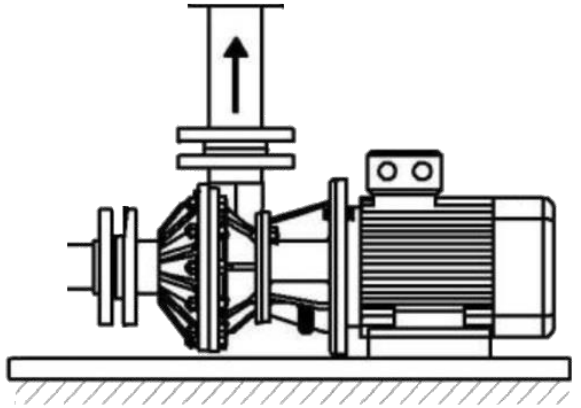
Pumps

An introductory guide to Pumps for Chemical Engineers



Content

Get Ready !

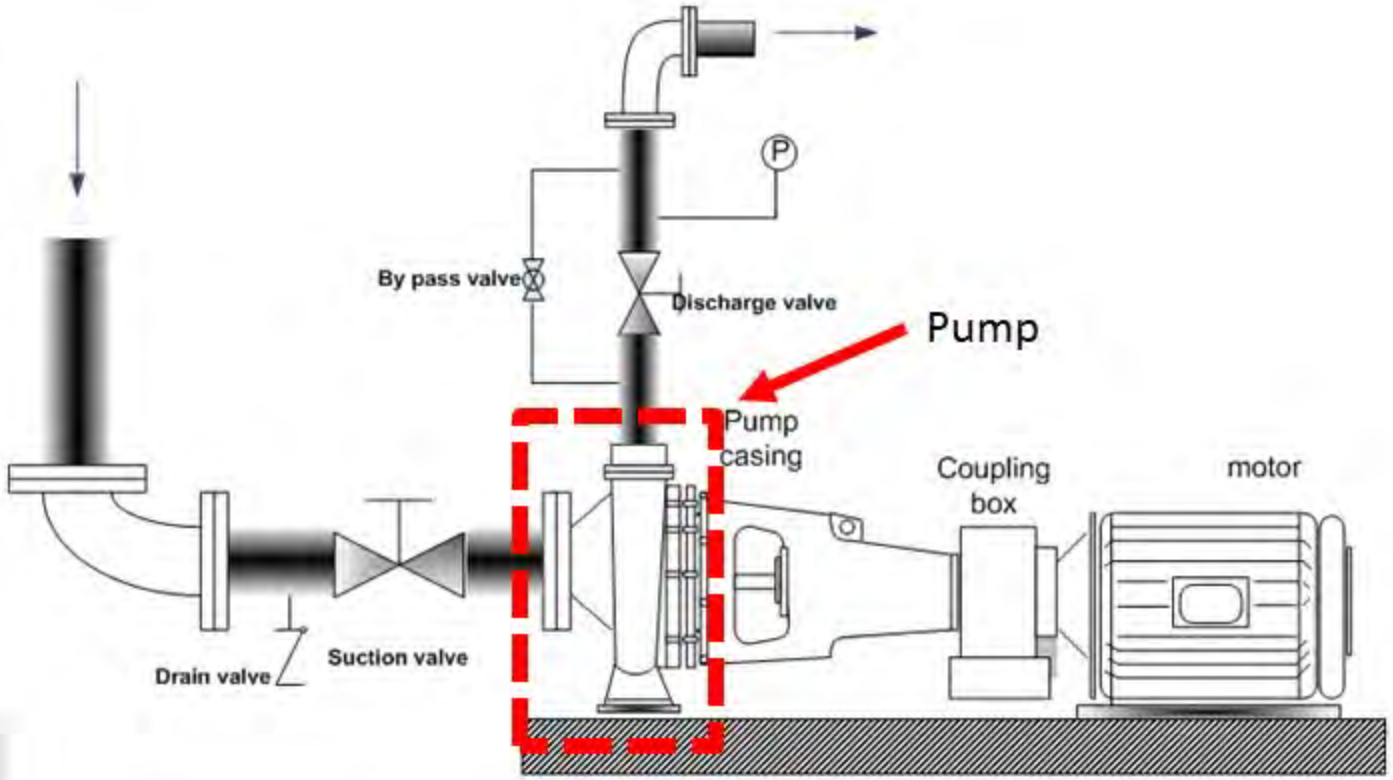
Part 1

1. Key Terms

- **Pump**
- **Head**

$$H = \frac{144 * P}{62.4 * Sp.gr}$$

H: Head (ft)
P: Pressure (PSI)
$Sp.gr$: Specific Gravity



2. Introduction

What Pumps do?

Pumps are machines used to move liquid.

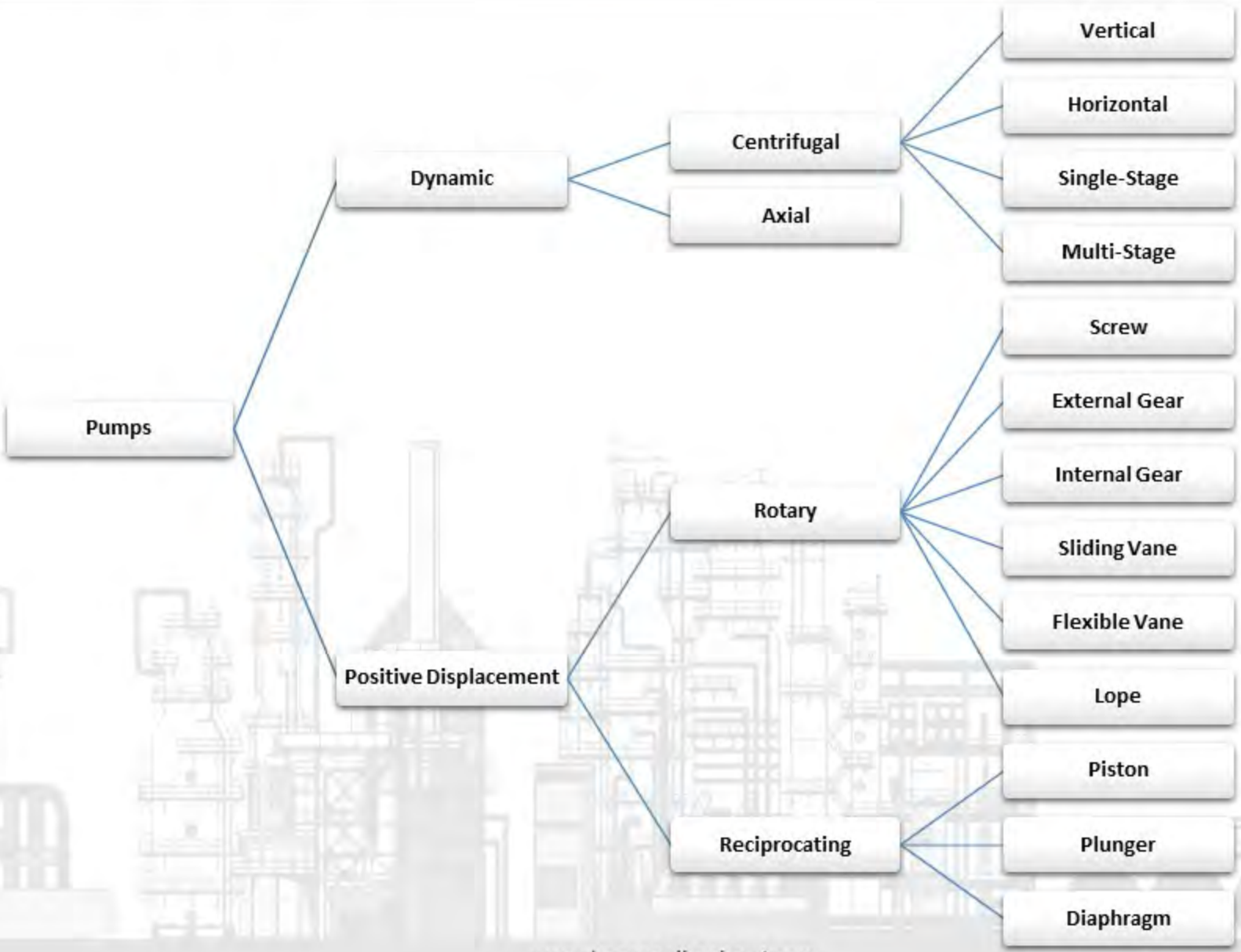
How They do it?

They convert mechanical energy into pressure in a flowing liquid.

Applications

Industrial Processes
Refrigeration
Automobiles
Home Heating Systems
Water Wells.

3. Classification



3. Classification

- Dynamic
  - Centrifugal
    - Horizontal
    - Vertical
    - Single-Stage
    - Multi-Stage
  - Axial

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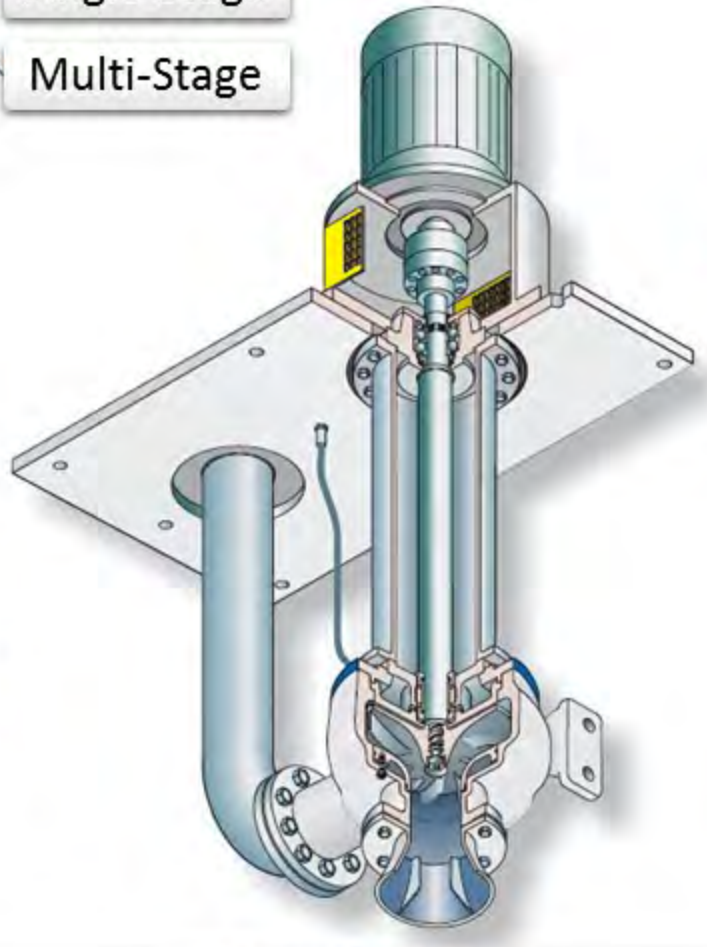

