ENVE 204

LECTURE 7:

Pumps, energy equation with pumps, pump curves, pumps in parallel, pumps in series

PUMPS

Pumps are divided into:

- Roto-dynamic or centrifugal pumps and
- Positive displacement pumps

Within these main groups there are many different types of pumps

Turbo-hydraulic pumps

Move fluids with a rotating vane or another moving fluid.

- Centrifugal pumps
- Propeller pumps
- Jet pumps

Positive-displacement pumps

Move fluids strictly by presice machine displacements such as a gear system rotating with a closed housing (screw pumps) or a piston moving in a sealed cylinder (reciprocal pumps)

Centrifugal pumps

Reciprocating Pump

Screw pump

CENTRIFUGAL PUMP

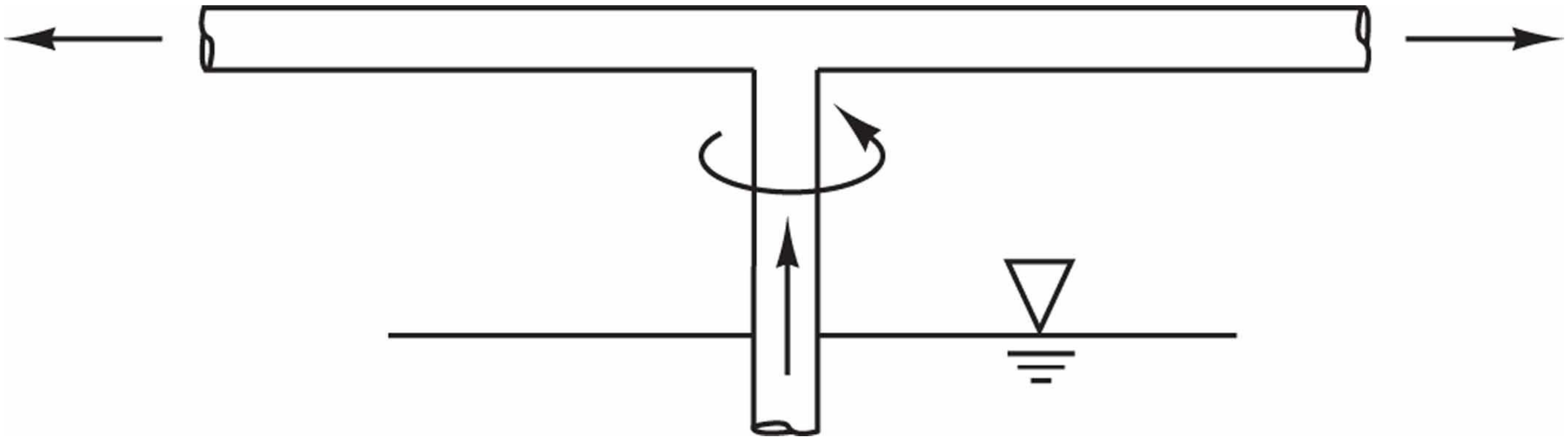
- A centrifugal pump is one of the simplest equipment pieces in any process plant

- Purpose: convert energy of a motor ➔ velocity or kinetic energy ➔ pressure energy of a fluid.

Two main parts of the pump

1) impeller : rotating part (convert driver energy into kinetic energy)
2) diffuser: stationary part (convert kinetic energy into pressure energy)

Figure 5.1 Demour's centrifugal pump



Liquid flow path inside a centrifugal pump

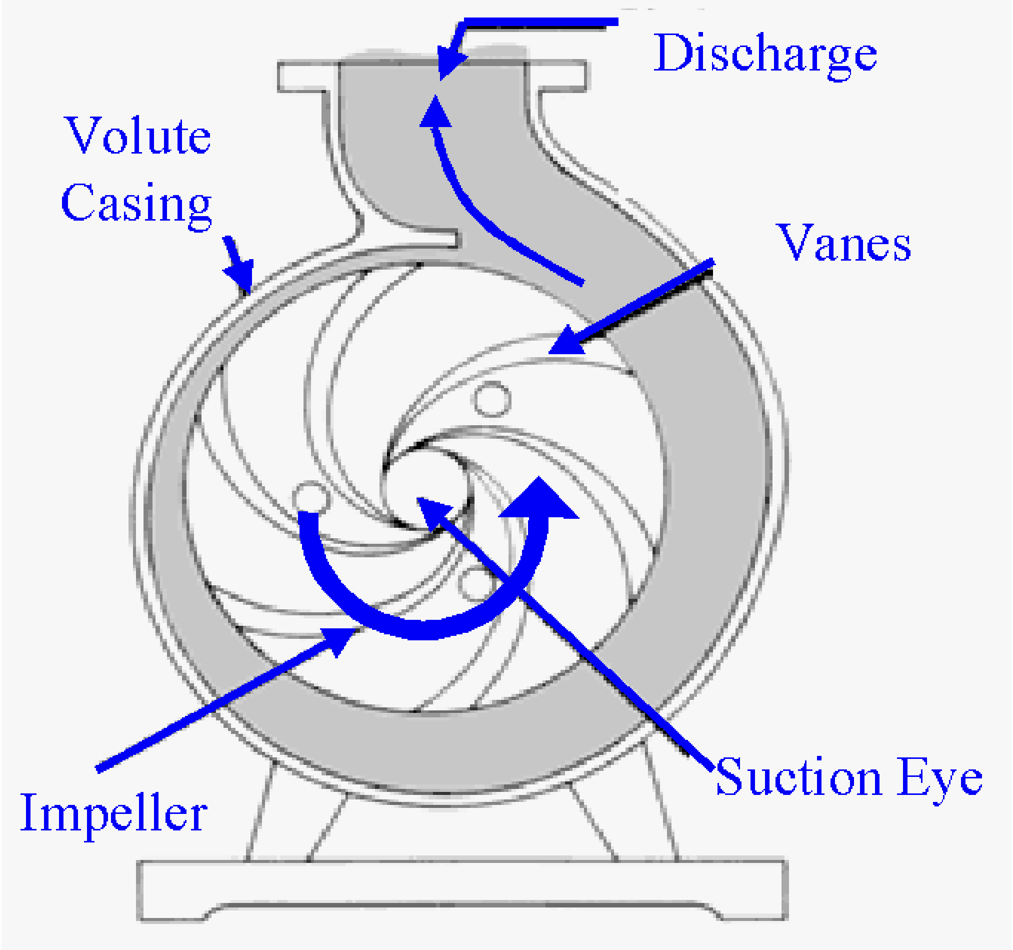
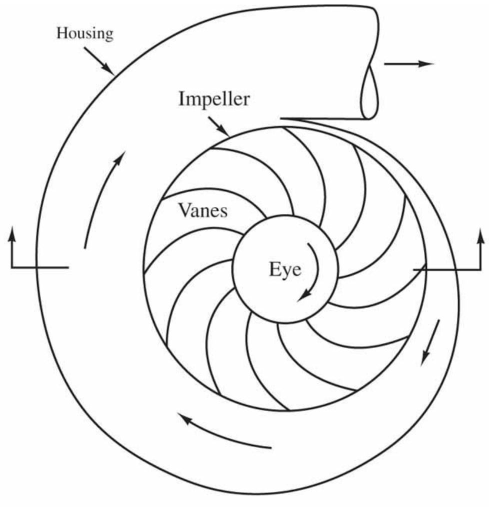
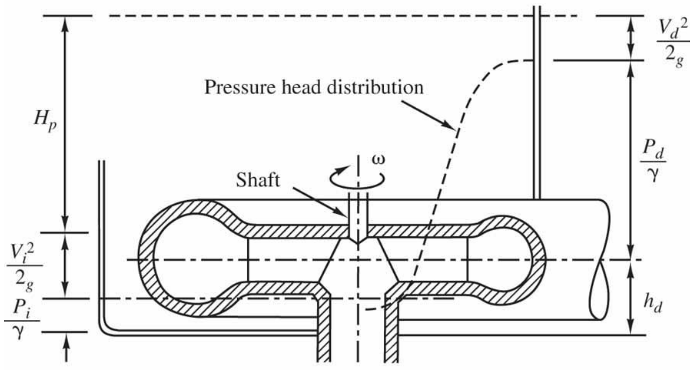
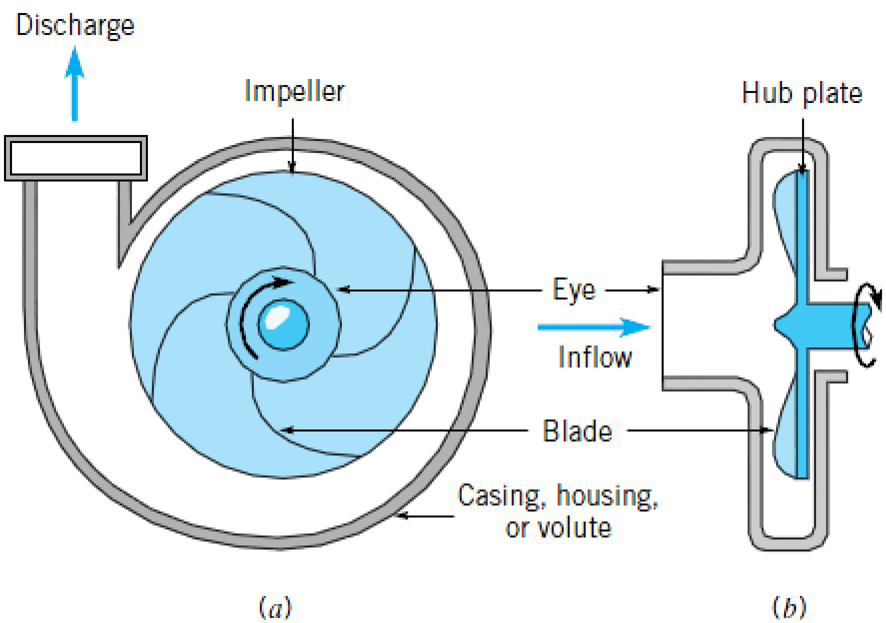


Figure 5.2 Cross sections of a centrifugal pump



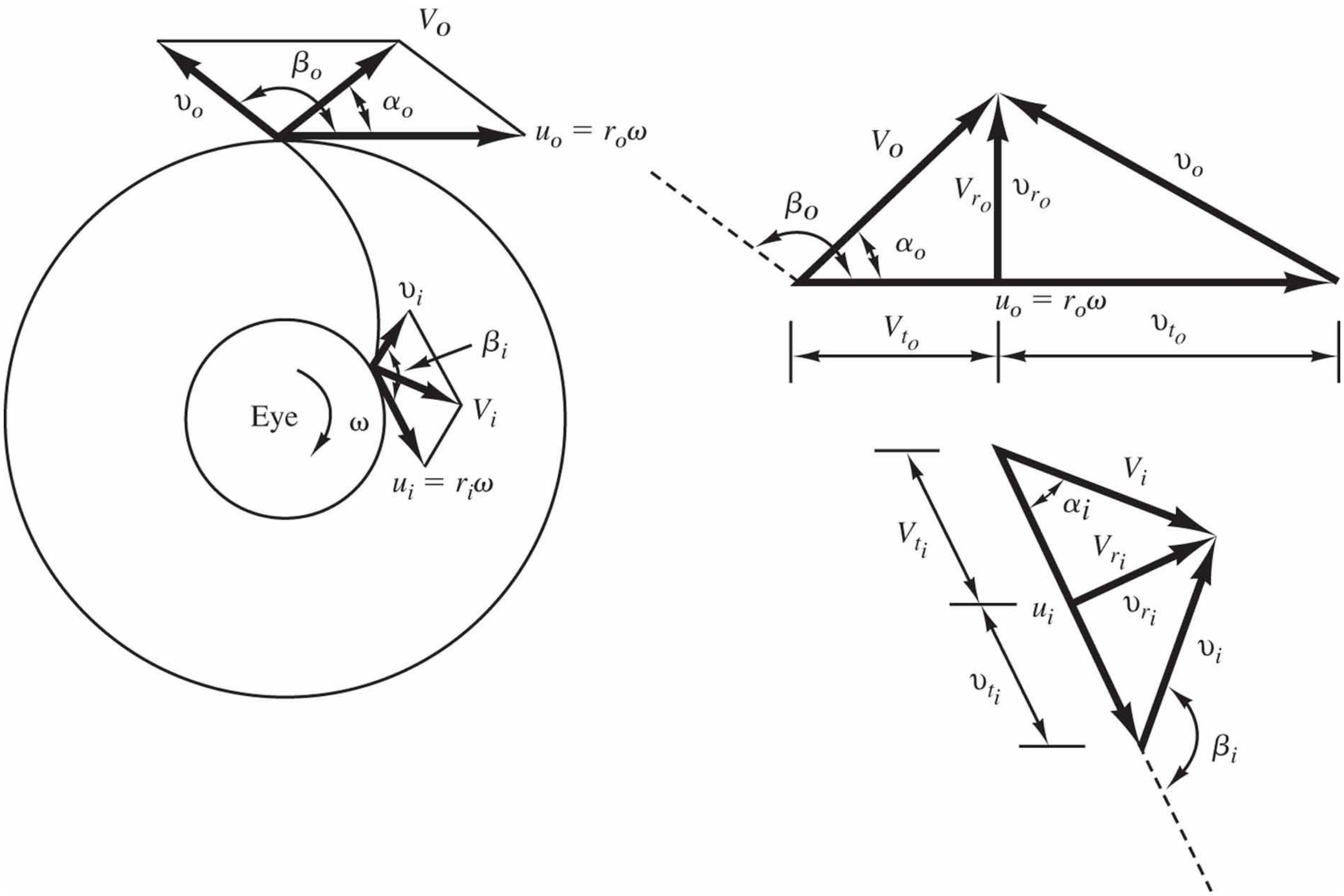


Hp: amount of energy that the pump imparts to the liquid.

