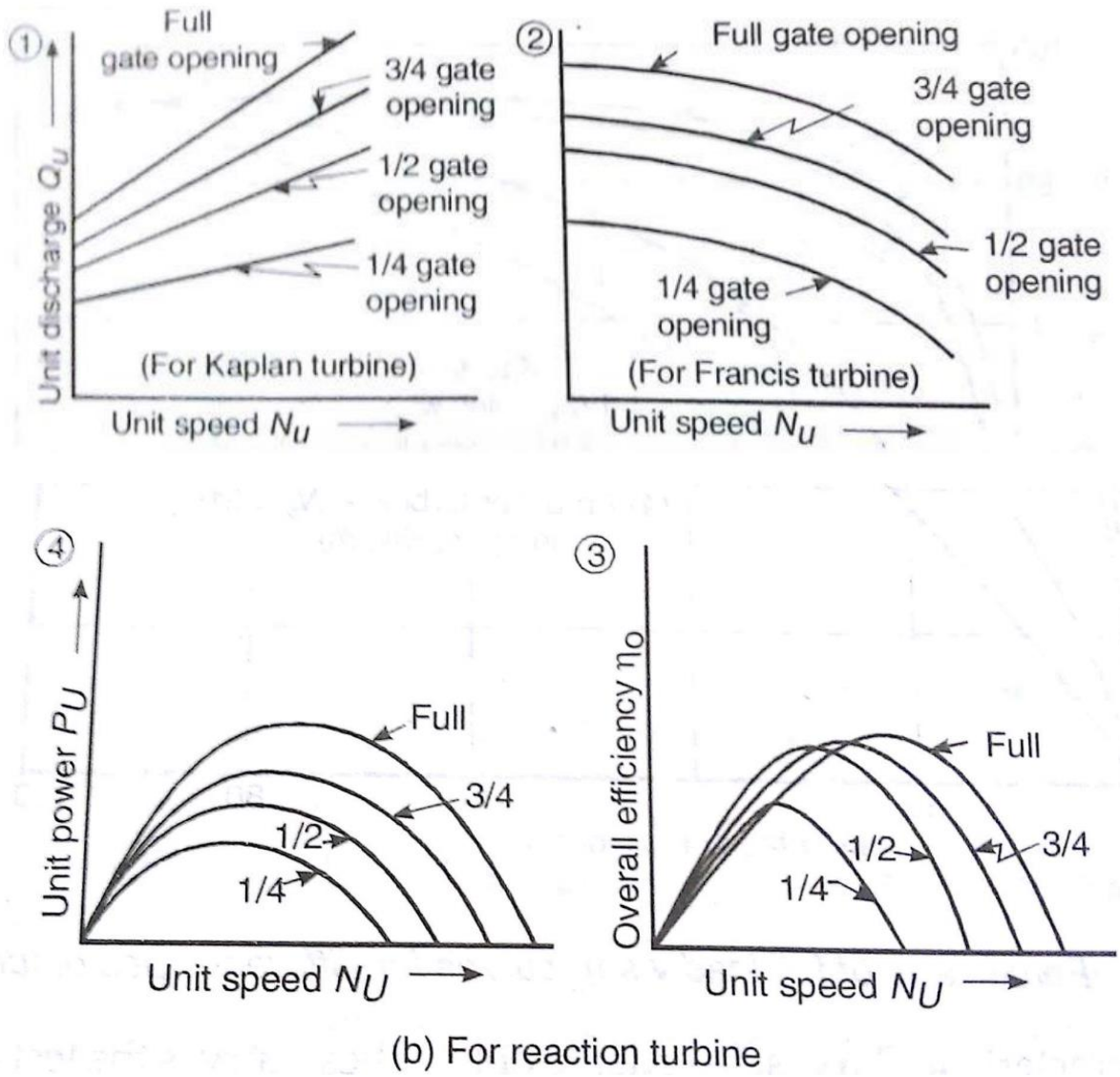
- Curves are drawn by conducting experiment at constant head.
- Head and gate openings are kept constant and speed is varied by varying load on the turbine.
- For each value of speed, corresponding values of power and discharge are obtained.