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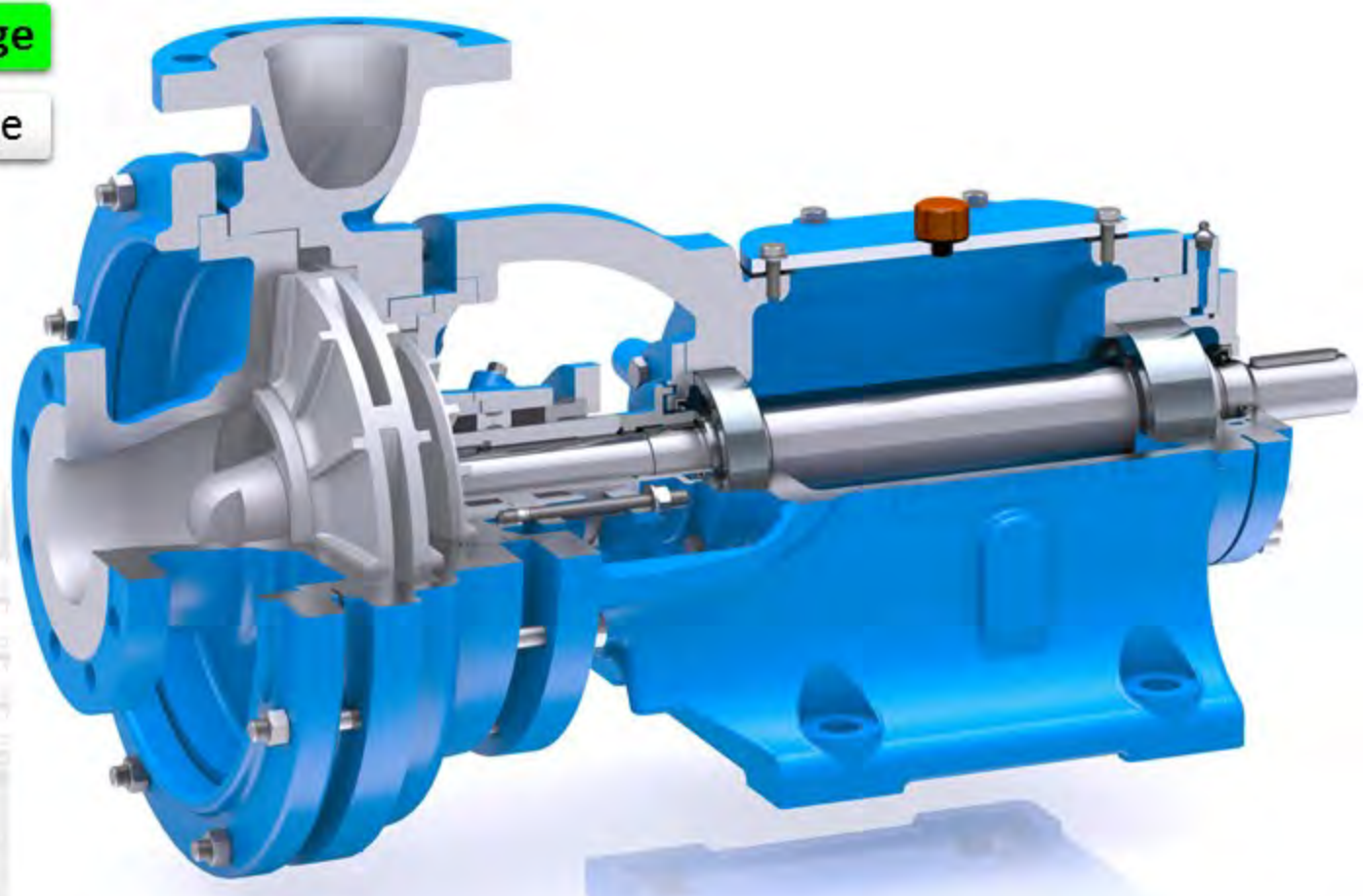

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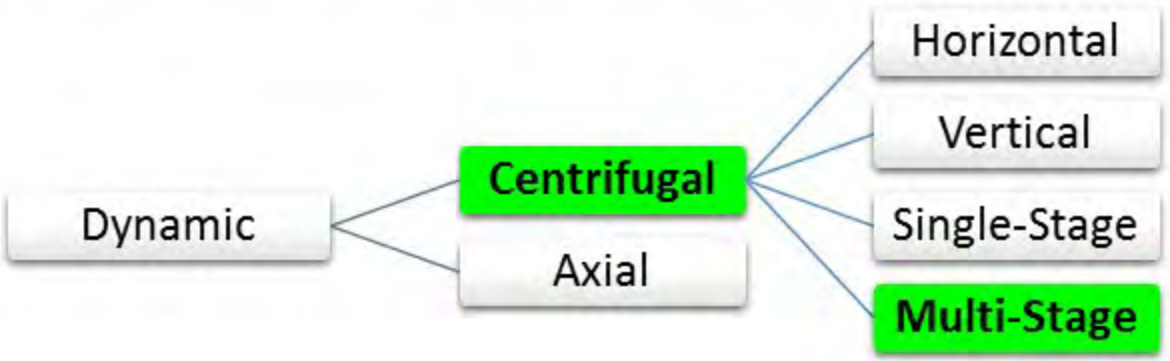