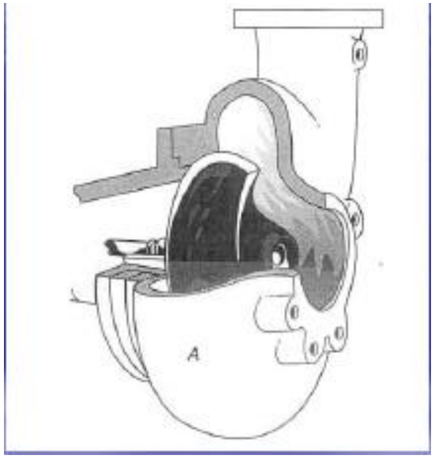


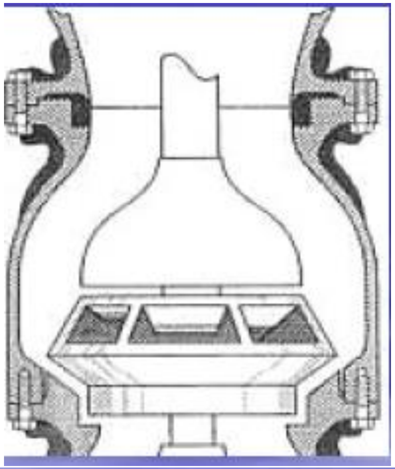
■ **FIGURE 12.6** **Schematic diagram of basic elements of a centrifugal pump.**

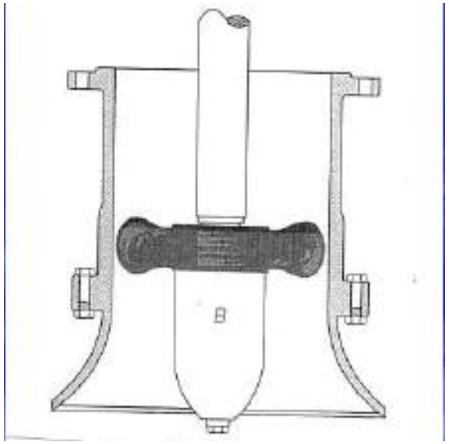
Figure 5.3 Velocity vector diagram; inlet side on the bottom and outlet side on the top (*Note:* u is the speed of the impeller vane ($u = r\omega$); V is the relative velocity of the liquid with respect to the vane; V is the absolute velocity of the liquid, a vector sum of u and v . β_0 is the vane angle at the exit, β_i is the vane angle at the entrance, $r = r_i$ is the radius of the impeller eye at the entrance, and $r = r_0$ is the radius of the impeller at the exit.)



Hydraulic Types of Pumps







Radial Flow Pump

High head low flow

Mixed Flow Pump

Axial Flow Pump

Low head, high flow

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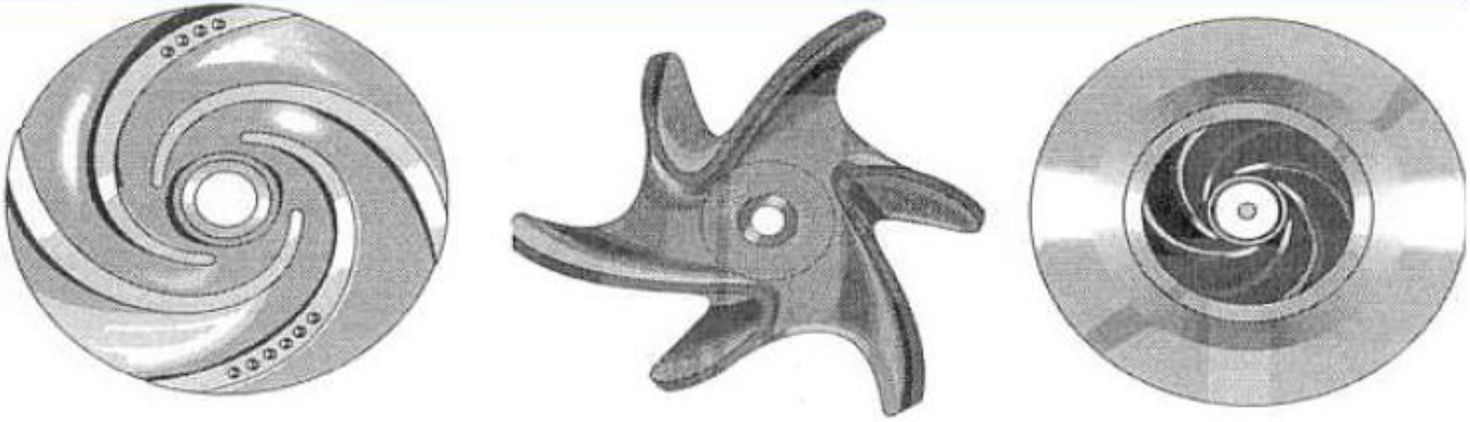
Impeller Types



Semi Open Impeller | Fully Open Impeller | Closed Impeller

Figure 5.4 Propeller pump

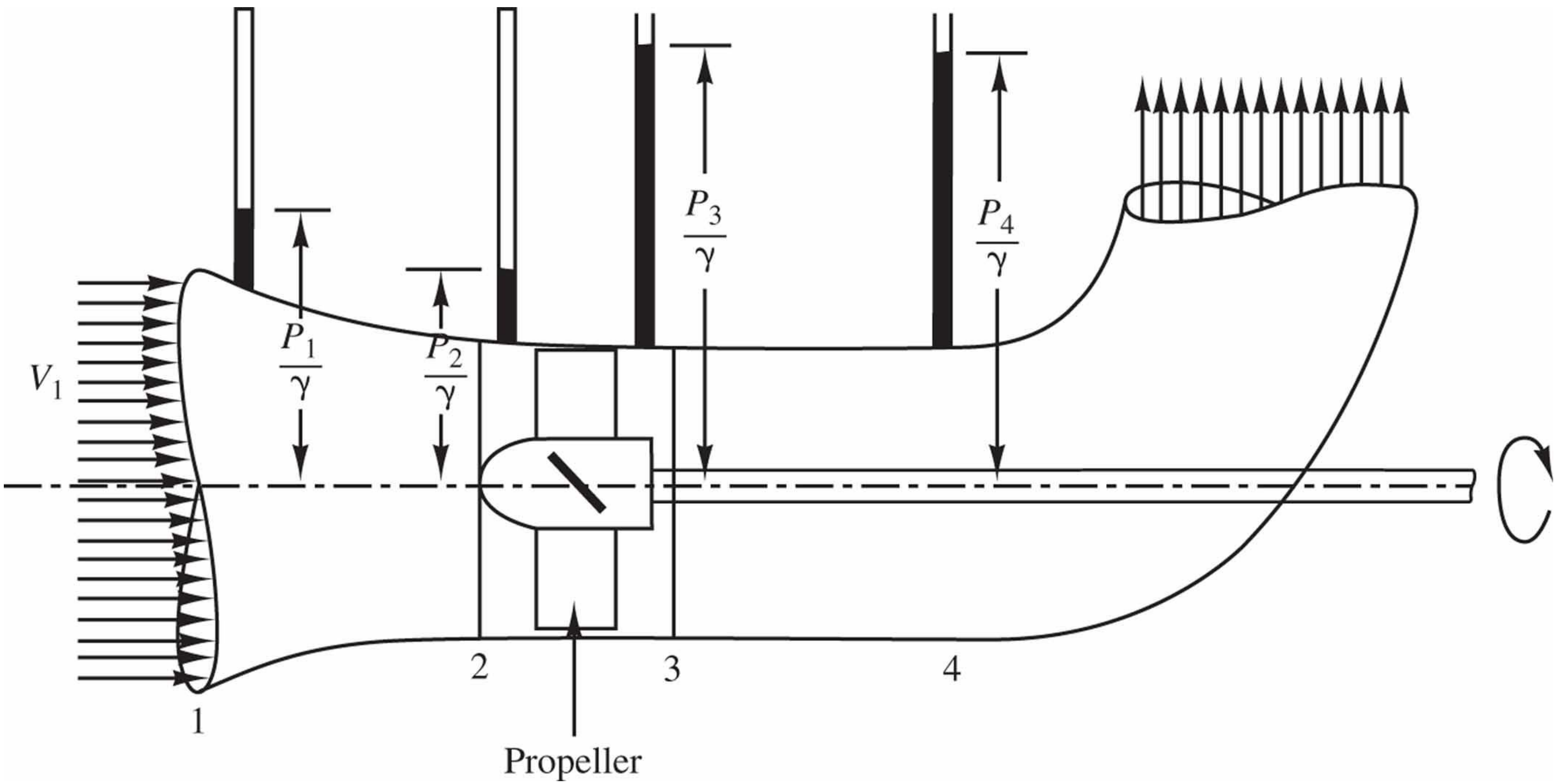


Figure 5.5 Multistage propeller pump

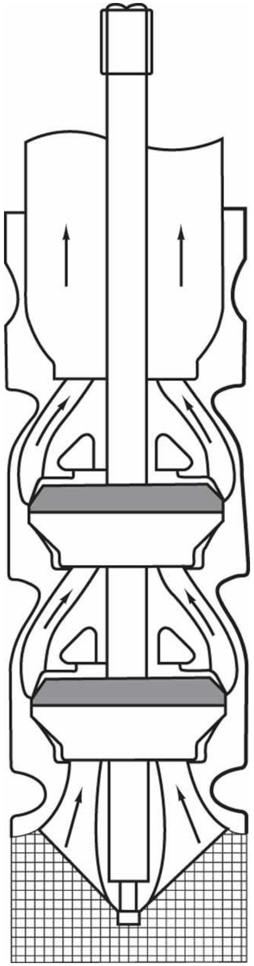


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Figure 5.6 Jet pump

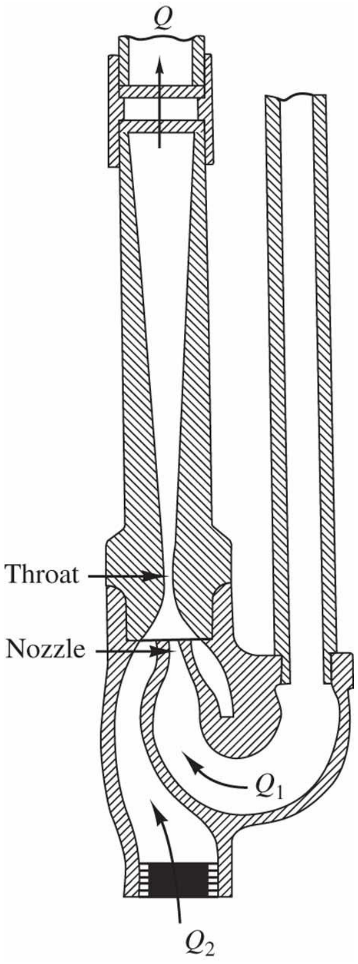
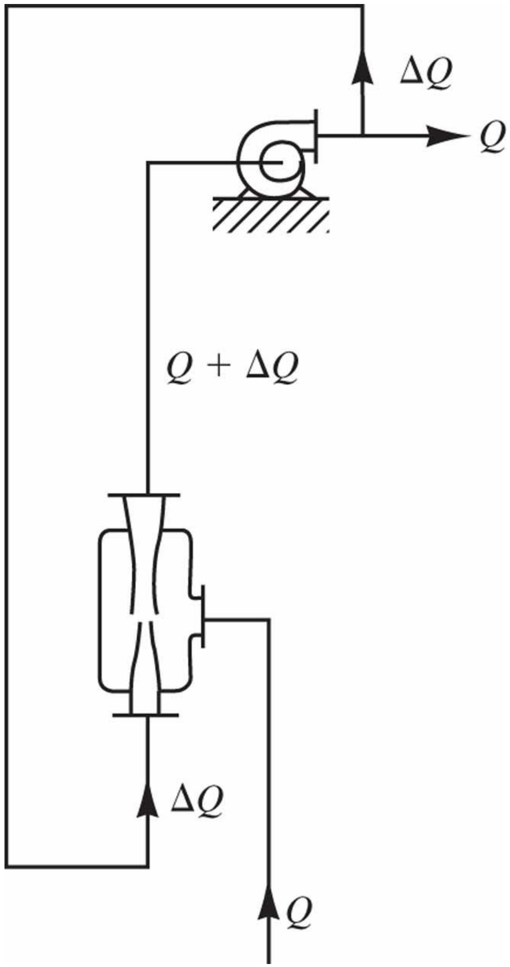


Figure 5.7 Jet pump as a booster



Definition of Important Terms

- Capacity
- Head
- BHP (Brake Horse Power)
- BEP (Best Efficiency Point)
- Specific Speed

Definition of Important Terms

Head:

Static Suction Head, hs

Static Discharge Head, hd

Friction Head, hf

Vapor Pressure Head, hpv

Pressure Head, hp

Velocity Head, hv

Total Suction Head, Hs

Total Discharge Head, Hd

Total Differential Head, Ht

Figure 5.8 Typical pump characteristic curves

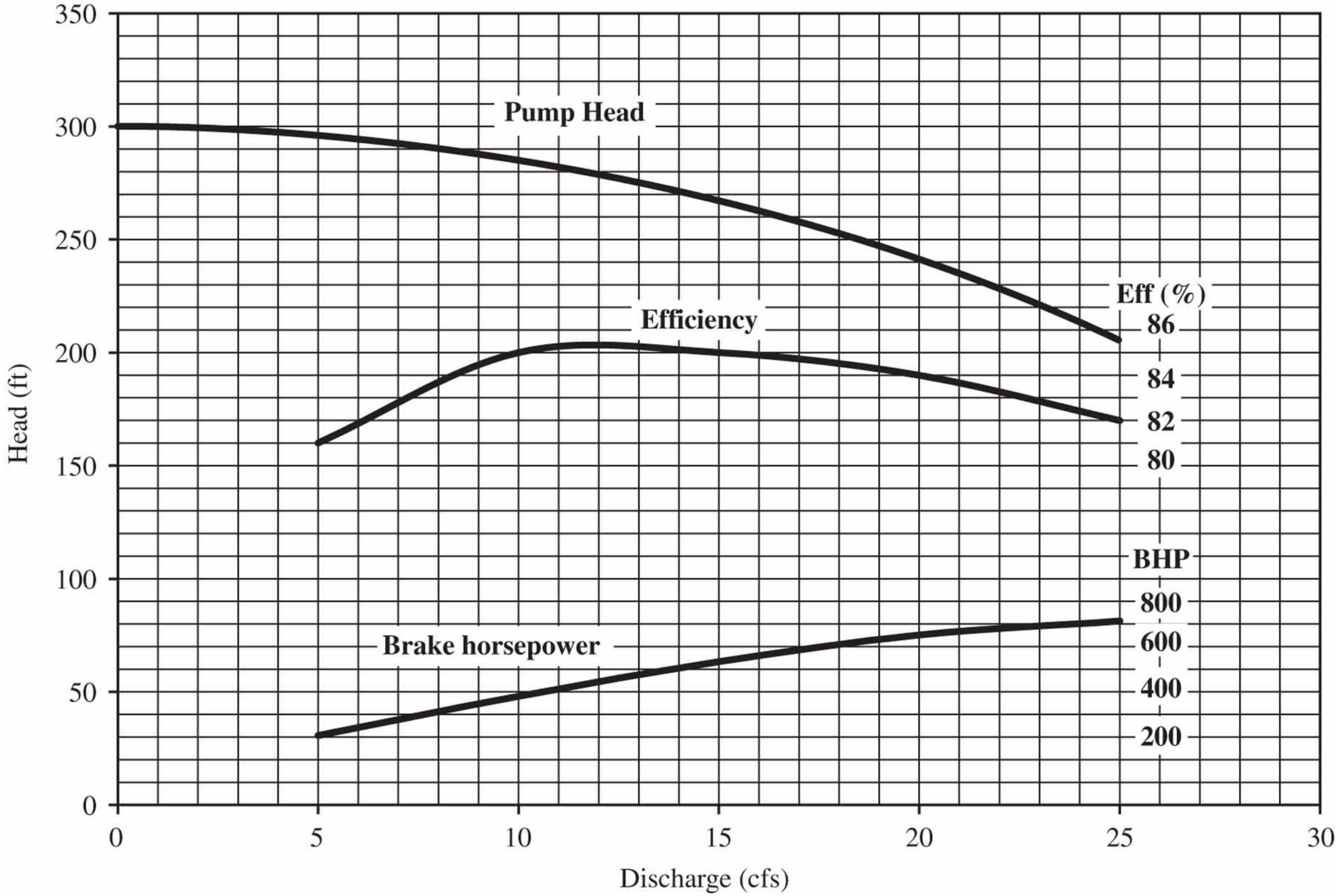


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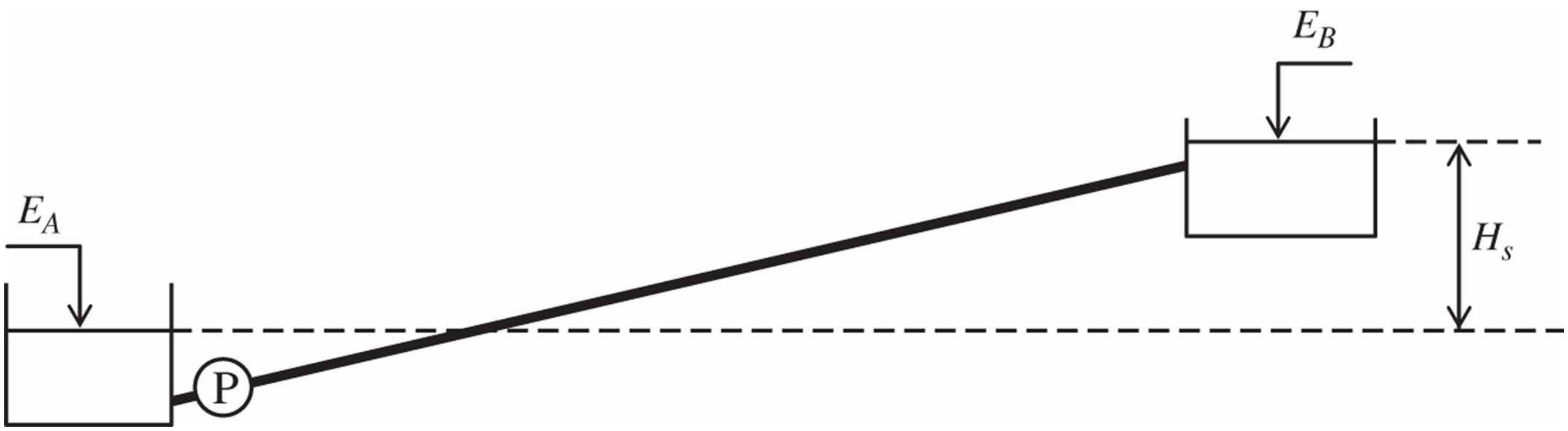
Figure 5.9 Single pump and pipeline



$$E_A + H_p = E_B + hf$$

or

$$H_p = E_B - E_A + hf$$

-Part of the energy added to the flow by the pump is expended in raising water from elevation E_A to E_B

-Part of it expended to overcome the flow resistance

$E_B - E_A$ = Hs= elevation rise (static head)

$$H_p = Hs + Hf$$

Figure 5.10A Single pump and pipeline analysis

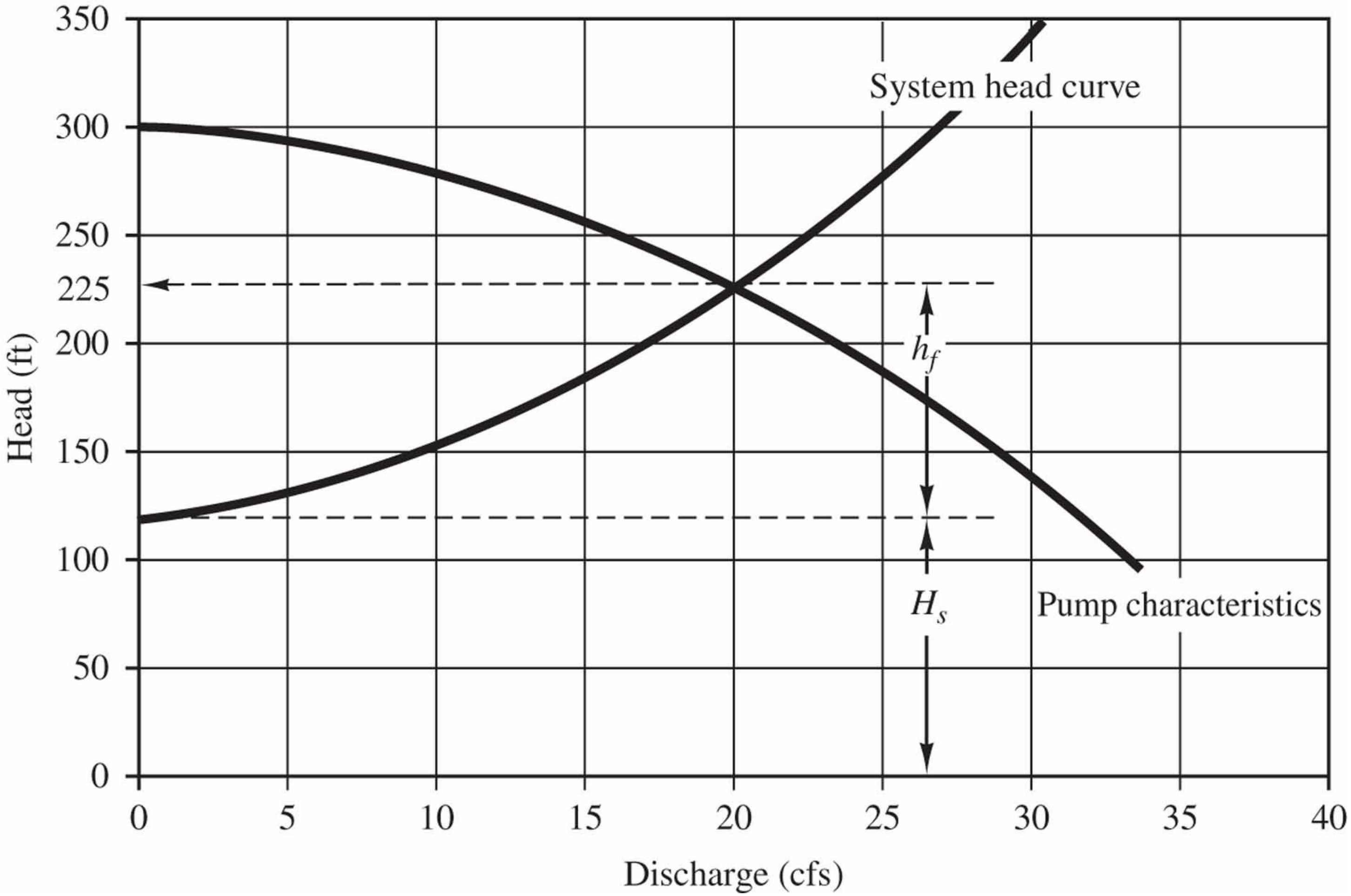
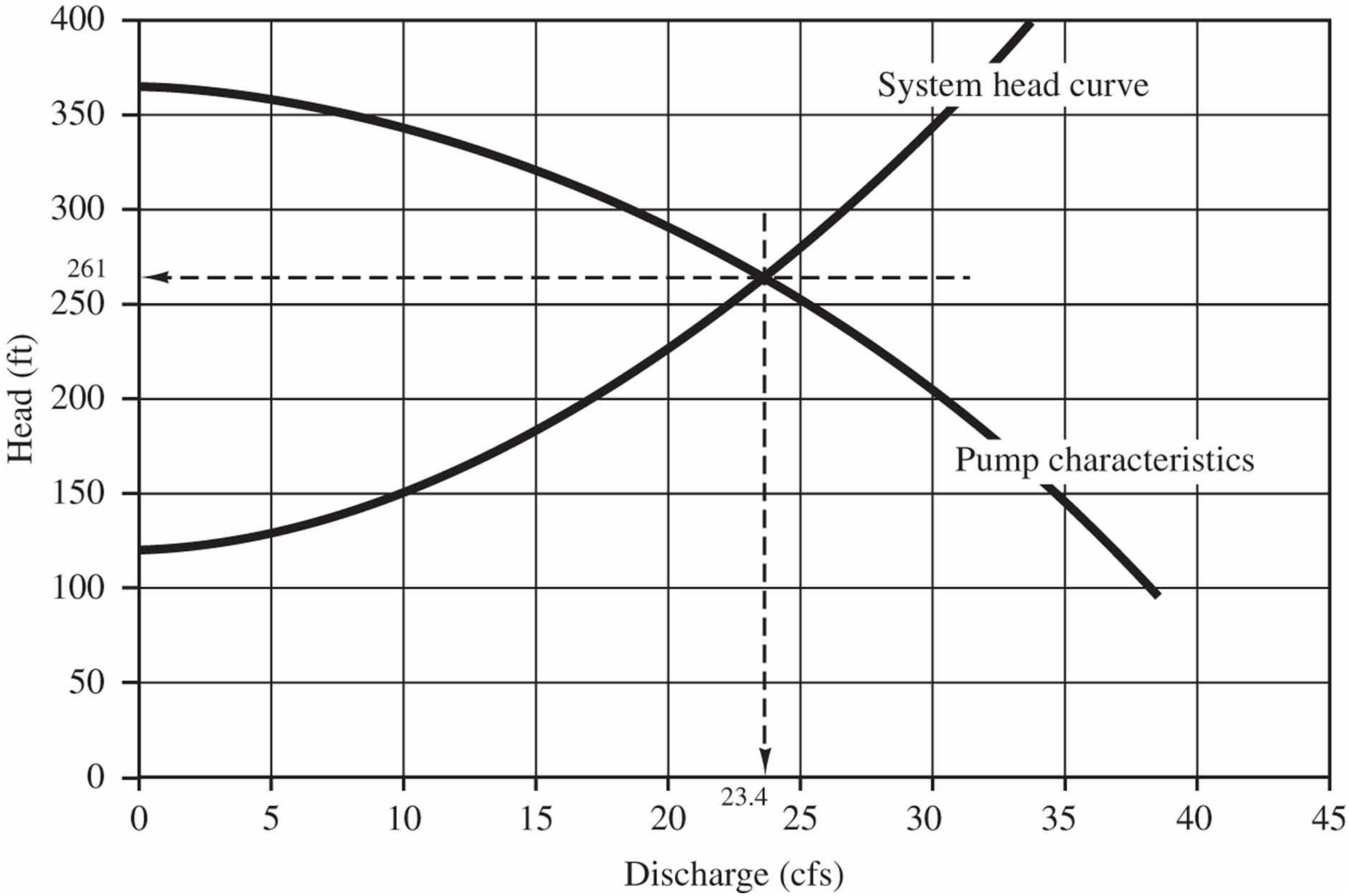
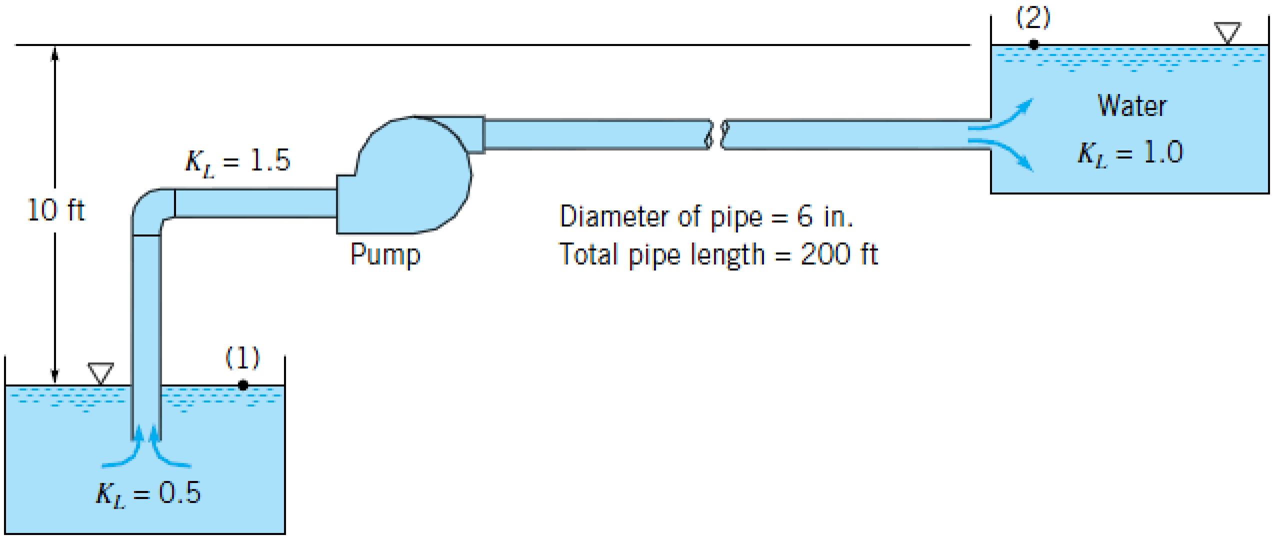


Figure 5.10B Single pump and pipeline analysis at a different rotational speed

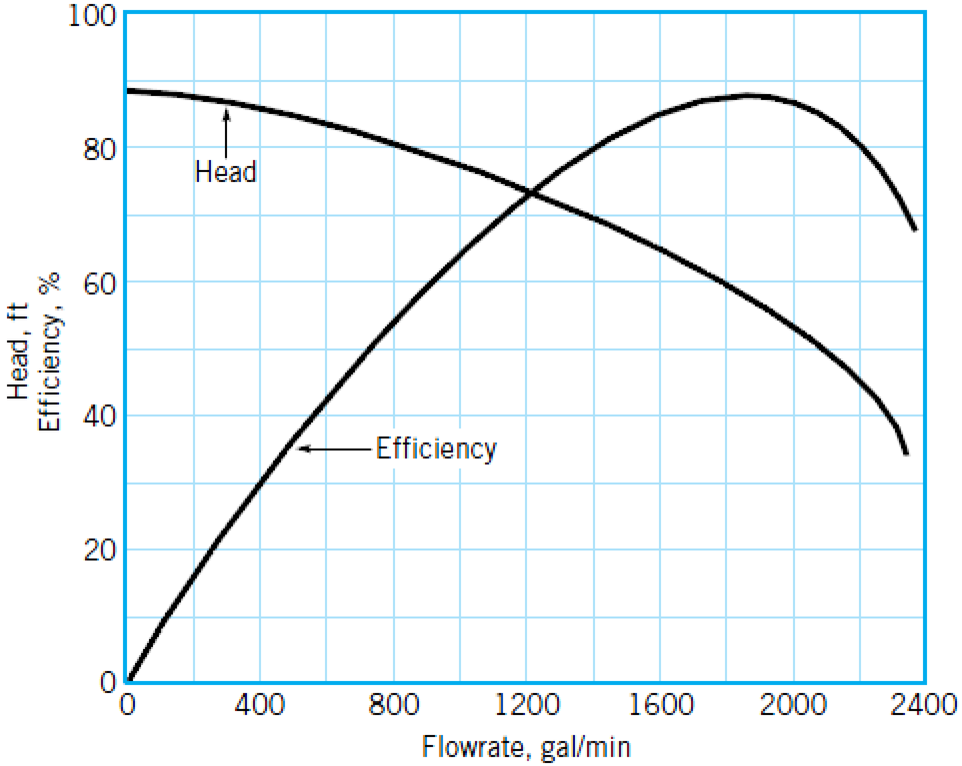


Water is to be pumped from one large, open tank to a second large, open tank as shown in Fig. E12.4*a*. The pipe diameter throughout is 6 in. and the total length of the pipe between the pipe entrance and exit is 200 ft. Minor loss coefficients for the entrance, exit, and the elbow are shown on the figure, and the friction factor for the pipe can be assumed constant and equal to 0.02. A certain centrifugal pump having the performance characteristics shown in Fig. E12.4*b* is suggested as a good pump for this flow system. With this pump, what would be the flowrate between the tanks? Do you think this pump would be a good choice?