For Pelton wheel



(a) For pelton wheel

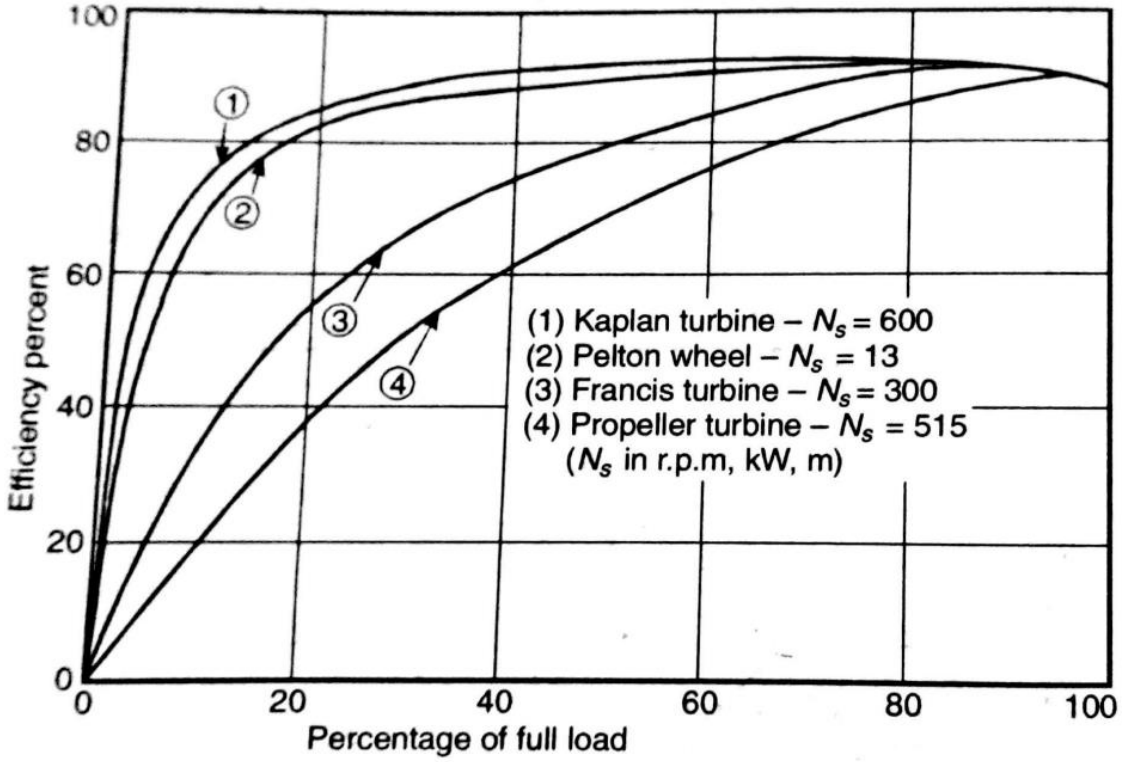
For Reaction turbines

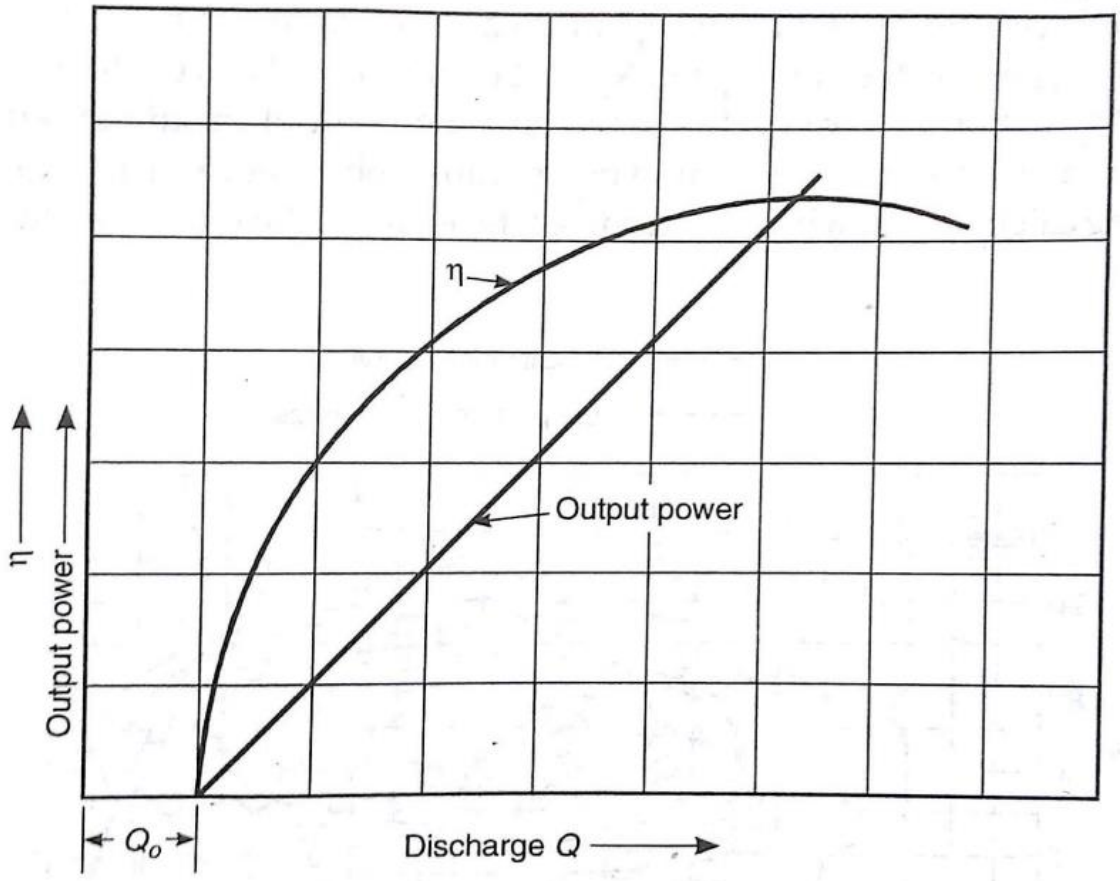


(b) For reaction turbine

Operating Characteristic Curves / Const. Speed Curves

- Tests are performed at constant speed.
- Const. speed is attained by regulating the gate opening thereby varying the discharge flowing through the turbine as the load varies.
- Head may or may not kept constant.


100
80
60
40
20
0
Efficiency percent
0
20
40
60
80
100
Percentage of full load
①
②
③
④
(1) Kaplan turbine – $N_s = 600$
(2) Pelton wheel – $N_s = 13$
(3) Francis turbine – $N_s = 300$
(4) Propeller turbine – $N_s = 515$
(N_s in r.p.m, kW, m)