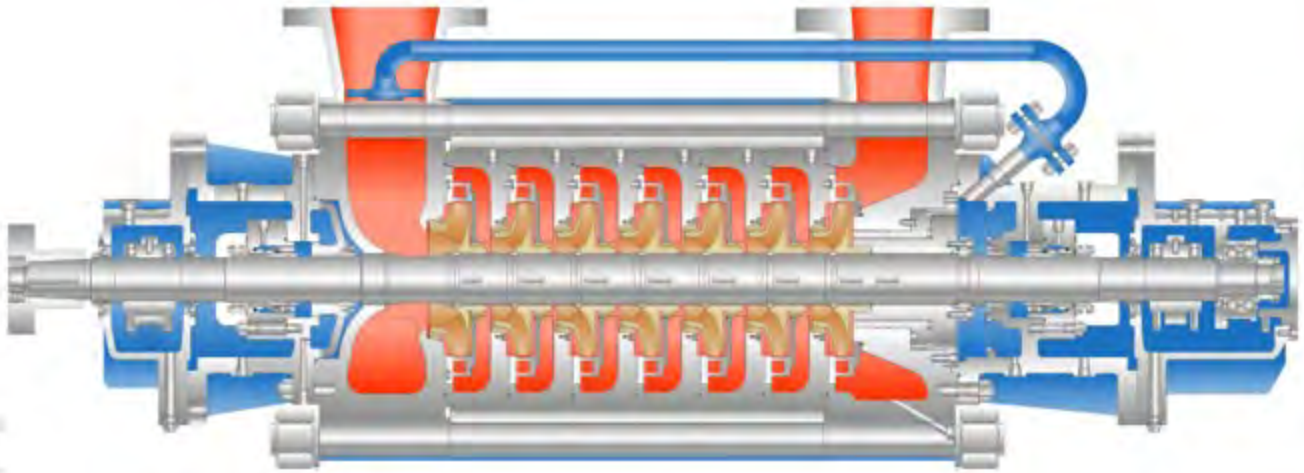

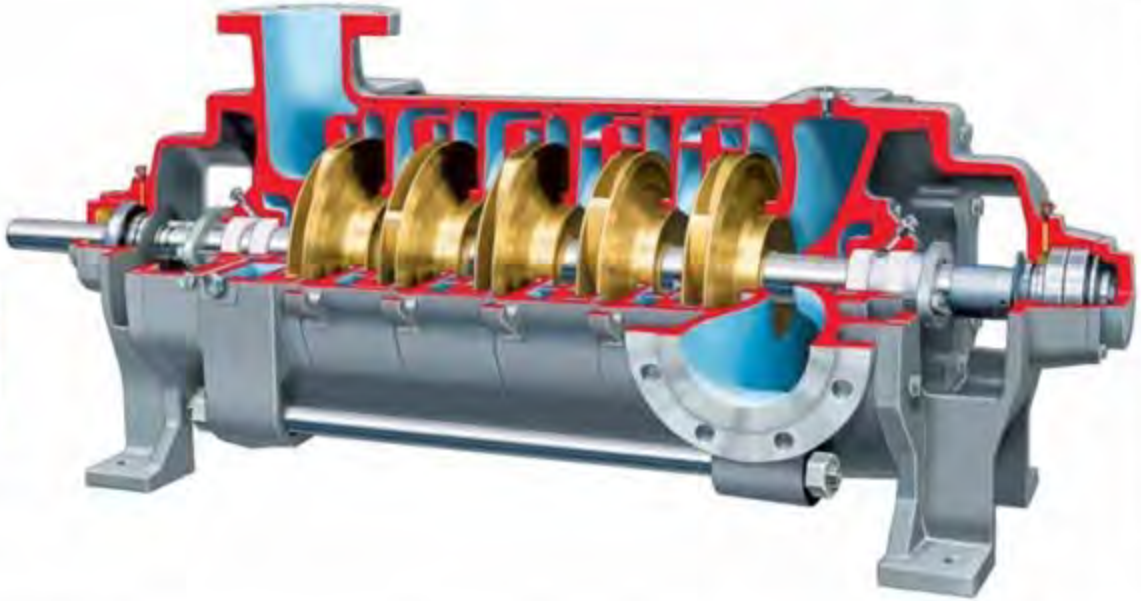

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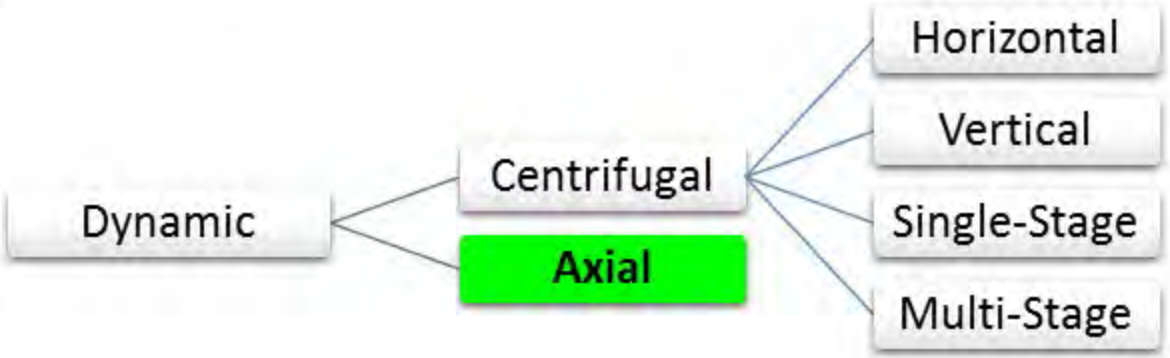
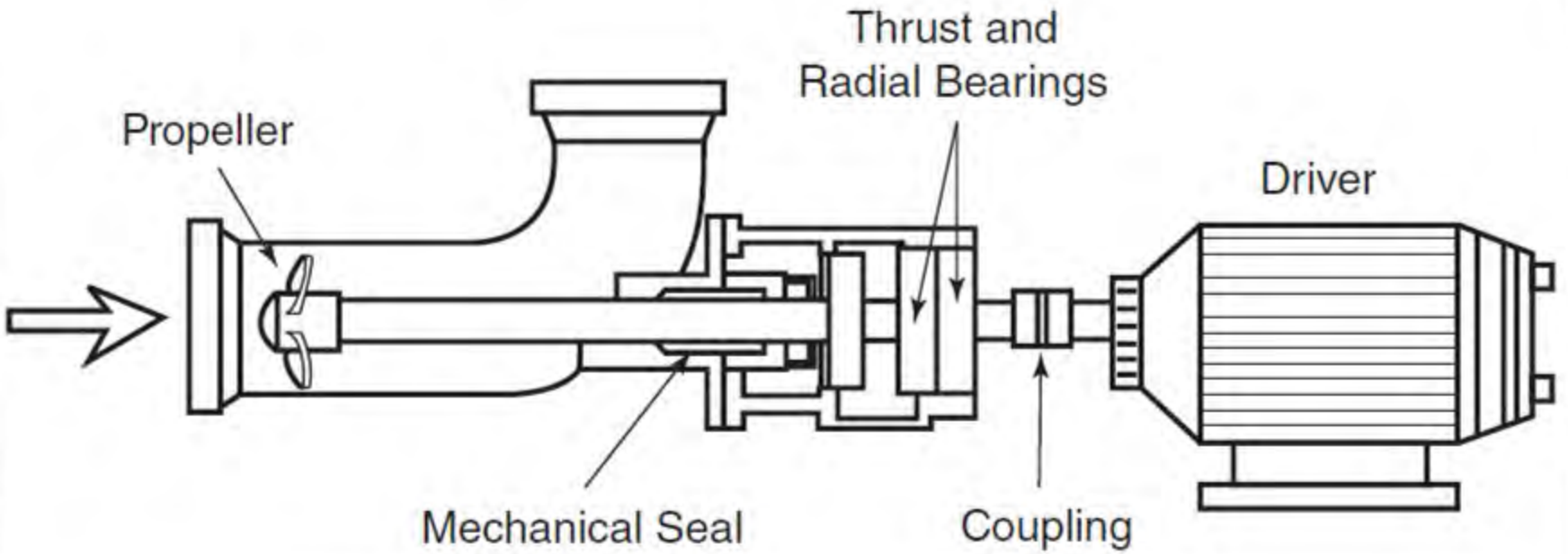
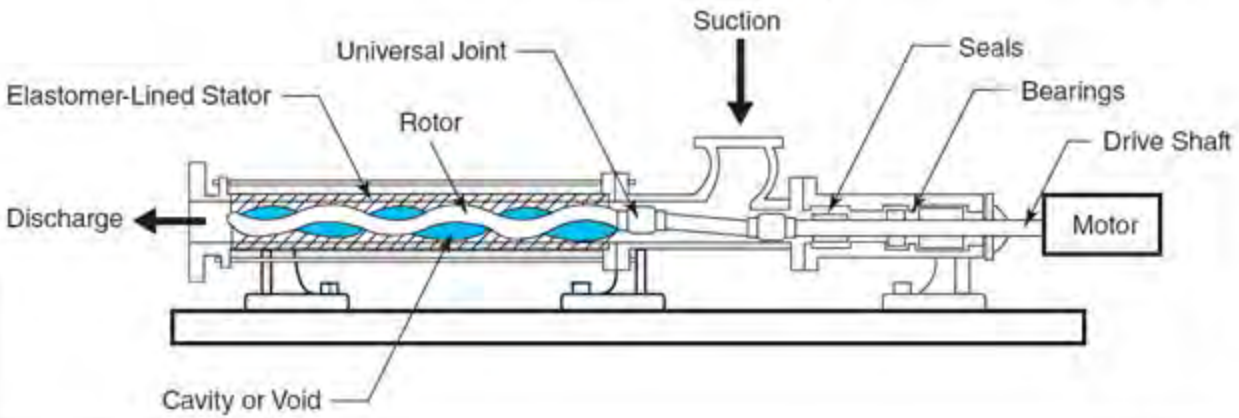
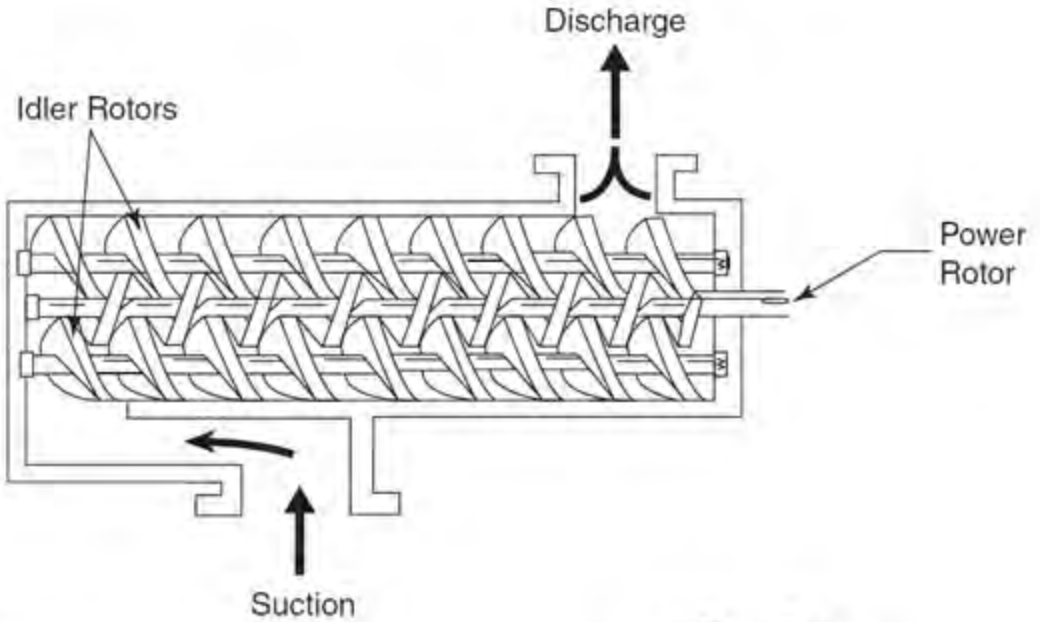


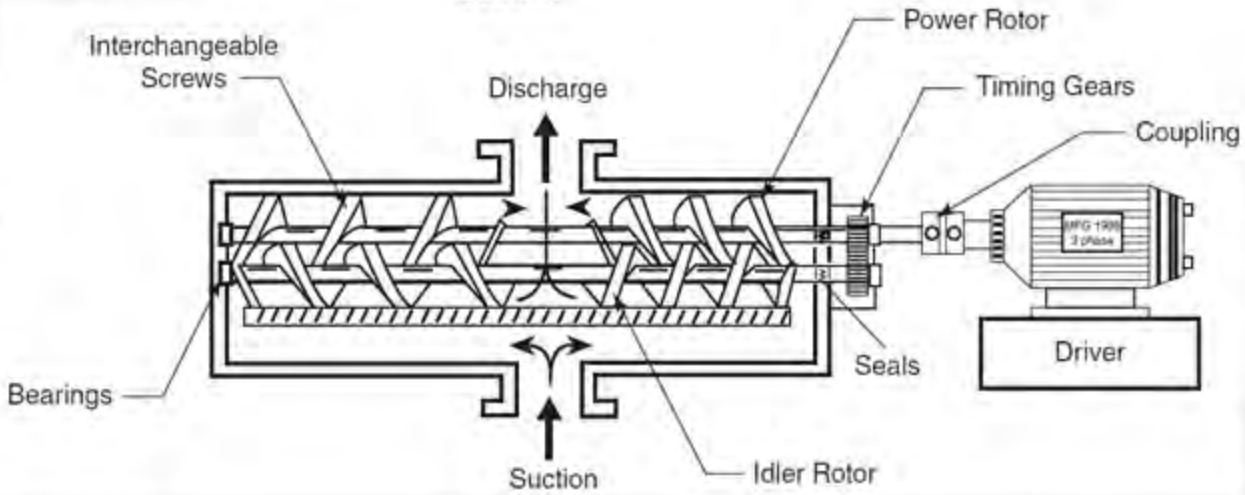


3. Classification

- Positive Displacement
  - Rotary
    - Screw
    - External Gear
    - Internal Gear
    - Sliding Vane
    - Flexible Vane
    - Lope
  - Reciprocating
    - Piston
    - Plunger