(*a*)

Pump performance & efficiency curve



(*b*)

Operating Conditions (Q, Hp, Eff.)

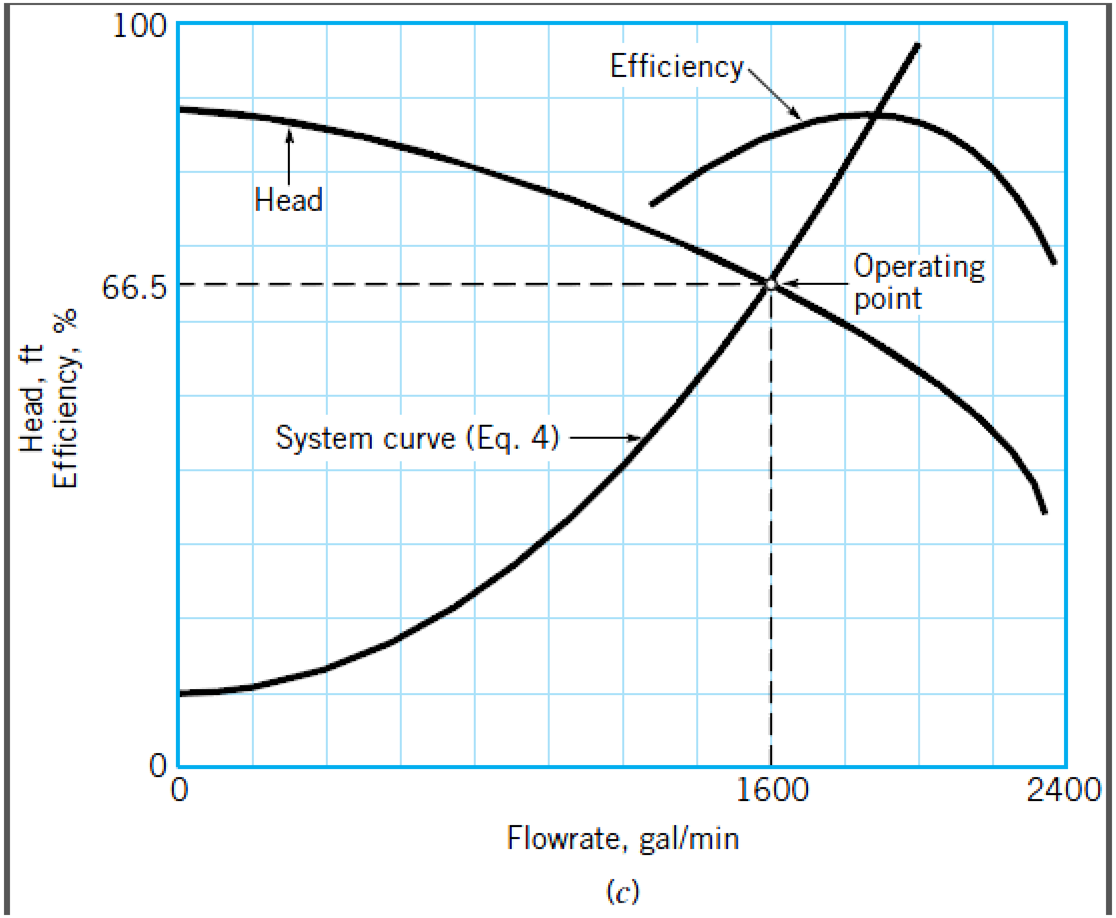


Figure 5.11 Pump characteristics for two pumps in parallel

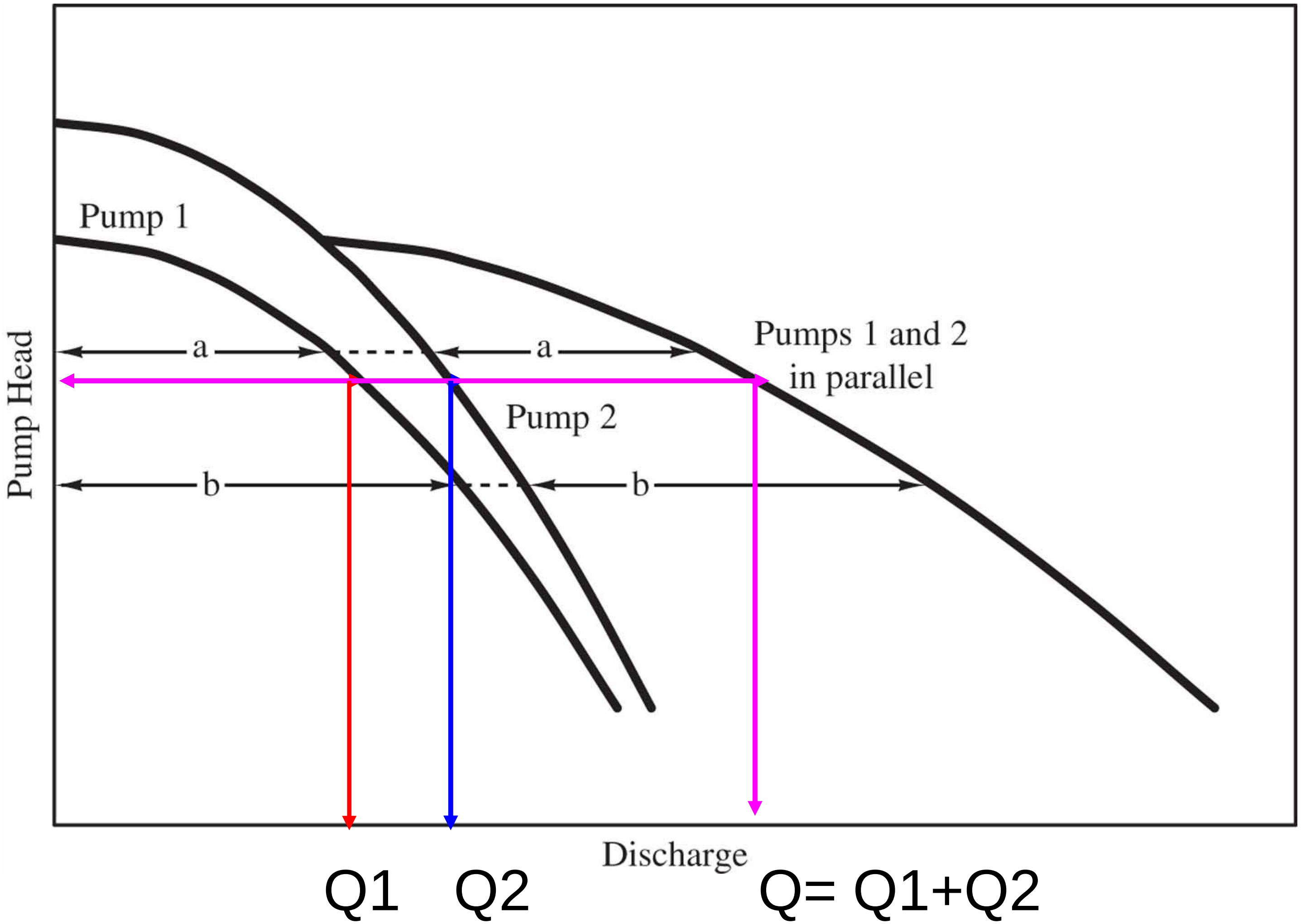


Figure 5.12 Pump characteristics for two pumps in series

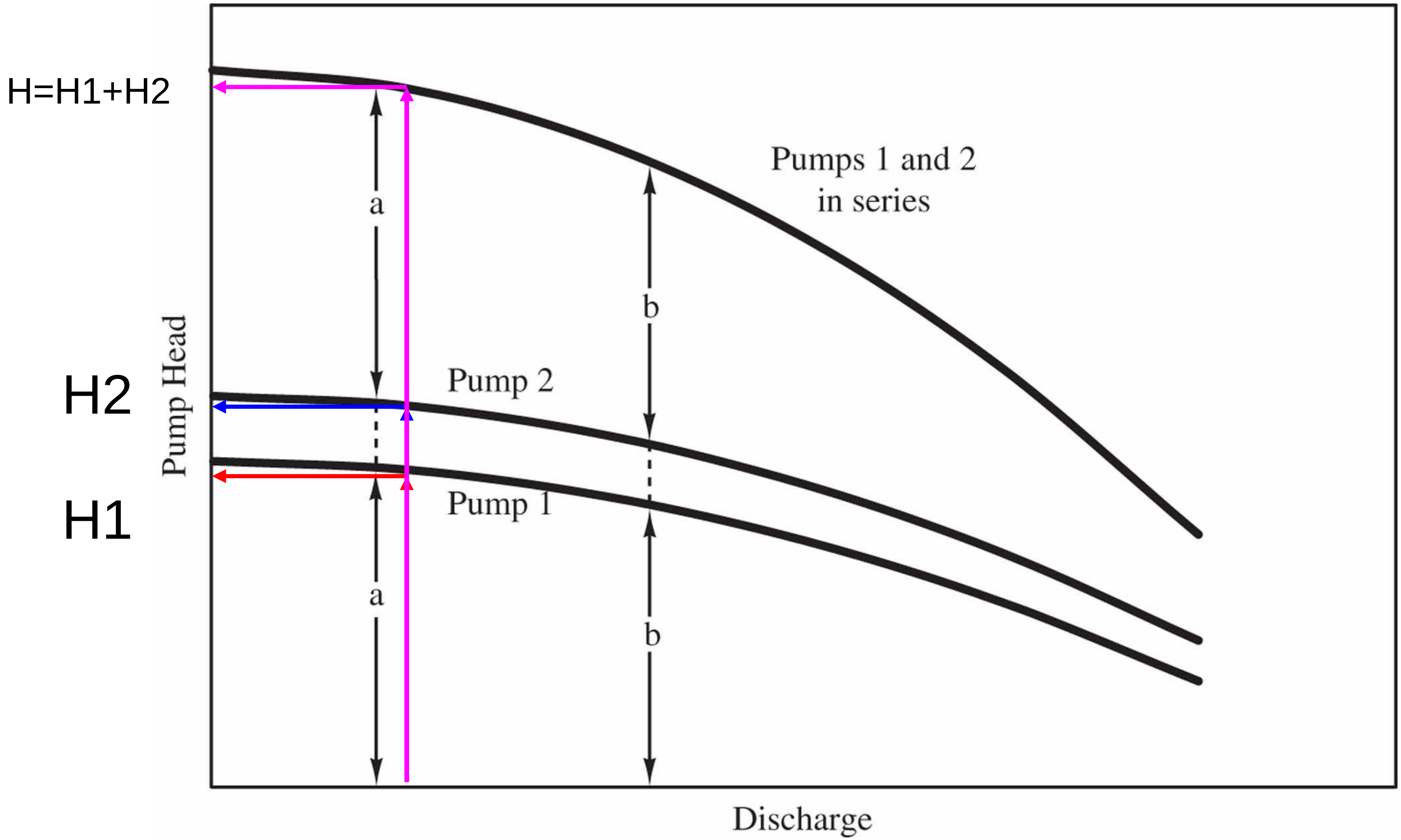


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Figure 5.13 Typical performance curves of two pumps connected in parallel *B* and in series *C*