η
Output power
η
Output power
Q_o
Discharge Q

Constant Efficiency Curves

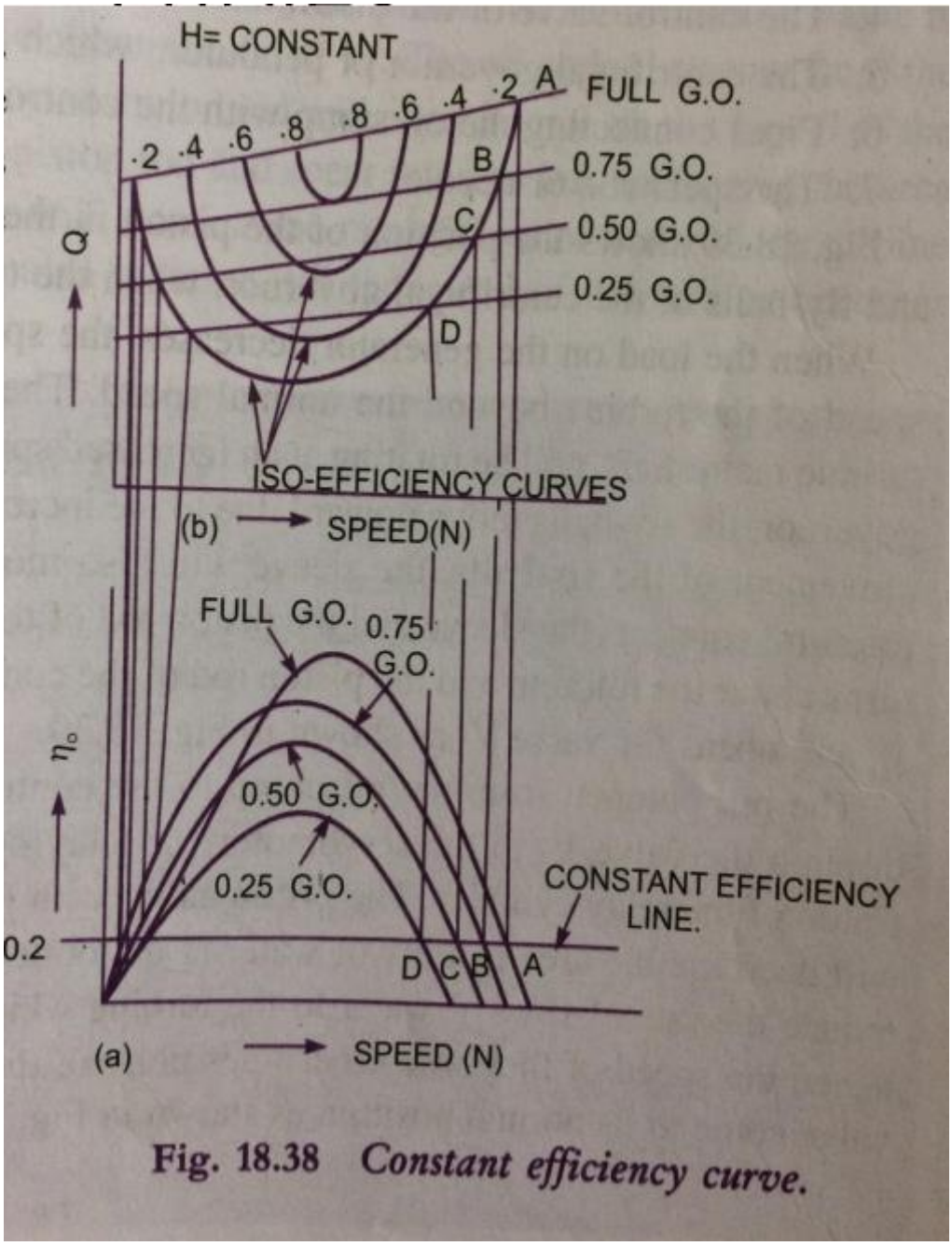
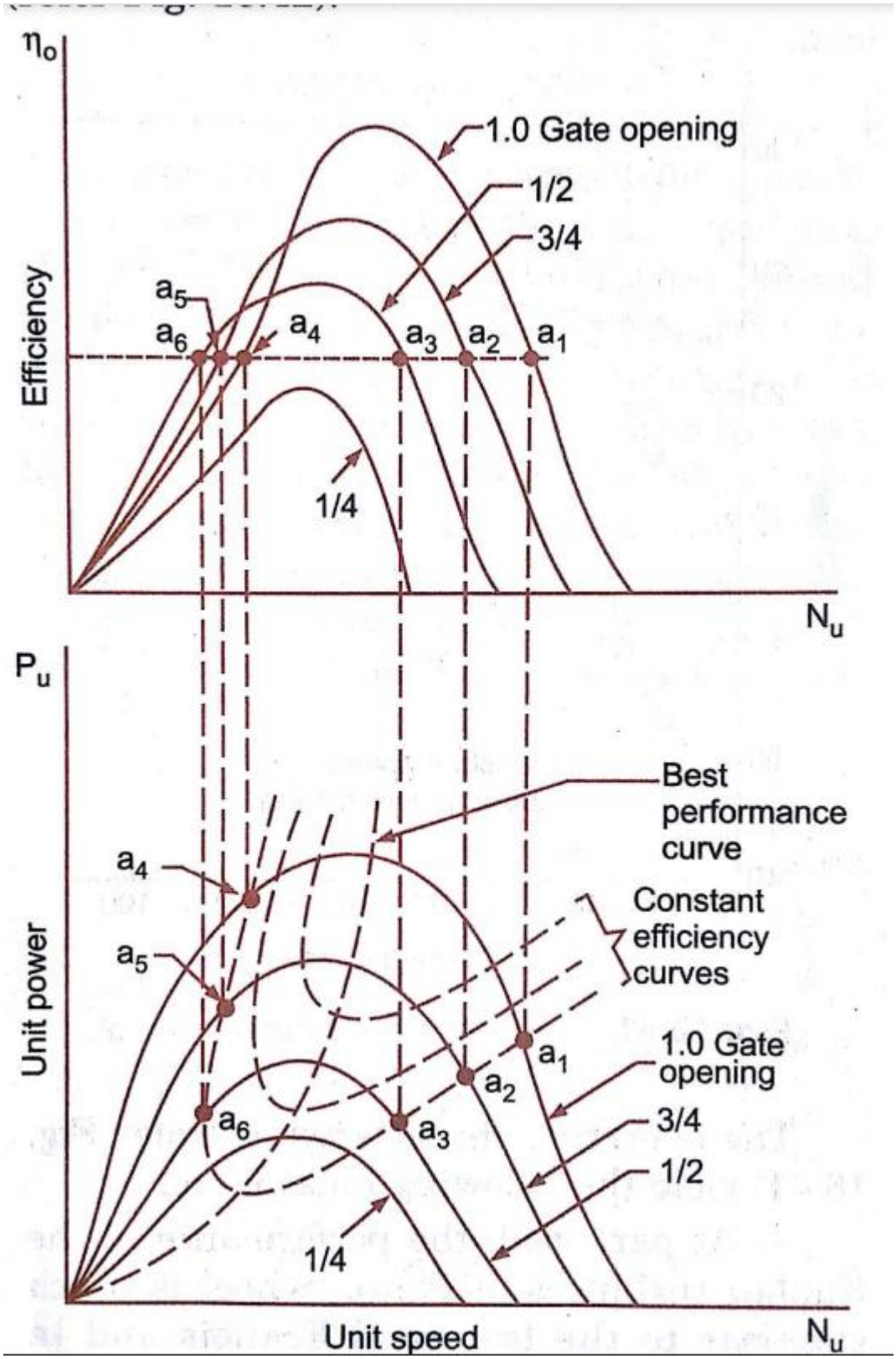


Fig. 18.38 *Constant efficiency curve.*


η_o
Efficiency
1.0 Gate opening
1/2
3/4
a_5
a_6
a_4
a_3
a_2
a_1
1/4
N_u
P_u
Unit power
Best performance curve
Constant efficiency curves
a_4
a_5
a_1
a_2
a_6
a_3
1.0 Gate opening
3/4
1/2
1/4
Unit speed
N_u