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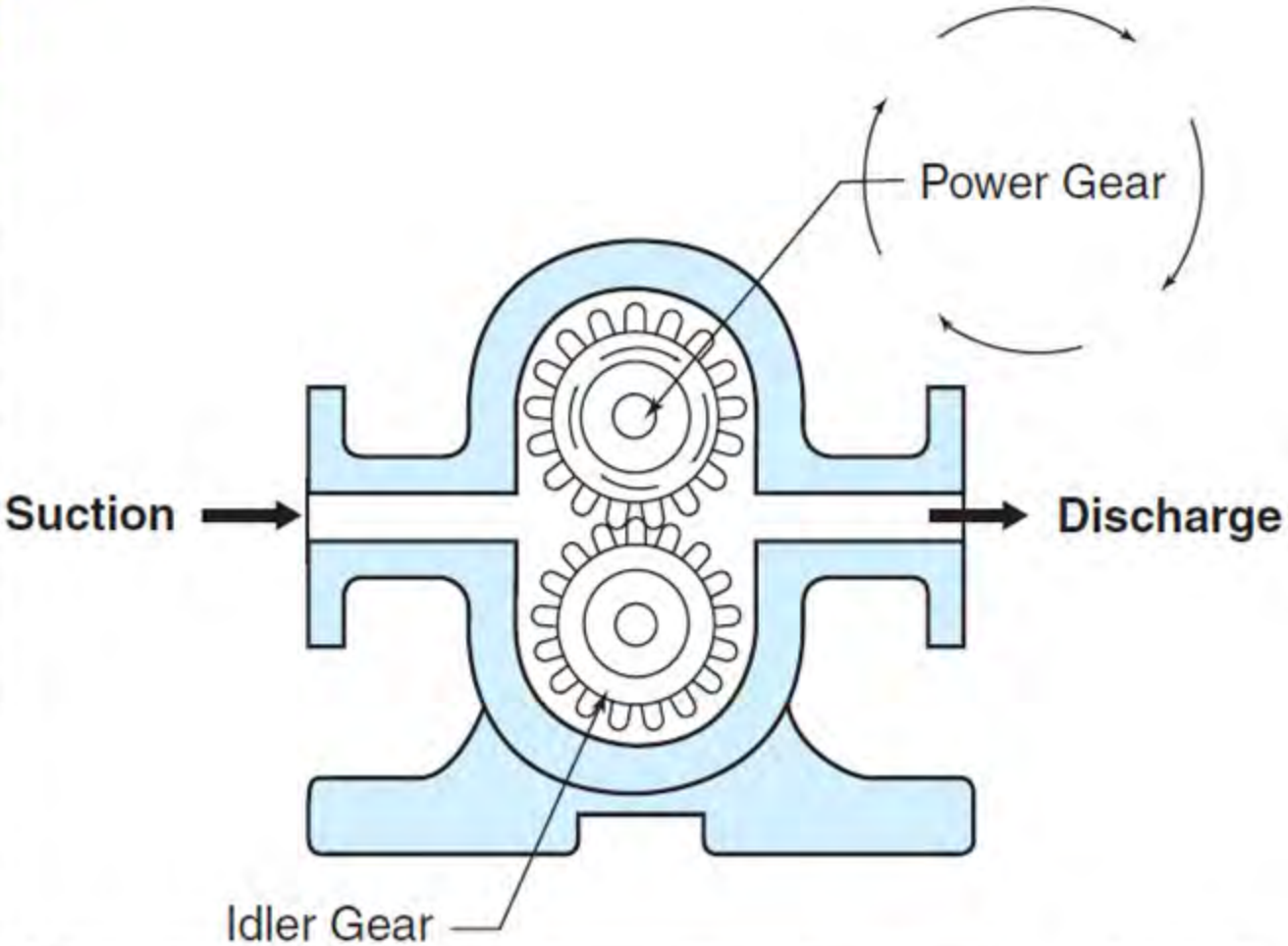

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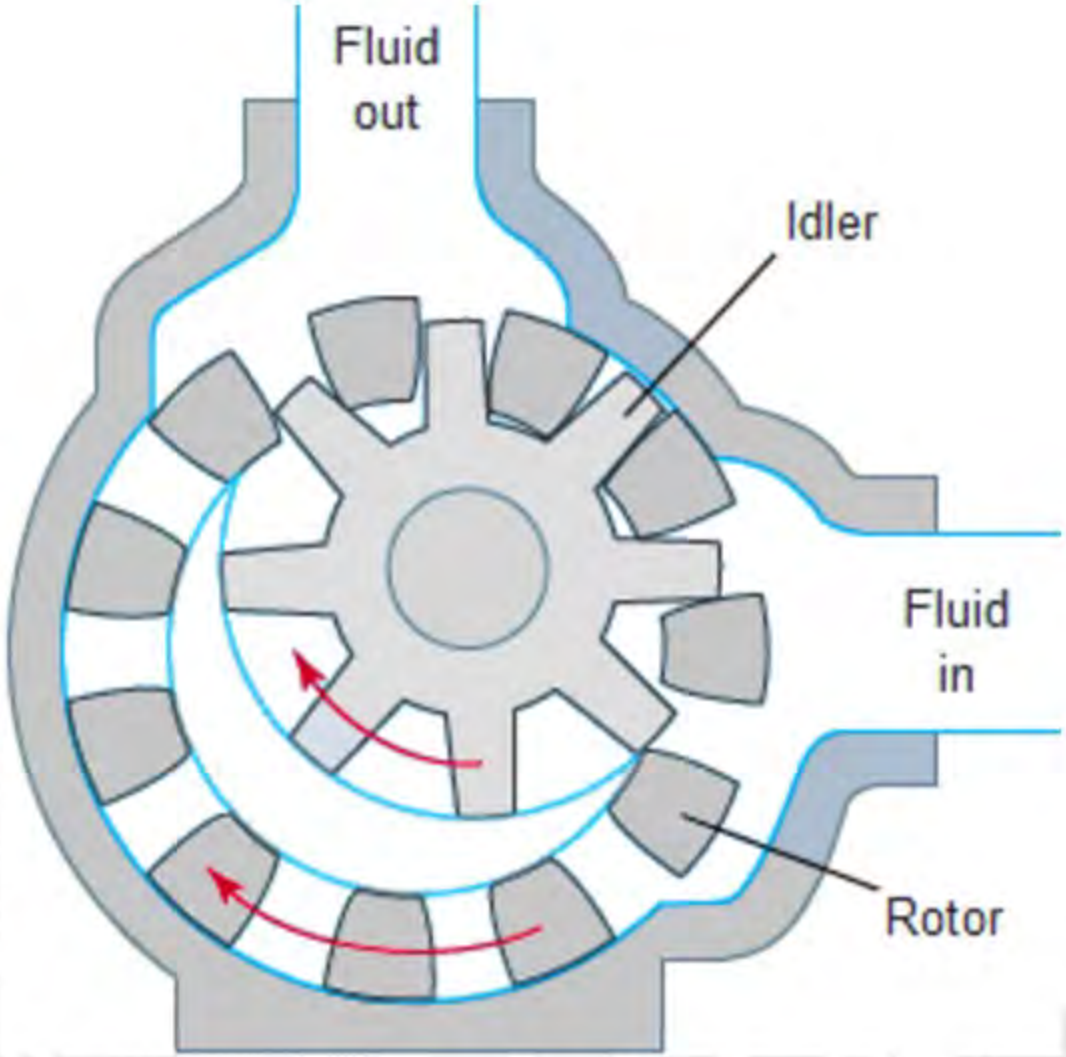

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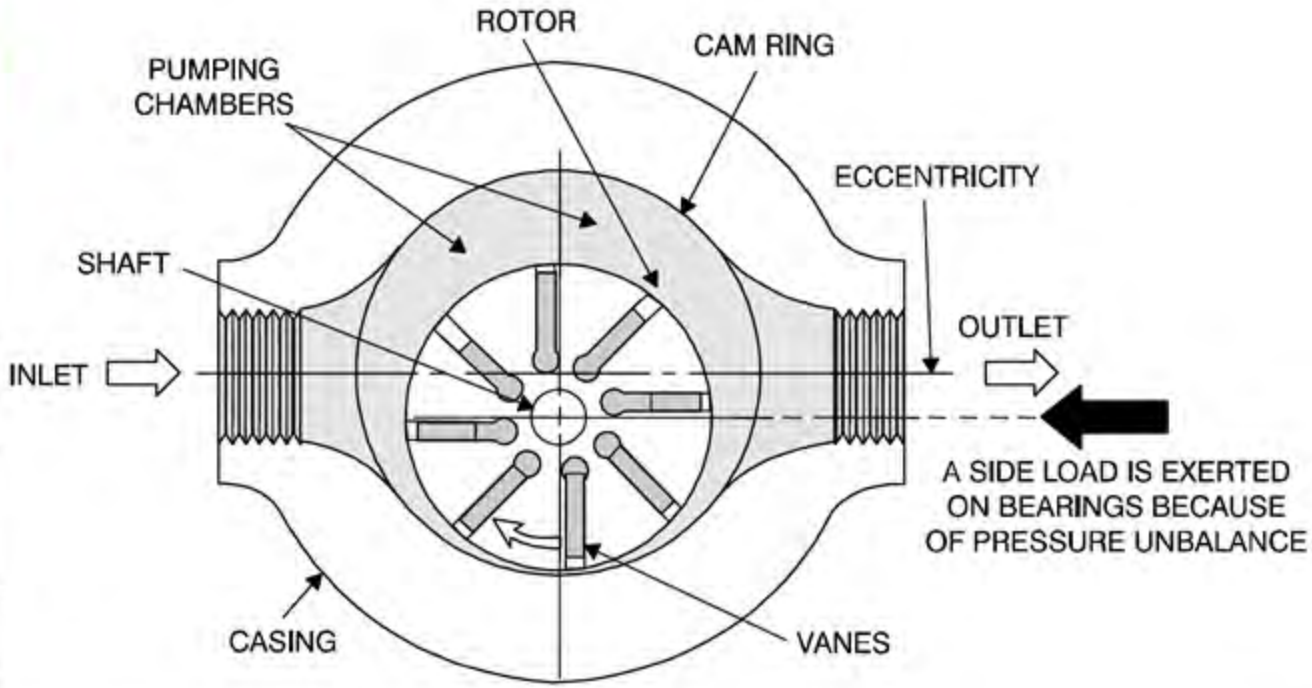