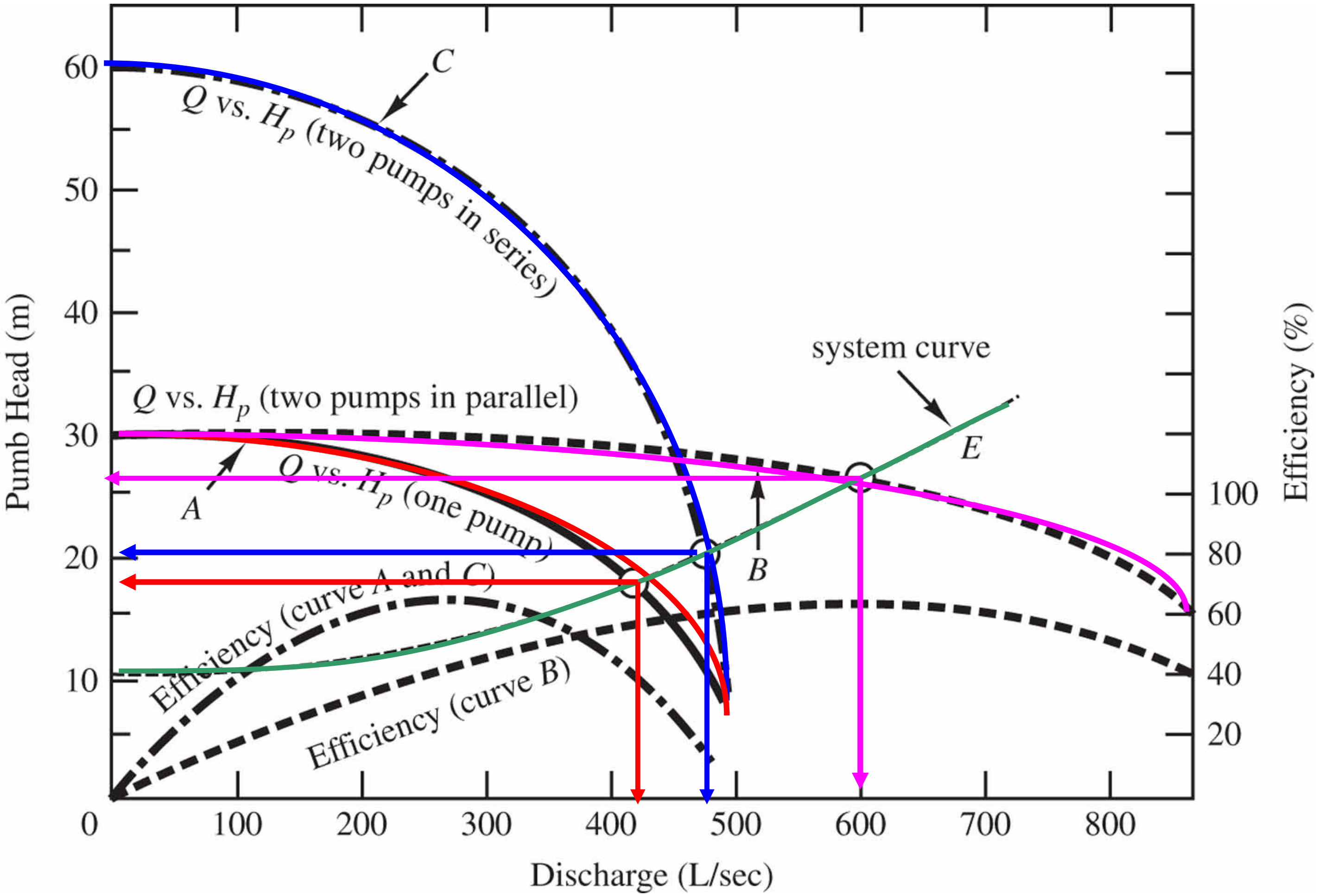


Figure 5.14 Schematic of pump operation either in series or in parallel

Parallel operation

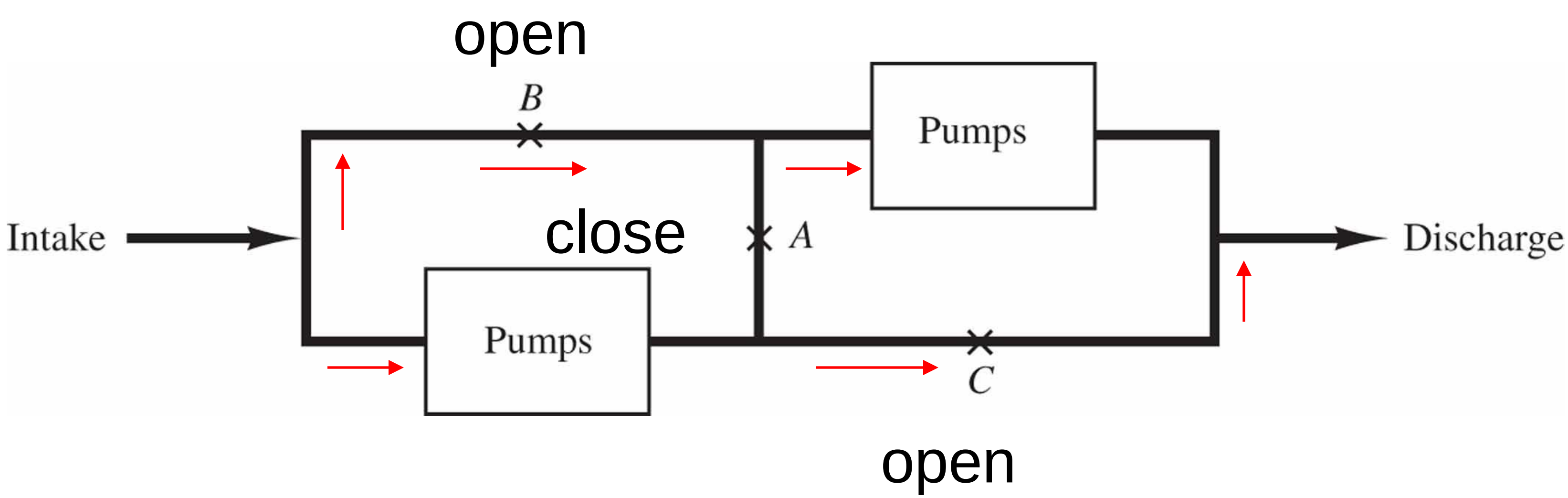


Figure 5.14 Schematic of pump operation either in series or in parallel

Series operation

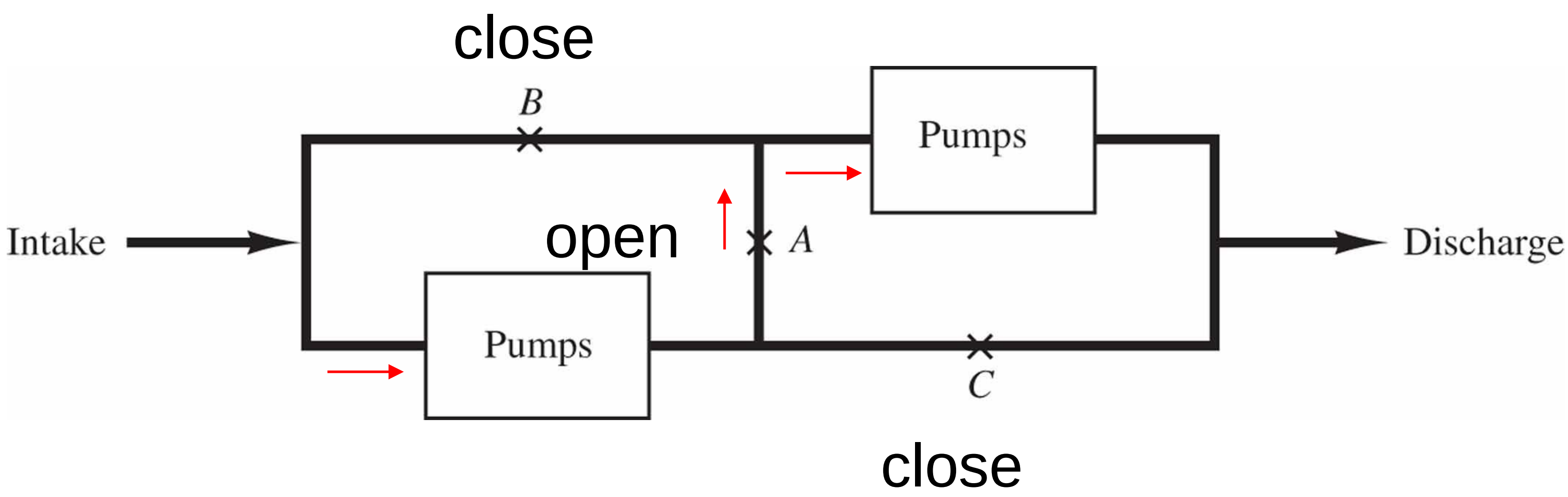


Figure 5.15 Single pump and two pipes

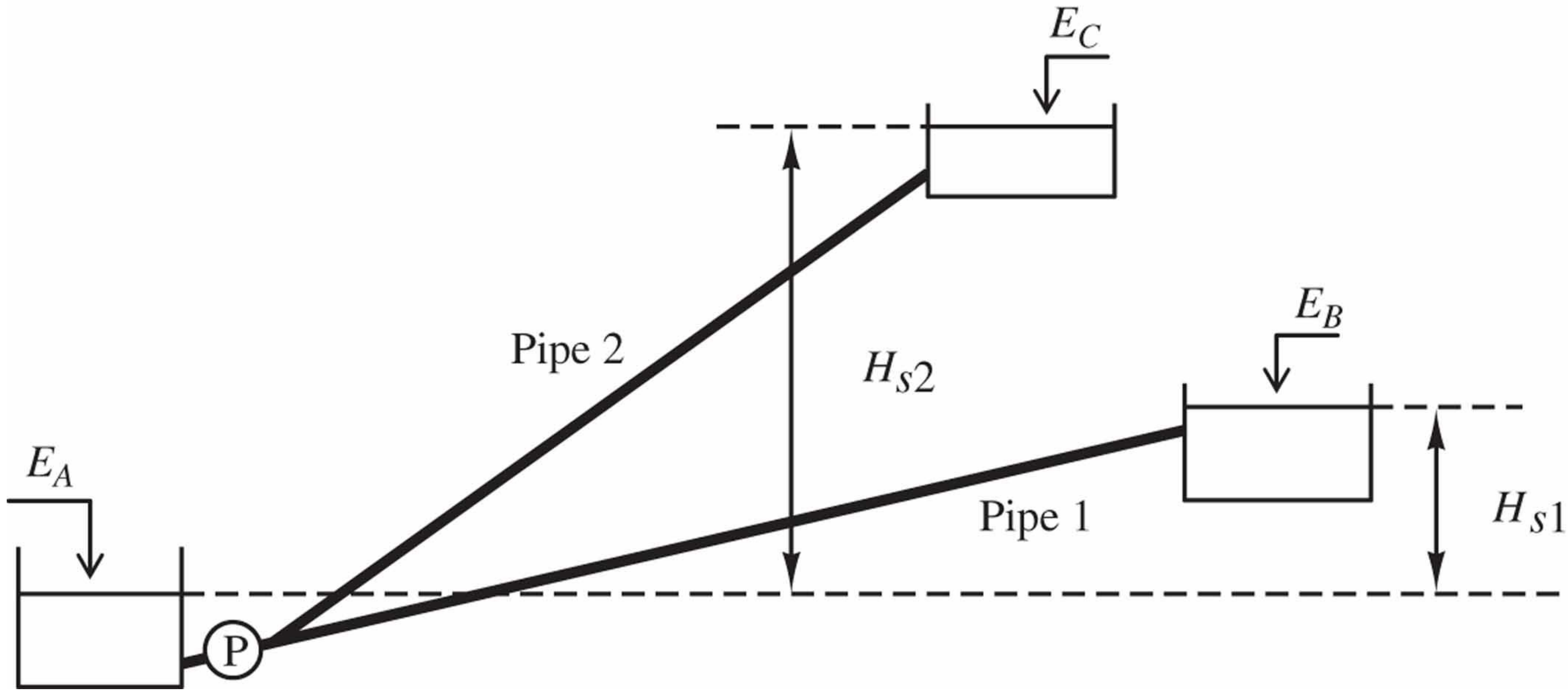


Figure 5.16 Graphical solution for Example 5.5

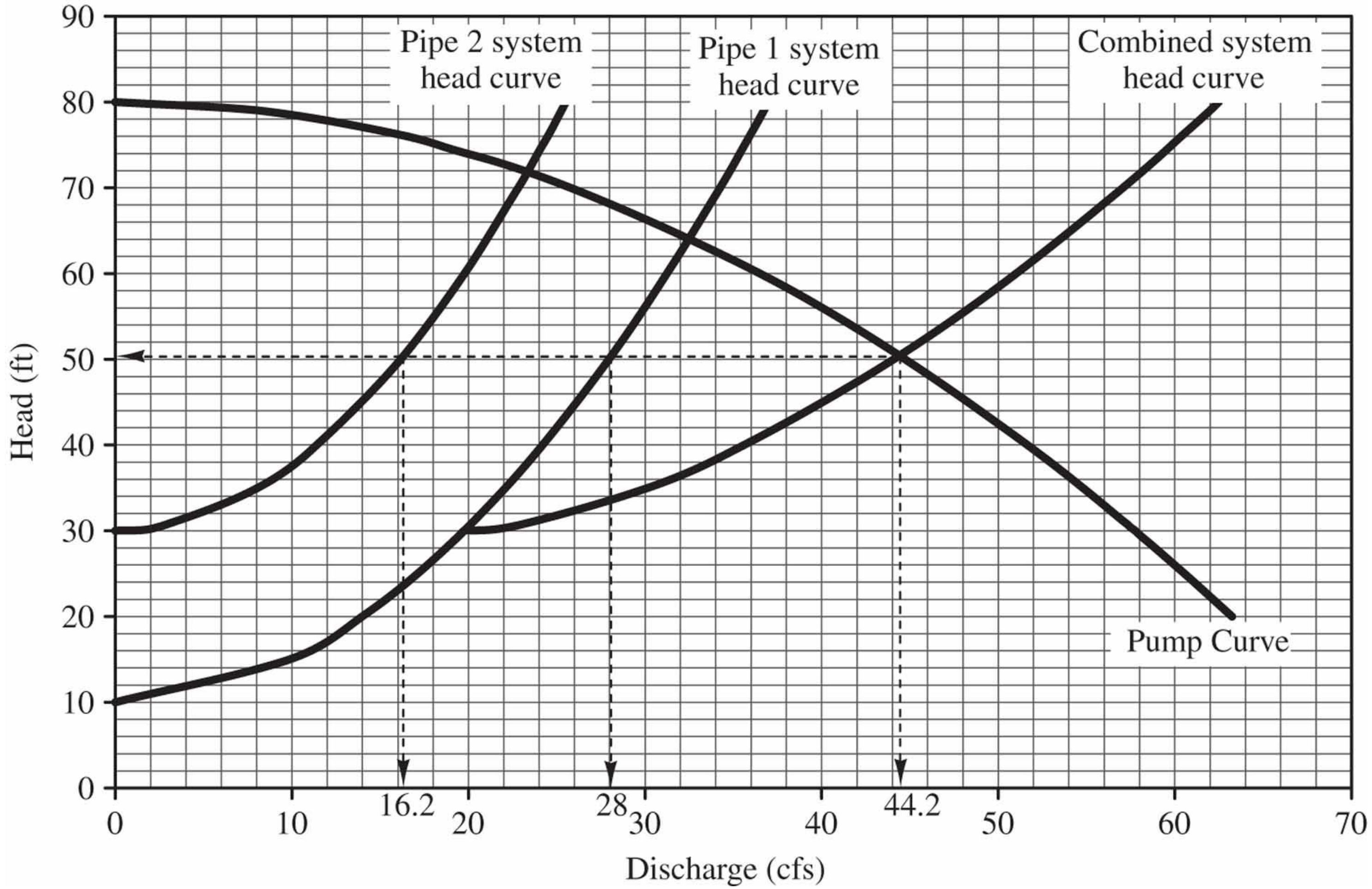


Figure 5.17 Branching pipe system of Example 5.6

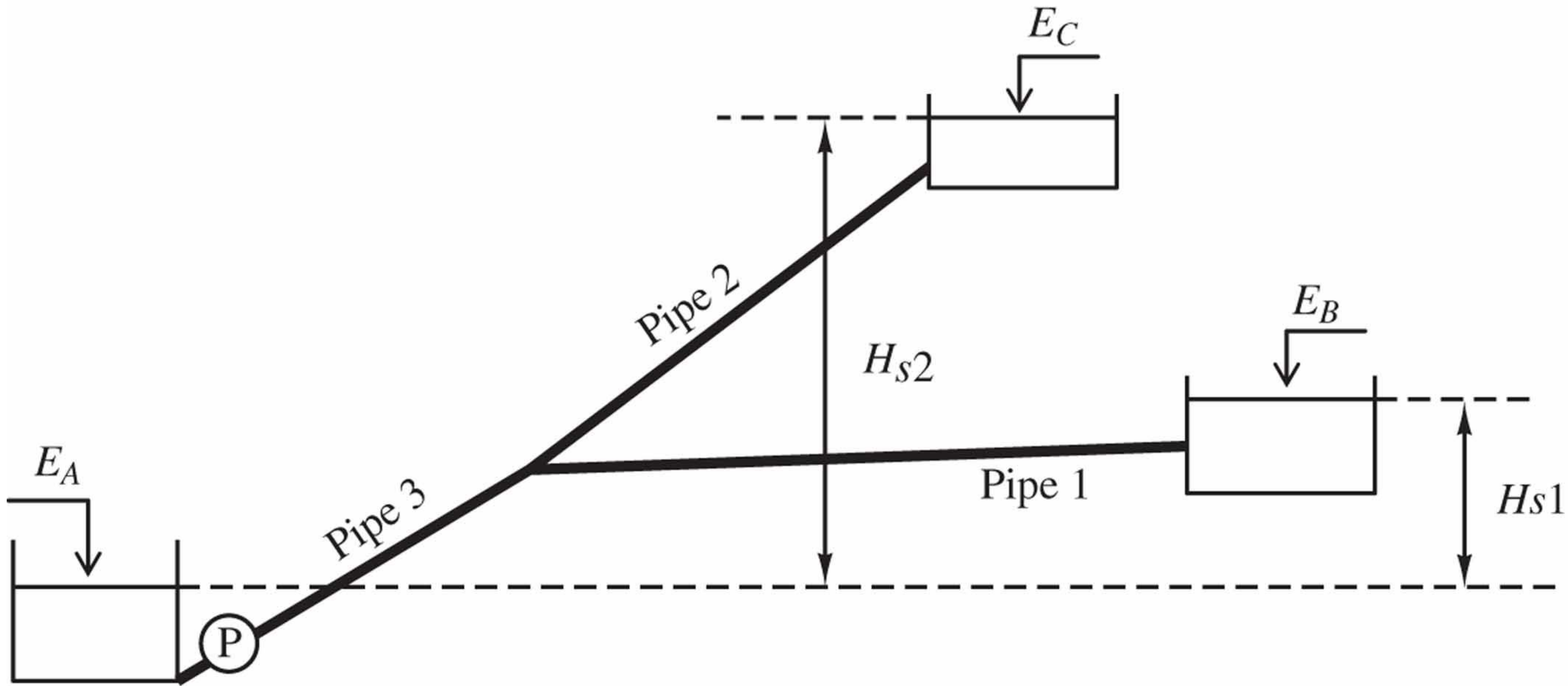


Figure 5.18 Graphical solution for Example 5.6

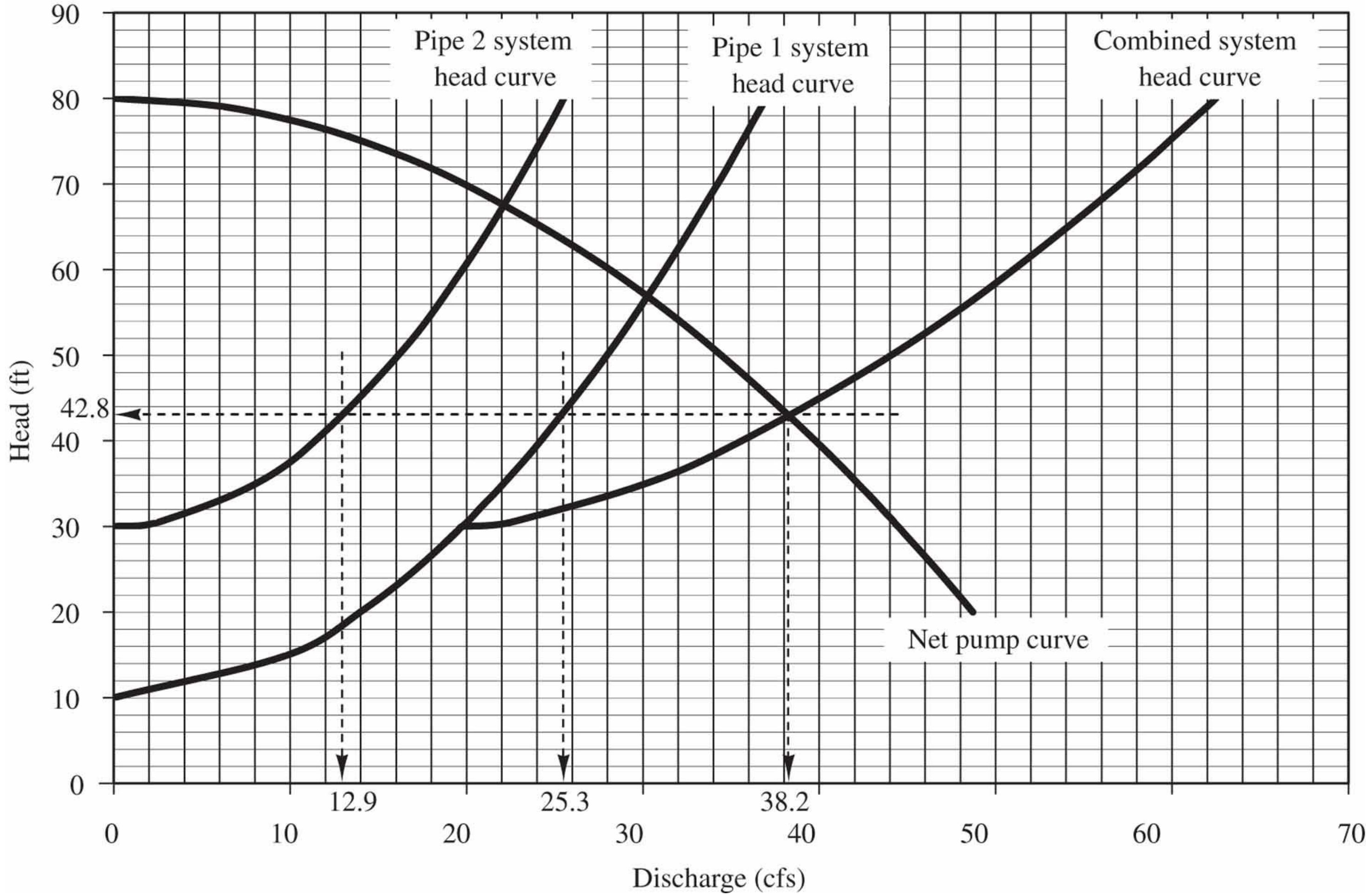


Figure 5.19 Pipe network for Example 5.7

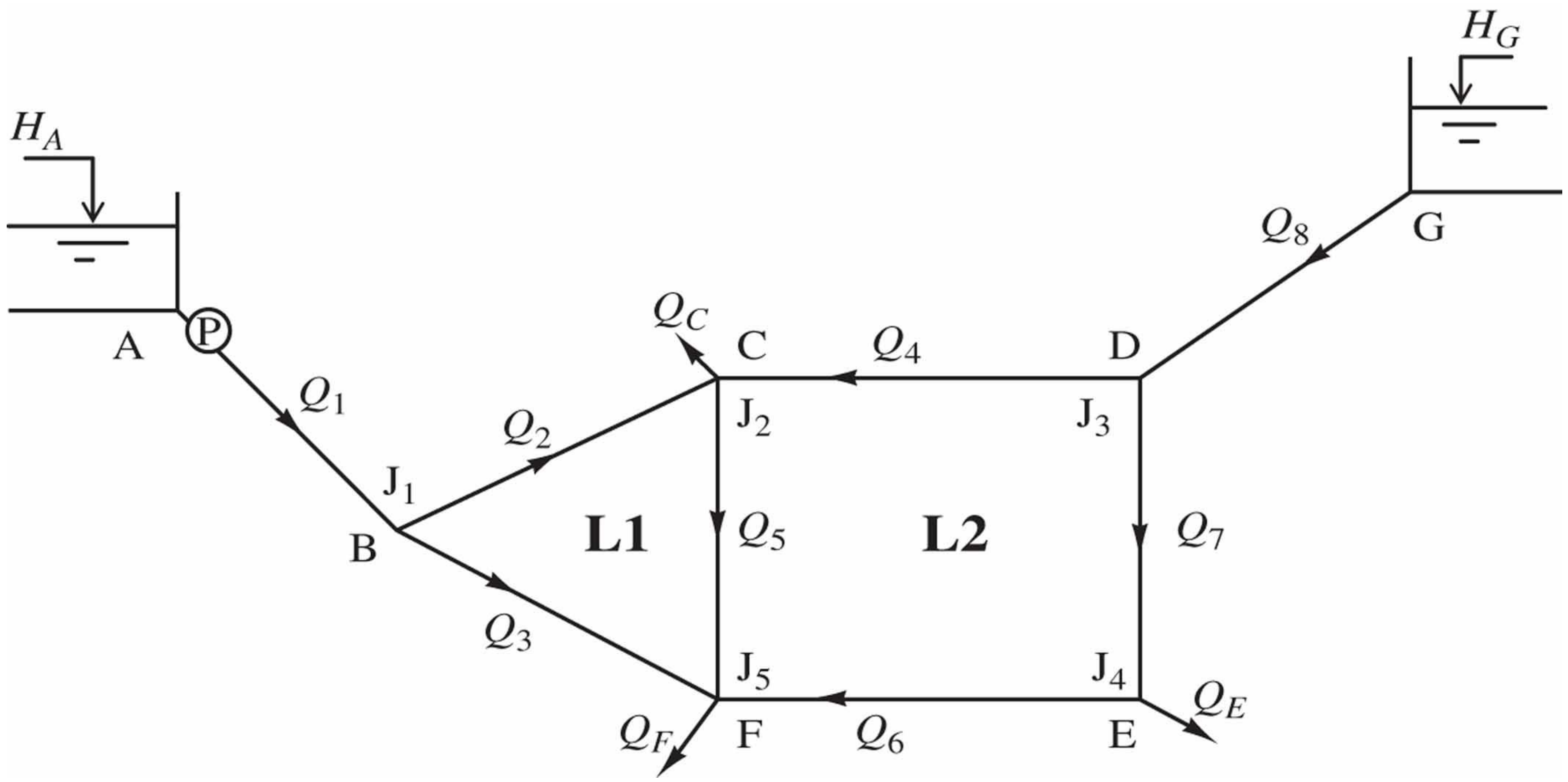


Figure 5.20 Energy and pressure relationship in a centrifugal pump

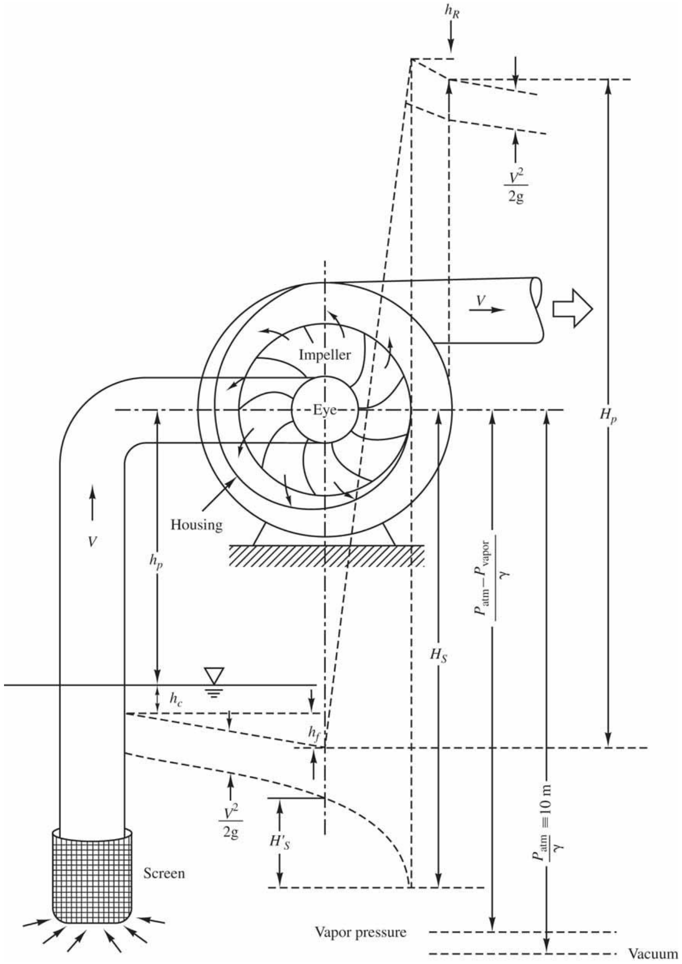


Table 5.1 Conversion of Specific Speed

TABLE 5.1 Conversion of Specific Speed

Units	Discharge Units	Head Units	Pump Speed	Equation	Symbol	Conversion	
United States	U.S. gal/min	ft	rev/min	(5.25)	N_{s1}	$N_{s1} = 45.6\ S$	$N_{s1} = 51.6\ N_{s3}$
English	Imp. gal/min	ft	rev/min	(5.25)	N_{s2}	$N_{s2} = 37.9\ S$	$N_{s2} = 43.0\ N_{s3}$
Metric	m^3/sec	m	rev/min	(5.25)	N_{s3}	$N_{s3} = 0.882\ S$	$N_{s3} = 0.019\ N_{s1}$
SI	m^3/sec	m	rad/sec	(5.24)	S	$S = 0.022\ N_{s1}$	$S = 1.134\ N_{s3}$

Note: $g = 9.81\ \text{m/sec}^2 = 32.2\ \text{ft/sec}^2$

Figure 5.21 Relative impeller shapes and the approximate values of shape numbers, *S*, as defined in Table 5.1