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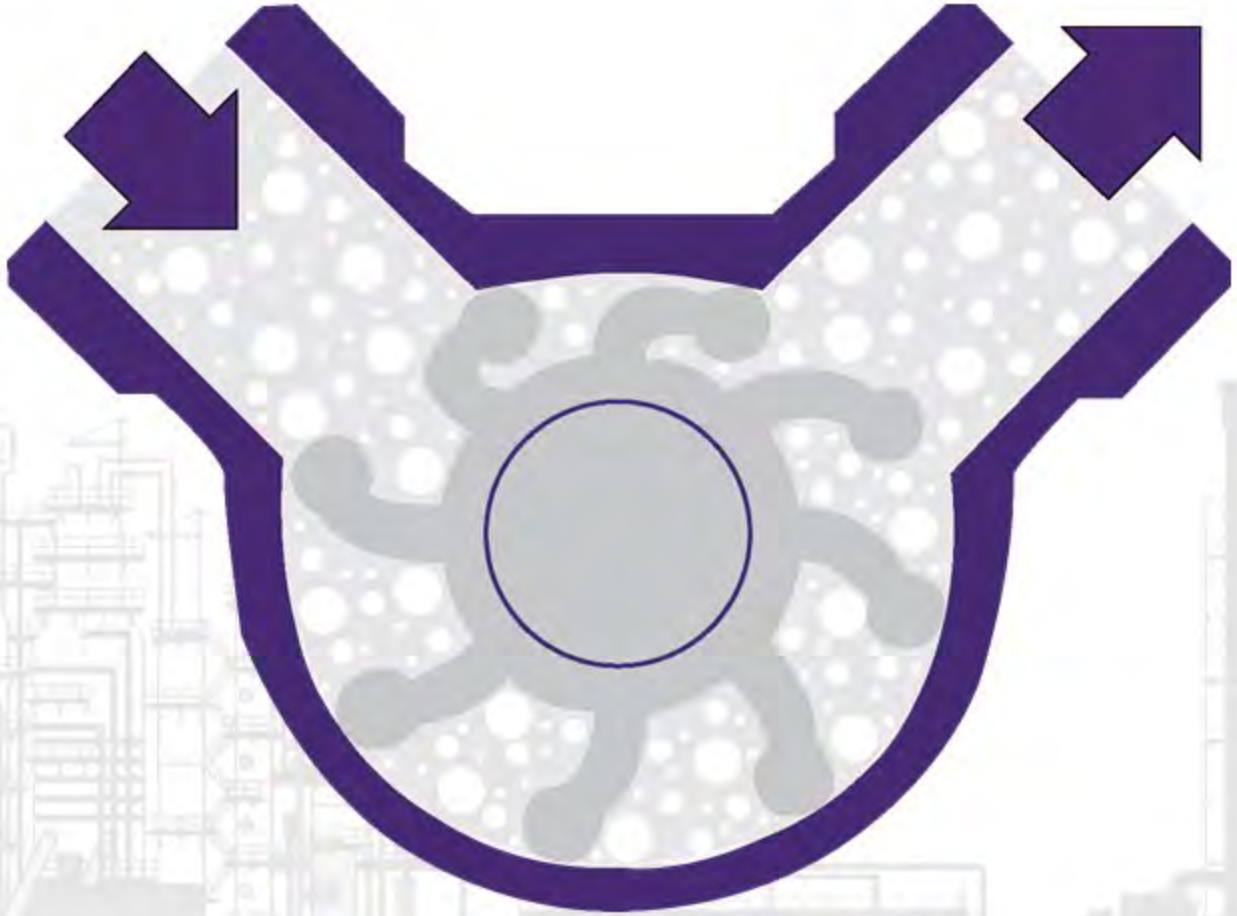

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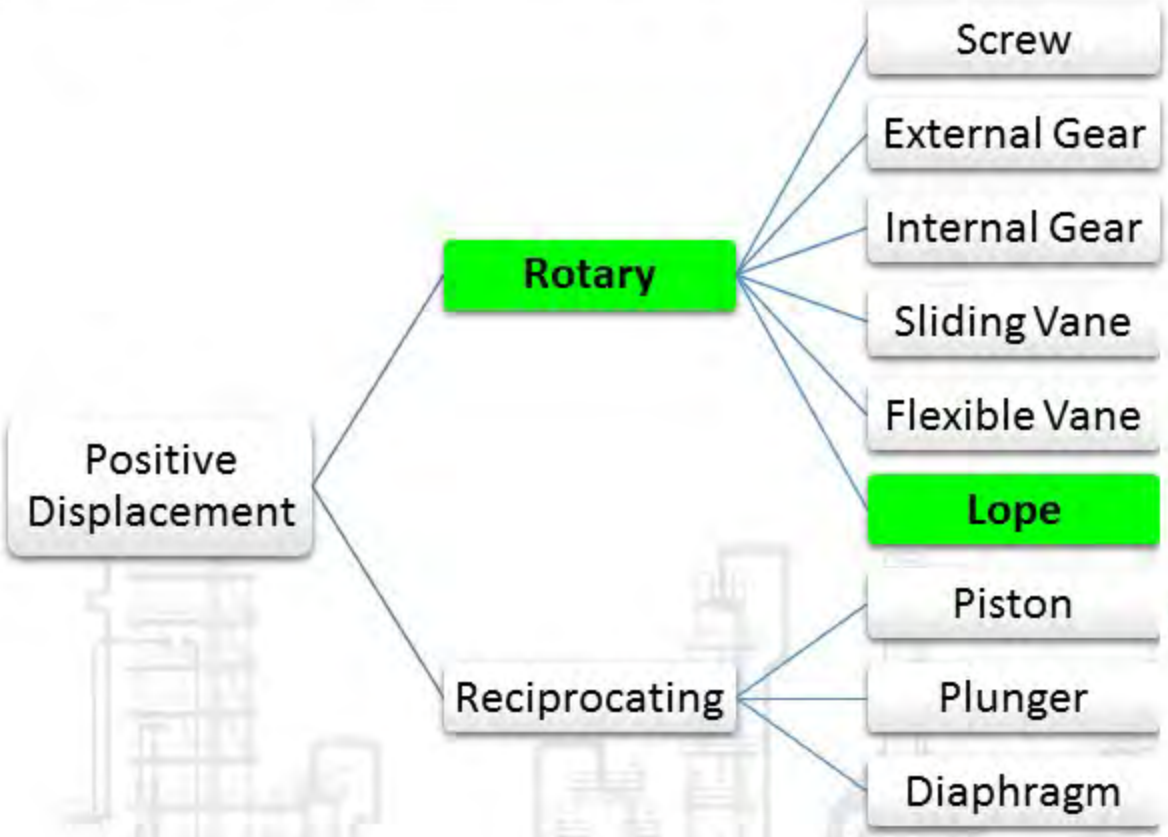

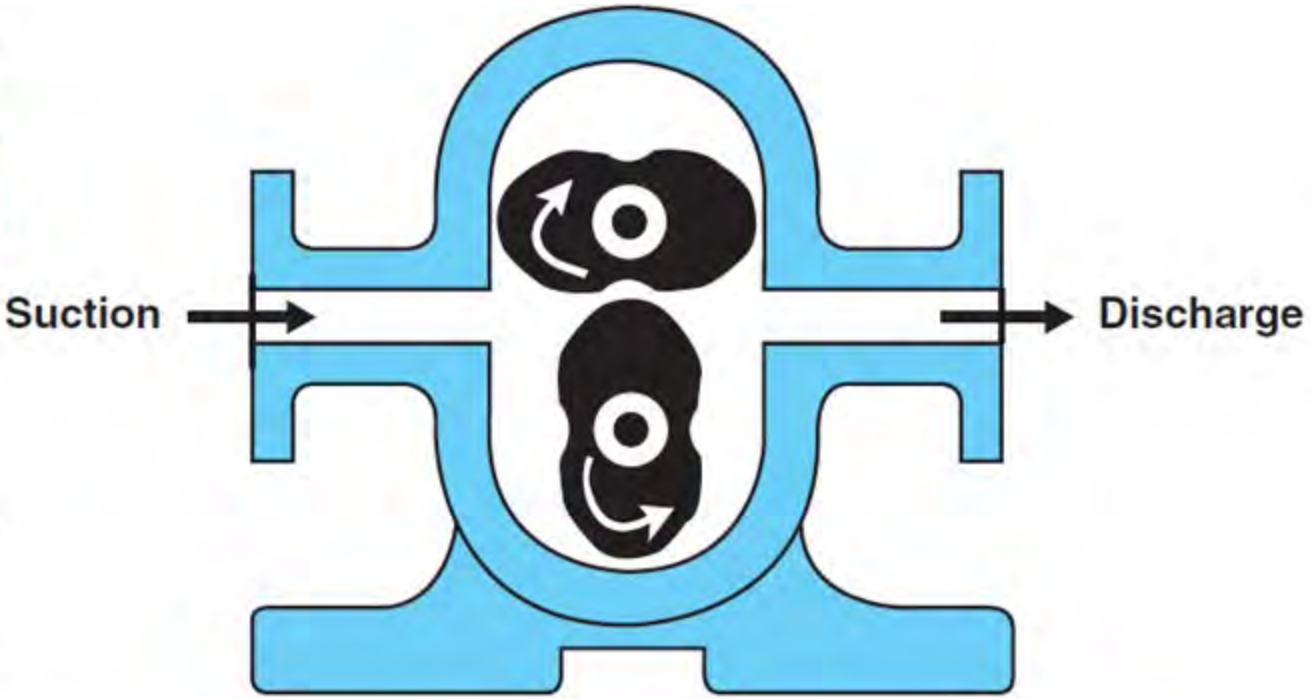

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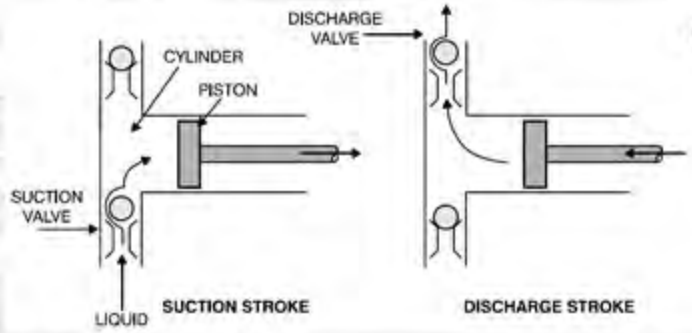