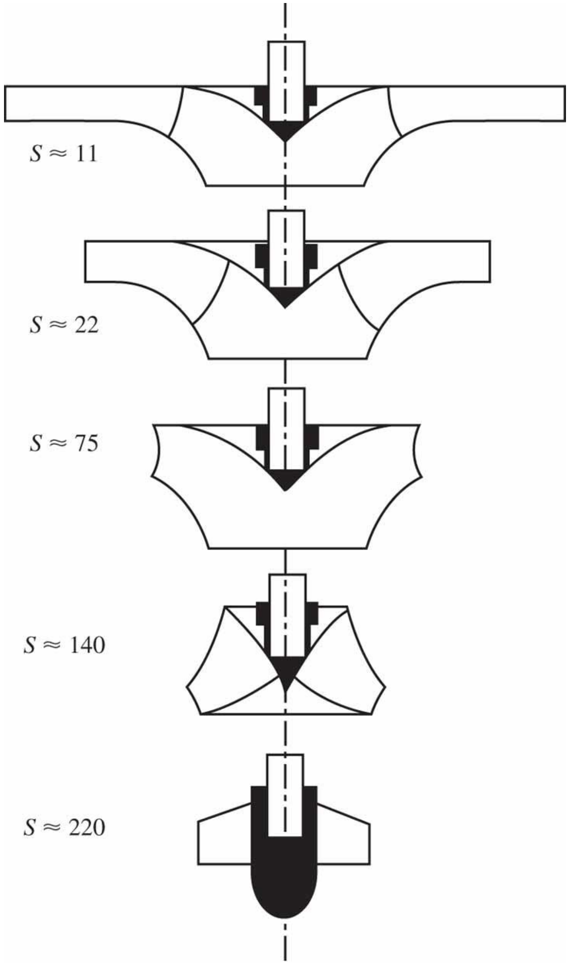


Figure 5.22 Discharge, head, and power requirements of different types of pumps

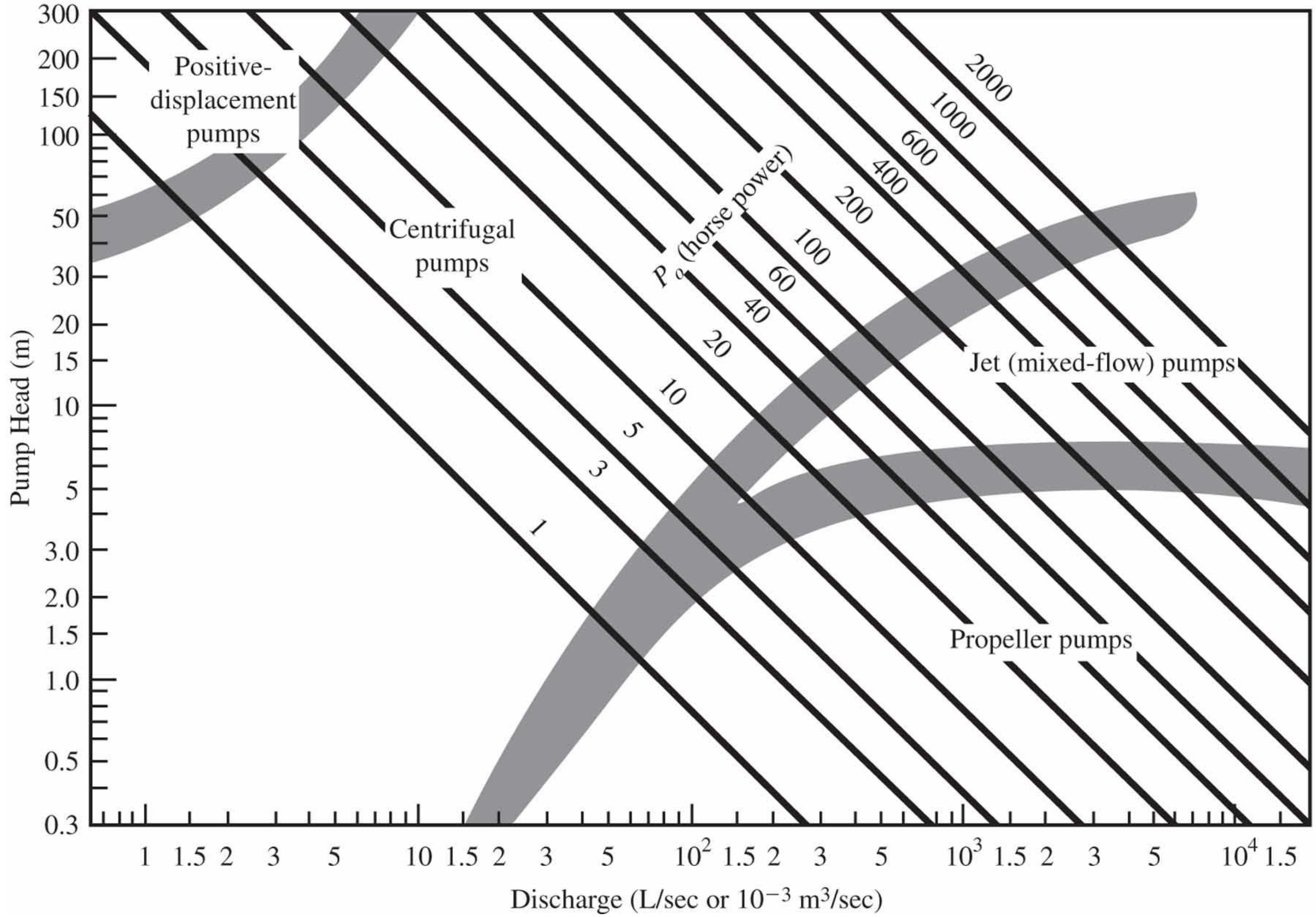


Figure 5.23 Pump model selection chart

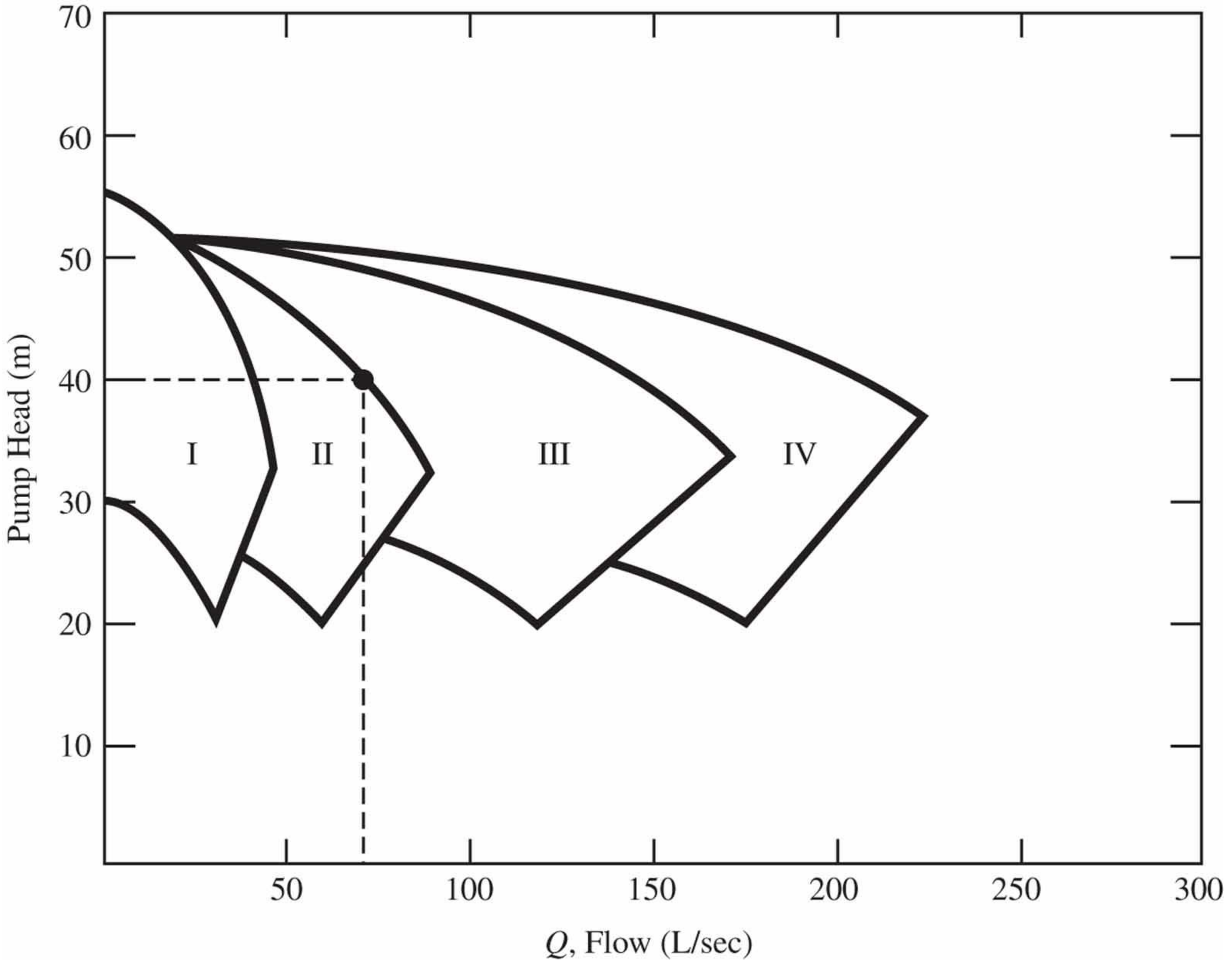


Figure 5.24 Characteristic curves for several pump models

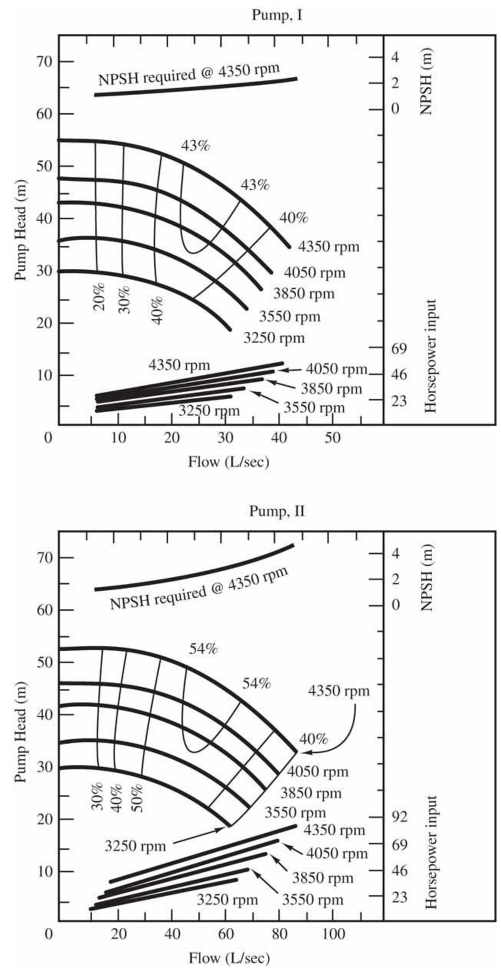
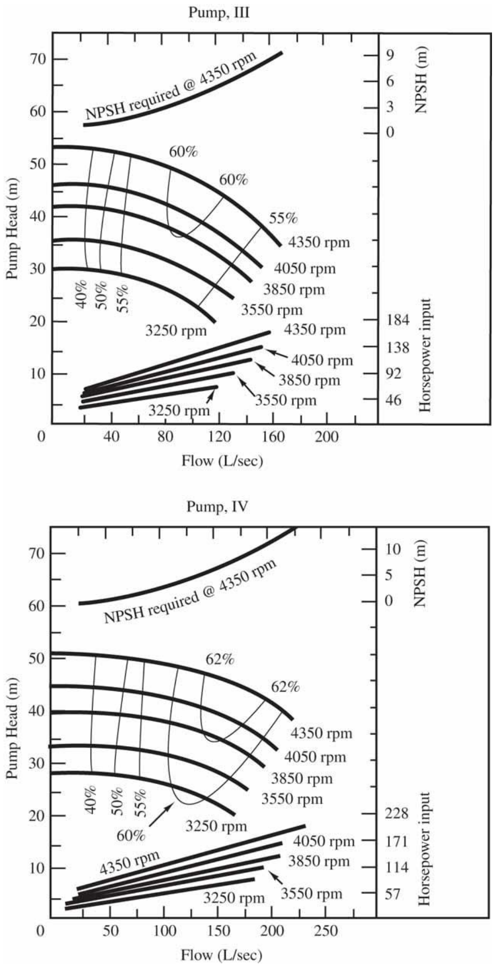


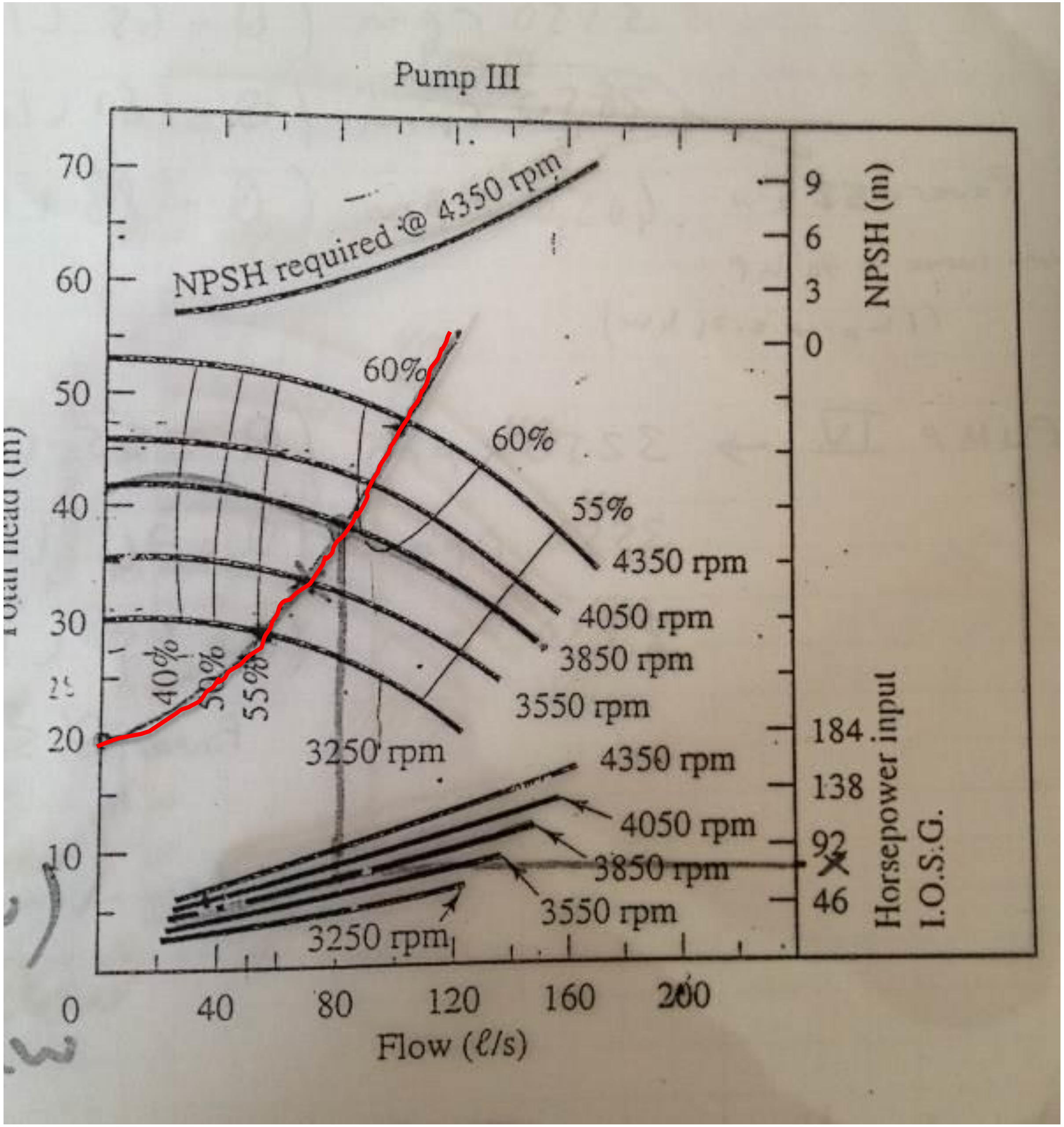
Figure 5.24 (continued) Characteristic curves for several pump models



Problem 5.4.5 (Hwang, 3rd Edition) : A 70-kW motor is avaliable to drive one of the pumps shown in Figure 5.24. The system is designed to deliver a minimum discharge of 80 L/s, over an elevation difference of 20 m. The system uses a wrought iron pipe, 150 m long and 15 cm in diameter to transport water at 10^0C.