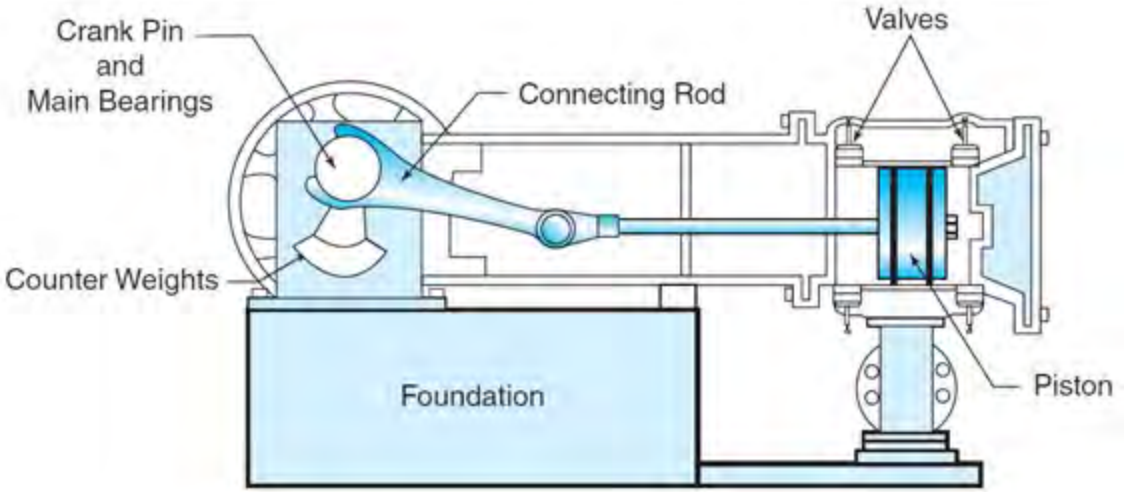

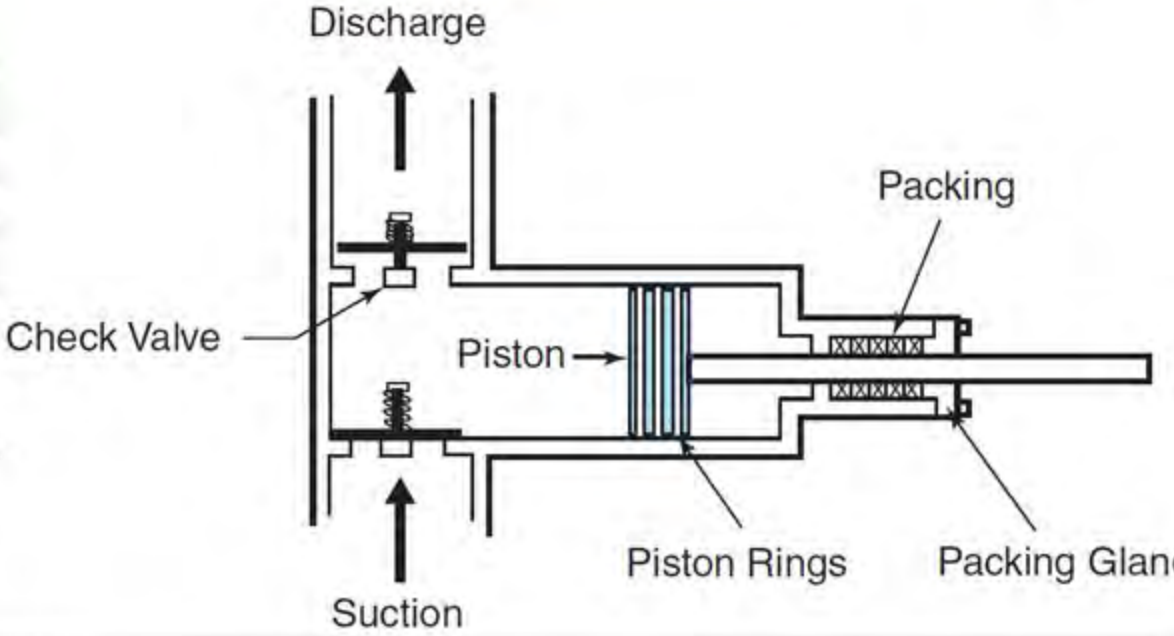

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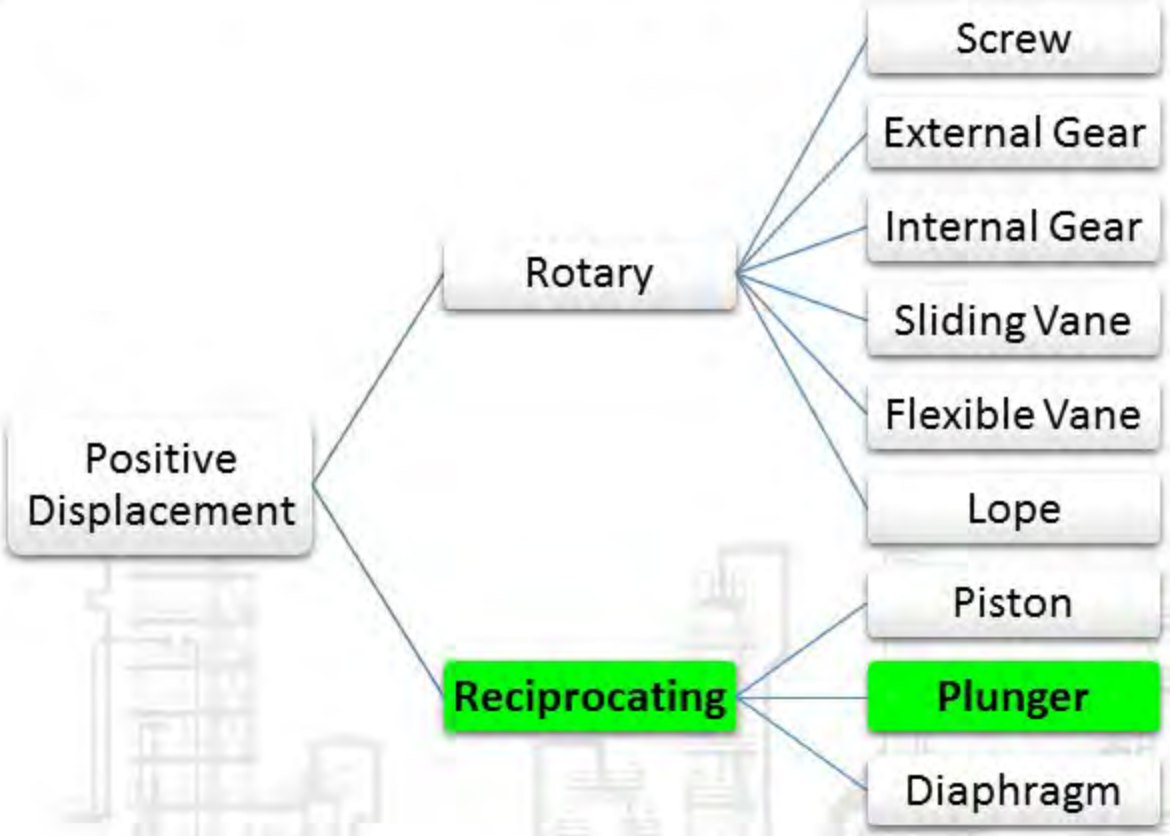