Select the pump based on the consideration of lowest energy consumption.

Min. Desired flowrate: 80 l/s (Pump III or IV can be used)
70 kw motor is avaliable
Static Head: 20 m, e: 0.045 (wrought iron pipe), L:150 m, D: 0.15 m, T: 10^0C.



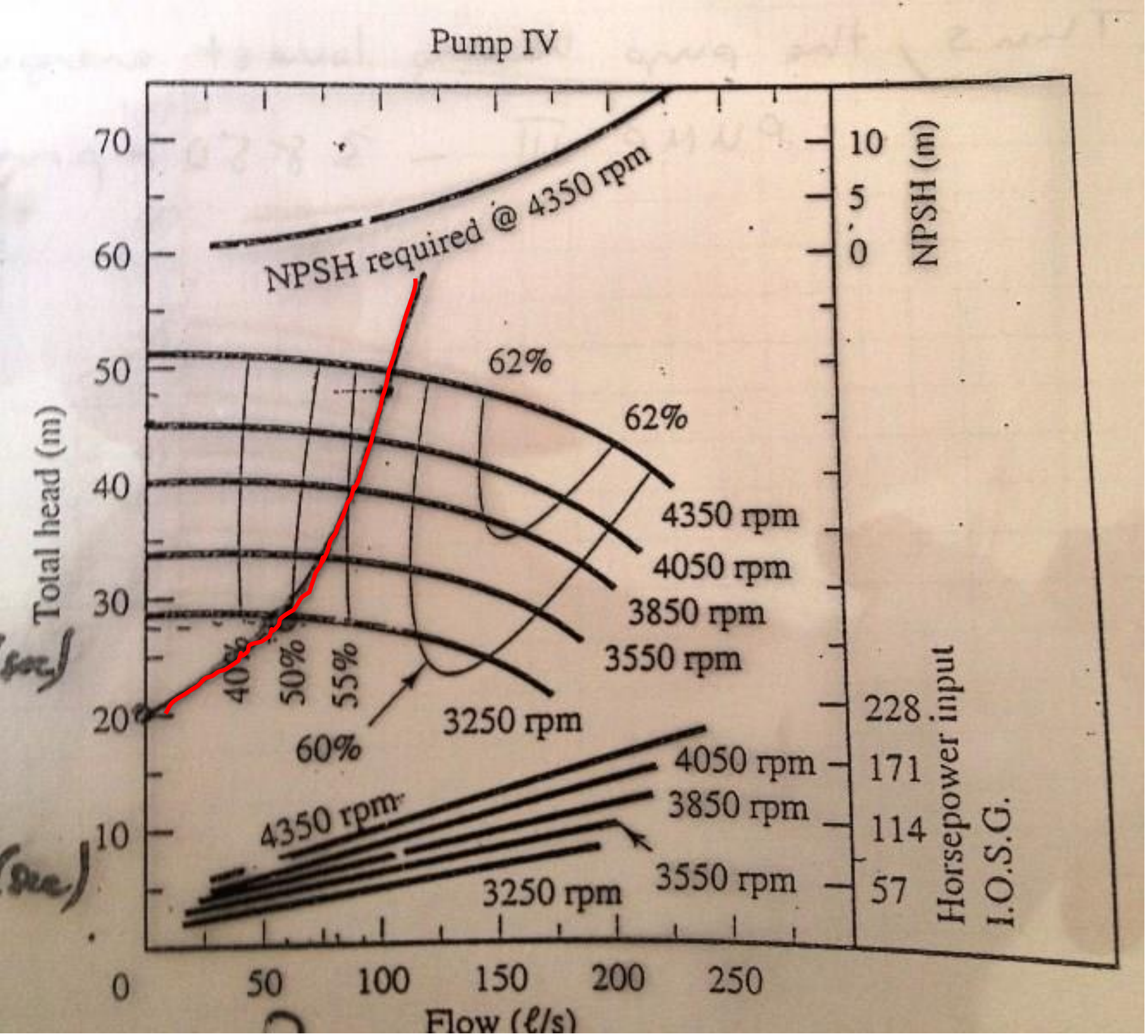
Pump III

3250 rpm
Q=52 L/s < 80 L/s

3550 rpm
Q=65 L/s < 80 L/s

3850 rpm
Q= 80 l/s
H=39 m
Eff= 59 %

4050 rpm
Q=86 L/s
H=42 m, Eff= 58-59 %



Pump IV

3250 rpm

Q=55 L/s < 80 L/s

3550 rpm

Q=74 L/s < 80 L/s

3850 rpm

Q= 85 l/s

H=38 m

Eff= 55 %

Pump III
3850 rpm
Q= 80 l/s
H=39 m
Eff= 59 %

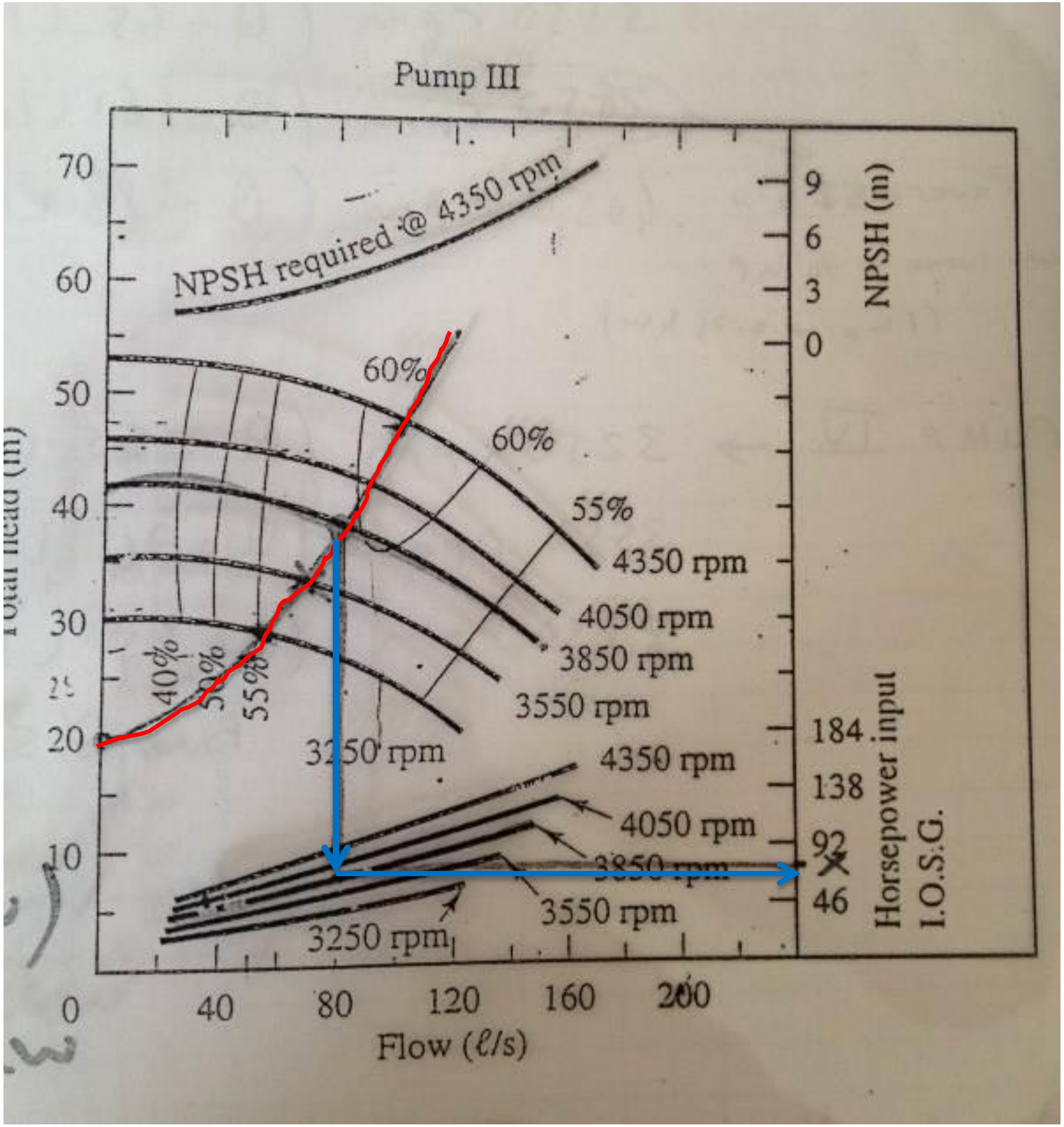
$$P = \frac{\gamma Q H}{ep} = \frac{9800 N/m3(\frac{0.08m3}{s})(39\ m)}{0.59}$$

$P =$ 51823 W= 51.8 kW

Pump IV
3850 rpm
Q= 85 l/s
H=38 m
Eff= 55 %

$$P = \frac{\gamma Q H}{ep} = \frac{9800 N/m3(\frac{0.085m3}{s})(38\ m)}{0.55}$$

$P =$ 57552 W= 57.5 kW



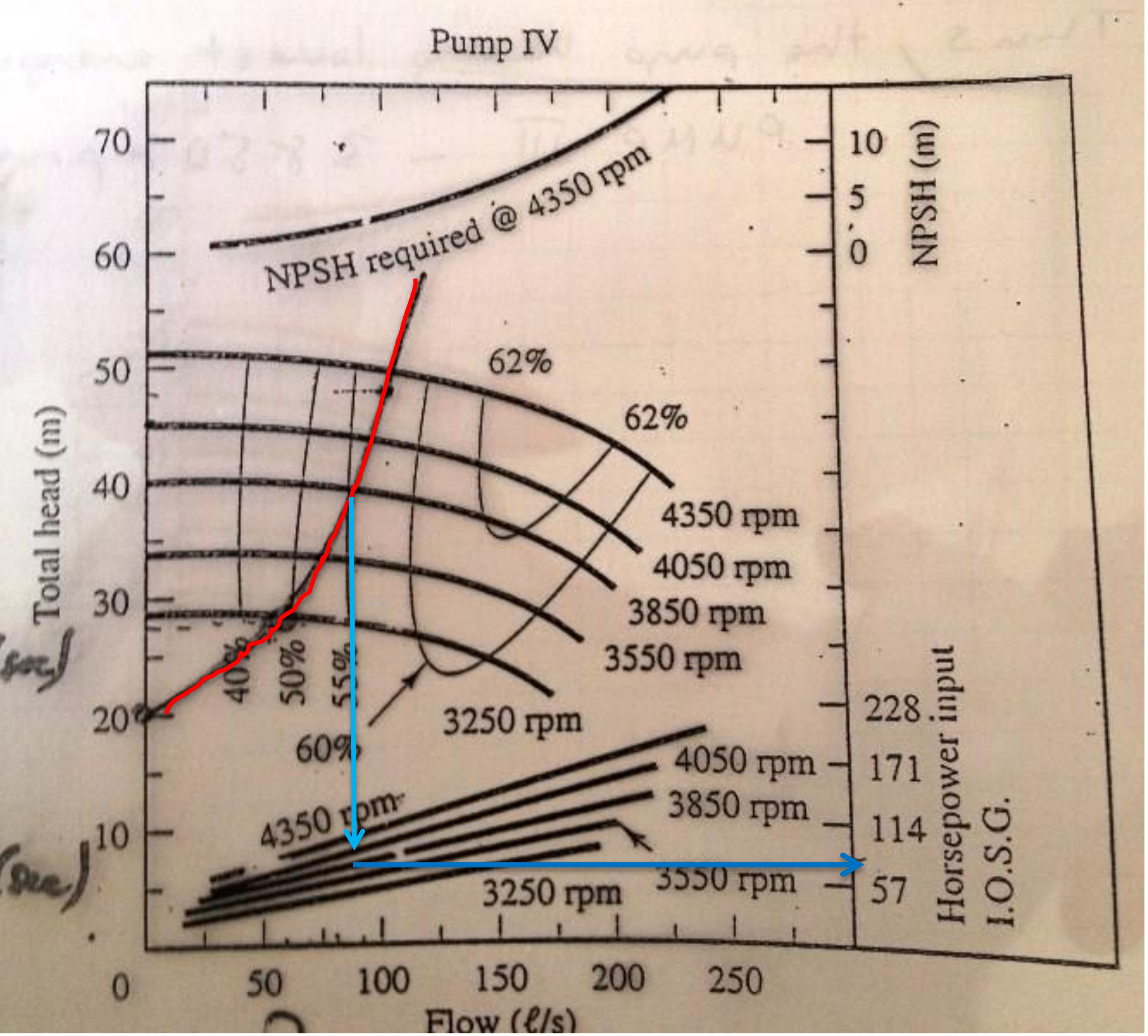
Pump III

3250 rpm
Q=52 L/s < 80 L/s

3550 rpm
Q=65 L/s < 80 L/s

3850 rpm
Q= 80 l/s
H=39 m
Eff= 59 %

4050 rpm
Q=86 L/s
H=42 m, Eff= 58-59 %



Pump IV

3250 rpm
Q=55 L/s < 80 L/s

3550 rpm
Q=74 L/s < 80 L/s

3850 rpm
Q= 85 l/s
H=38 m
Eff= 55 %