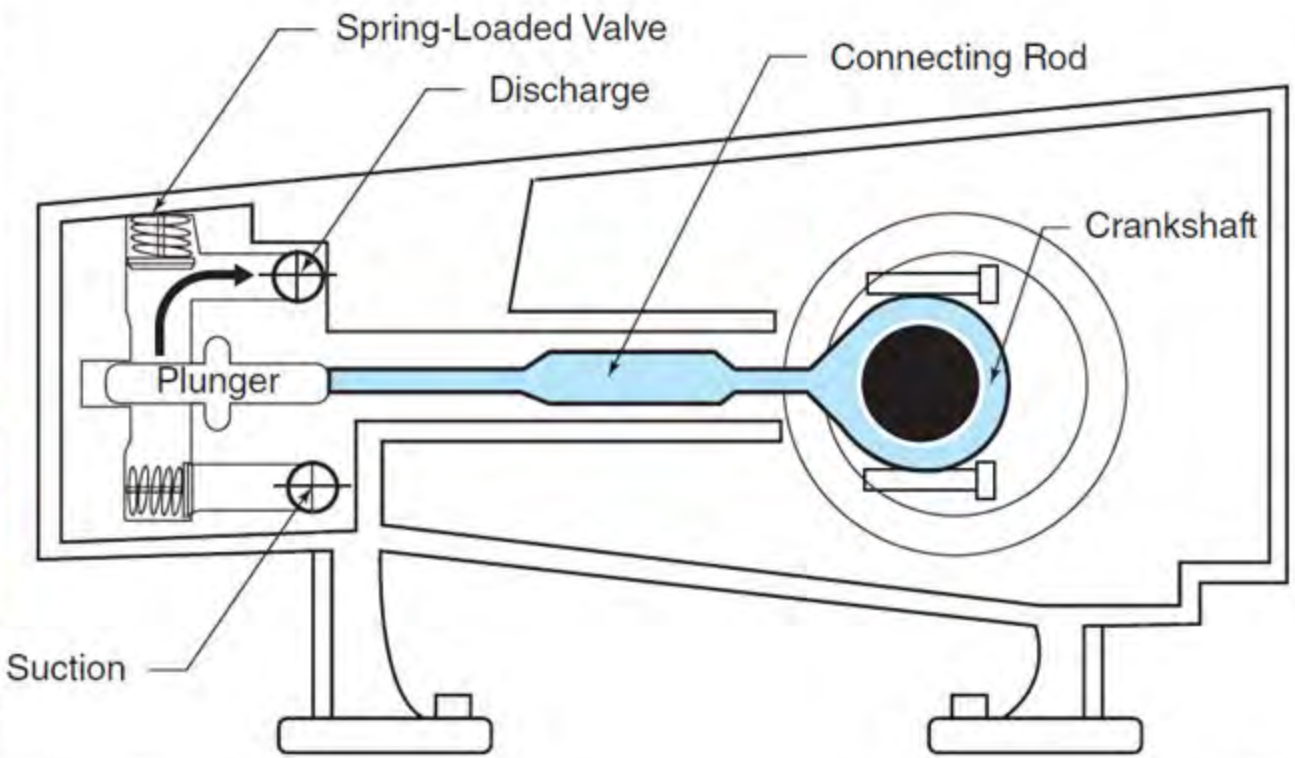

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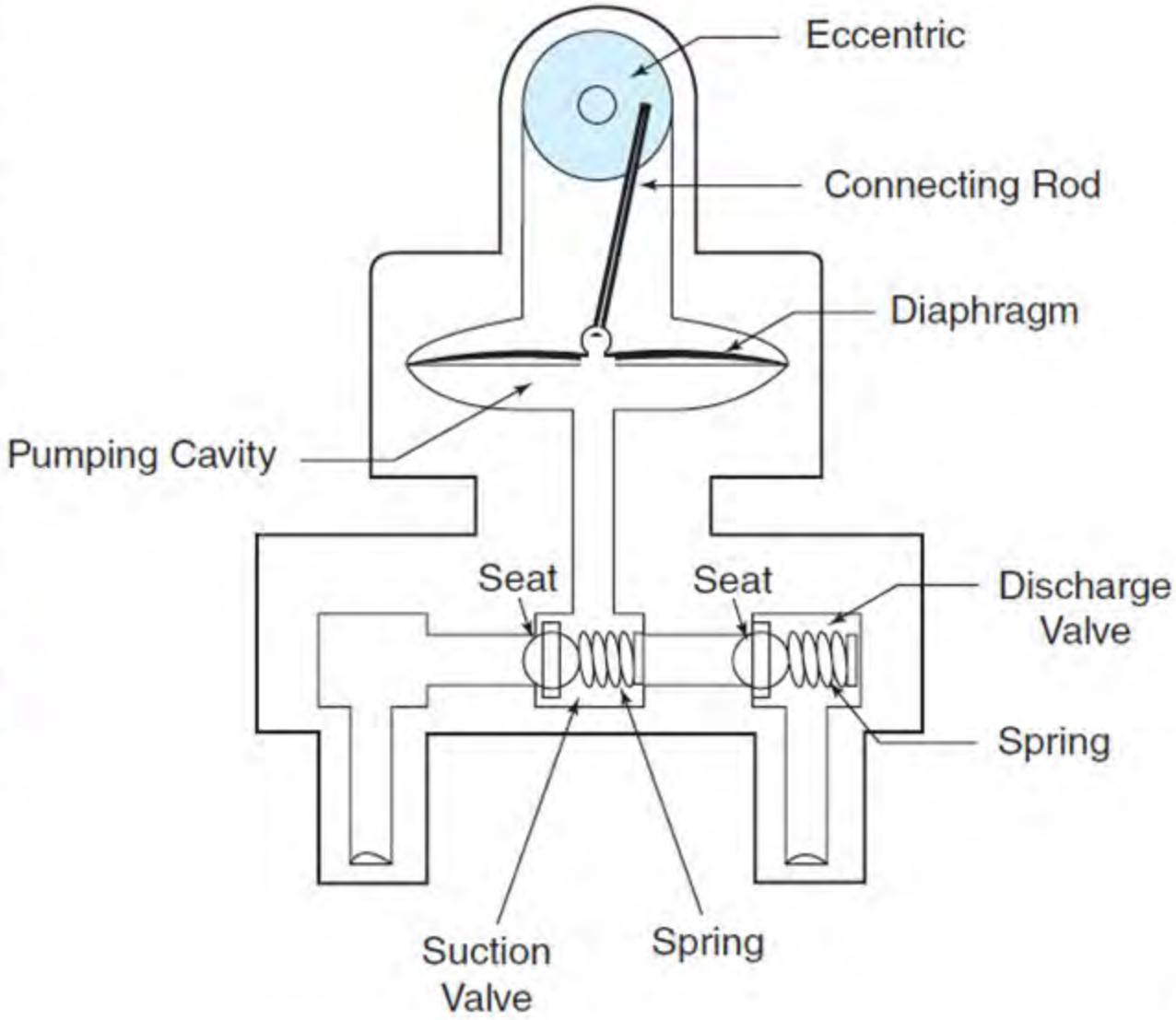

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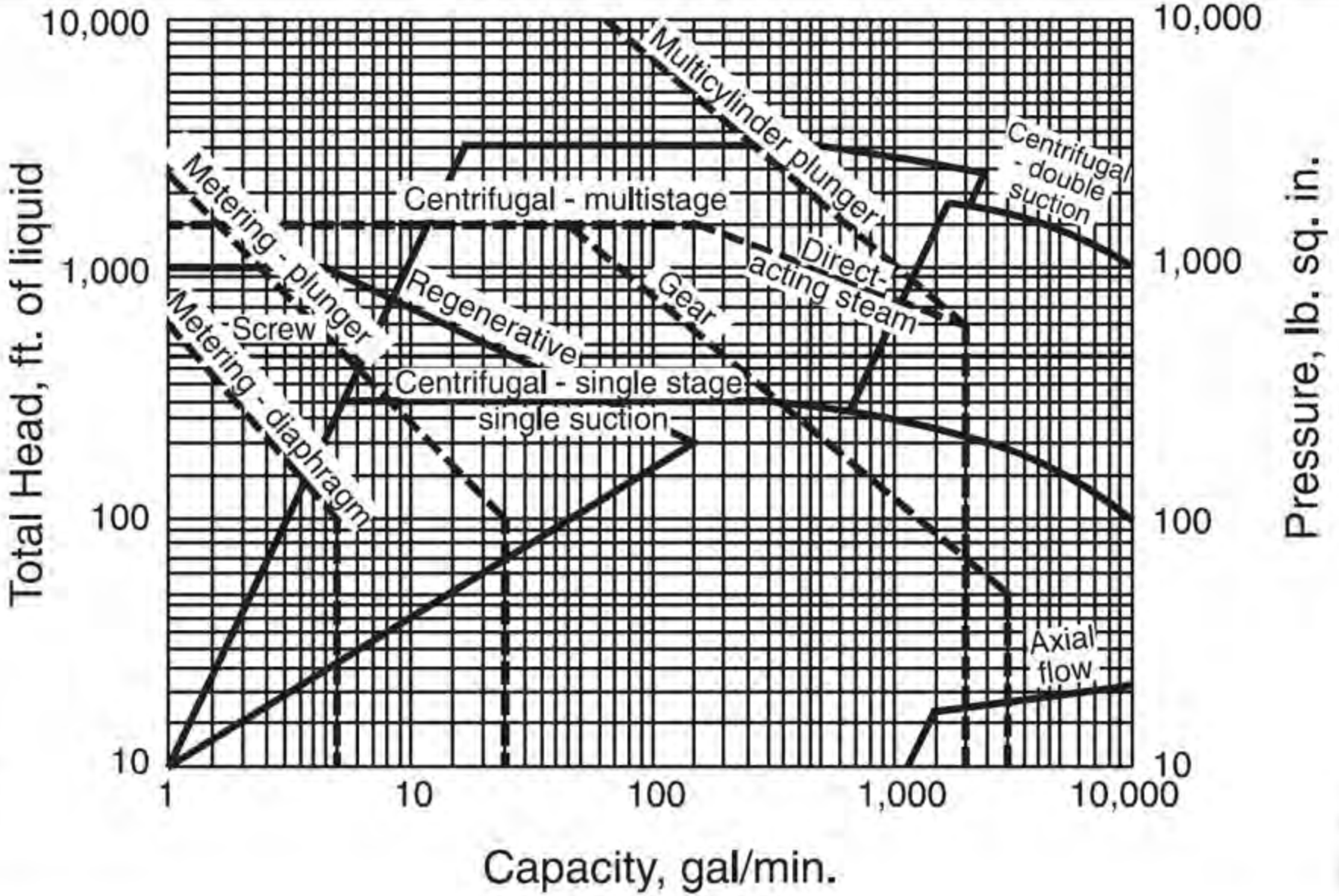
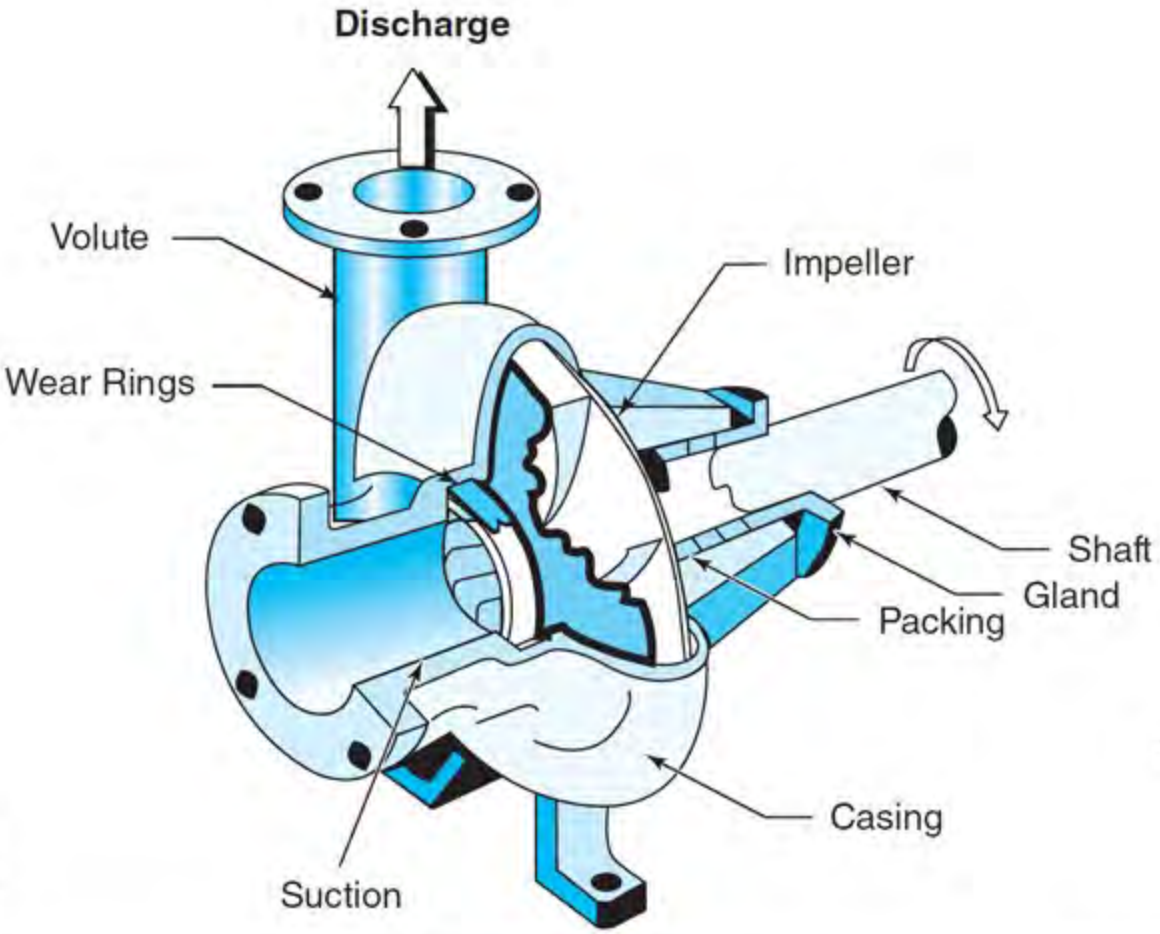


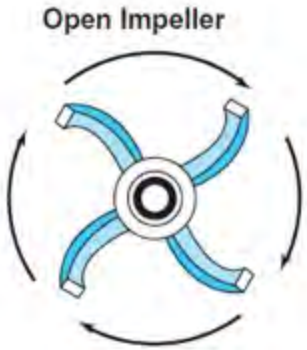
Get Ready !

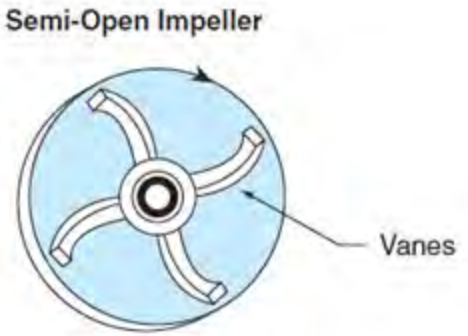
Part 2

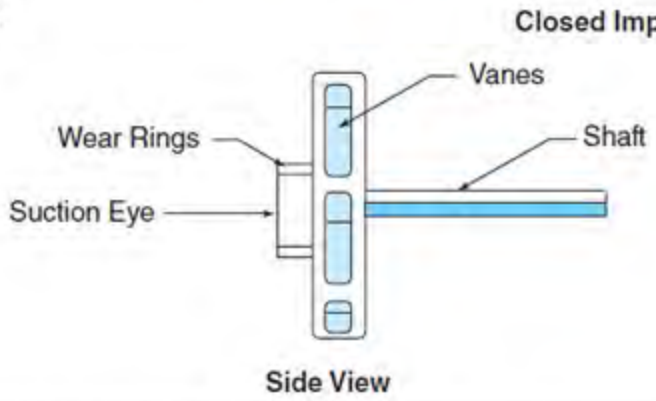
4. Basic Principles

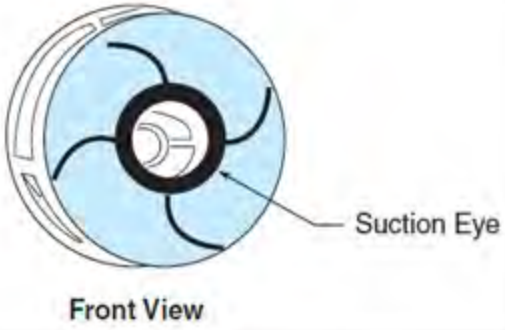
Most Common Pump : **Centrifugal Pump**



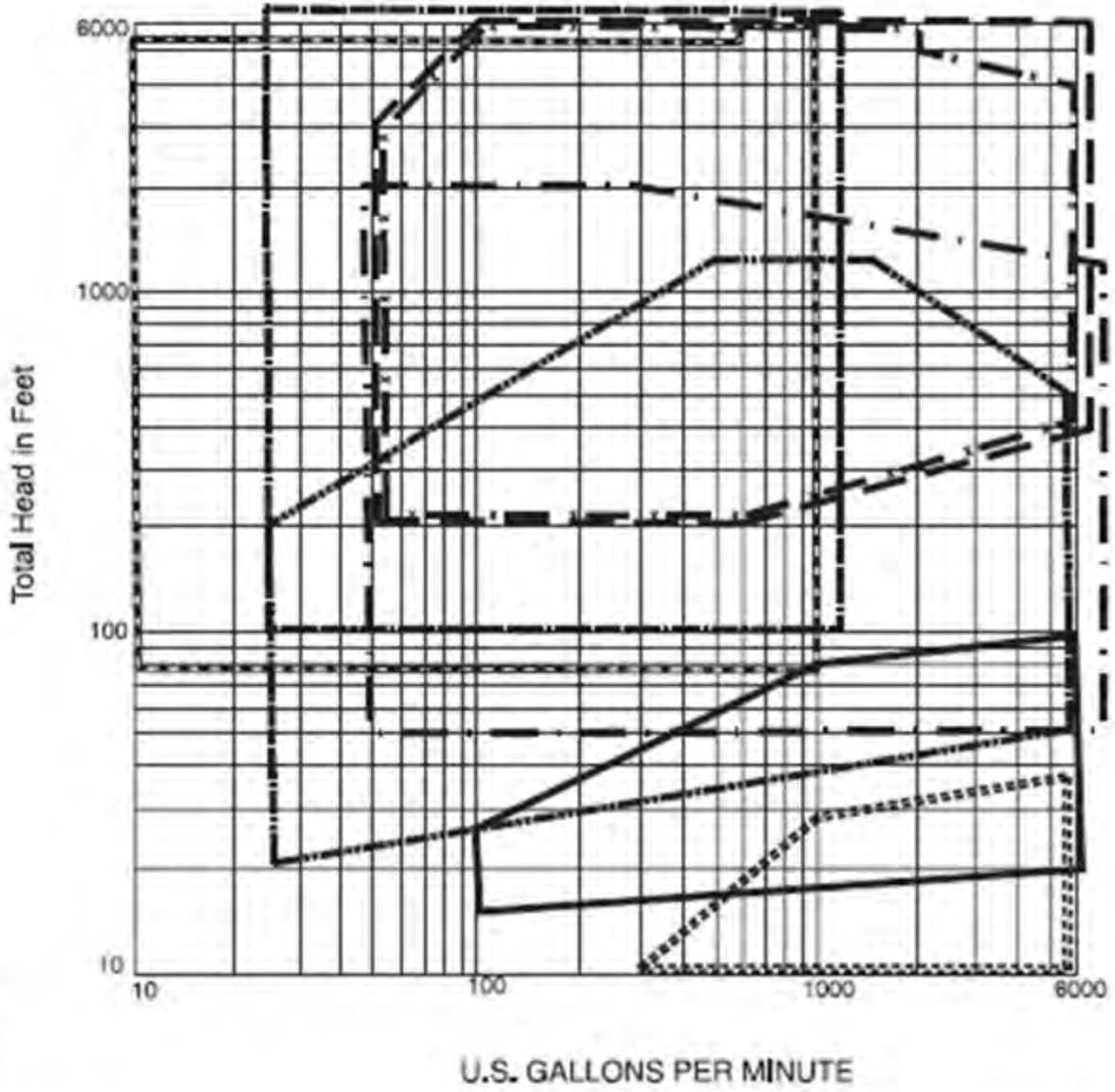








4. Basic Principles



Single Stage – Std. rpm (Single/Double Suction
Vertical Multistage – Barrel Type
Single Stage – High rpm
Horizontal Multistage – Barrel Type
Single Stage – Axial Flow
Single Stage – Mixed Flow
Horizontal Multistage – Single Case
Vertical Multistage – Barrel Type

Courtesy of Bingham – Willamette Ltd.

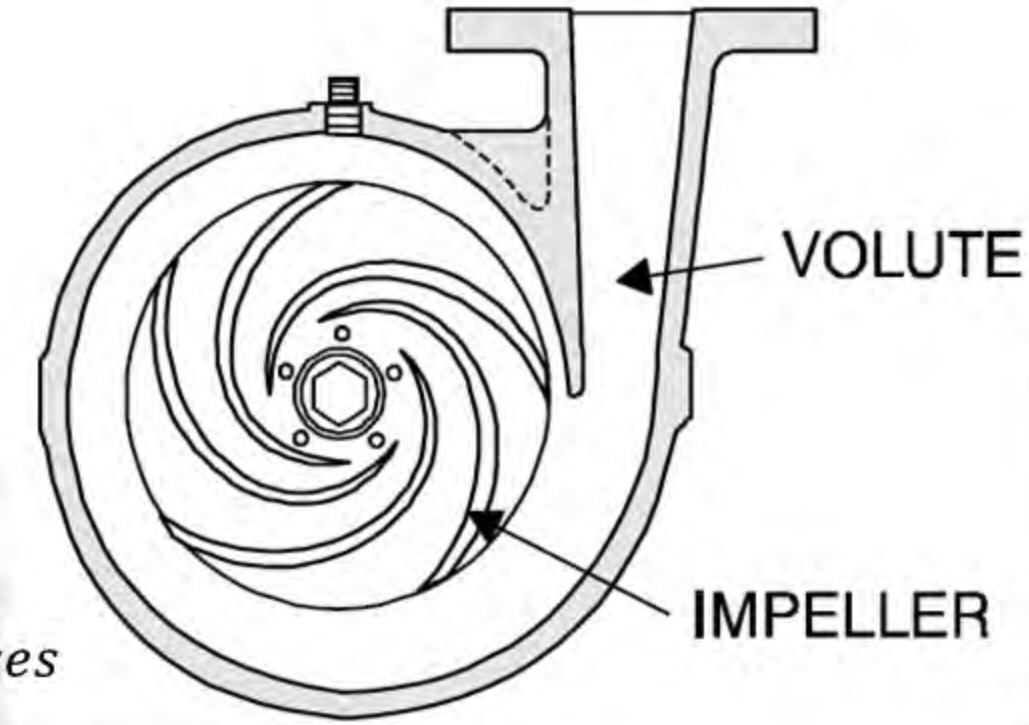
4. Basic Principles

- **Continuity Equation**

$$A_1 V_1 = A_2 V_2 = \text{Constant}$$

- **Bernoulli Equation**

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + H_{losses}$$



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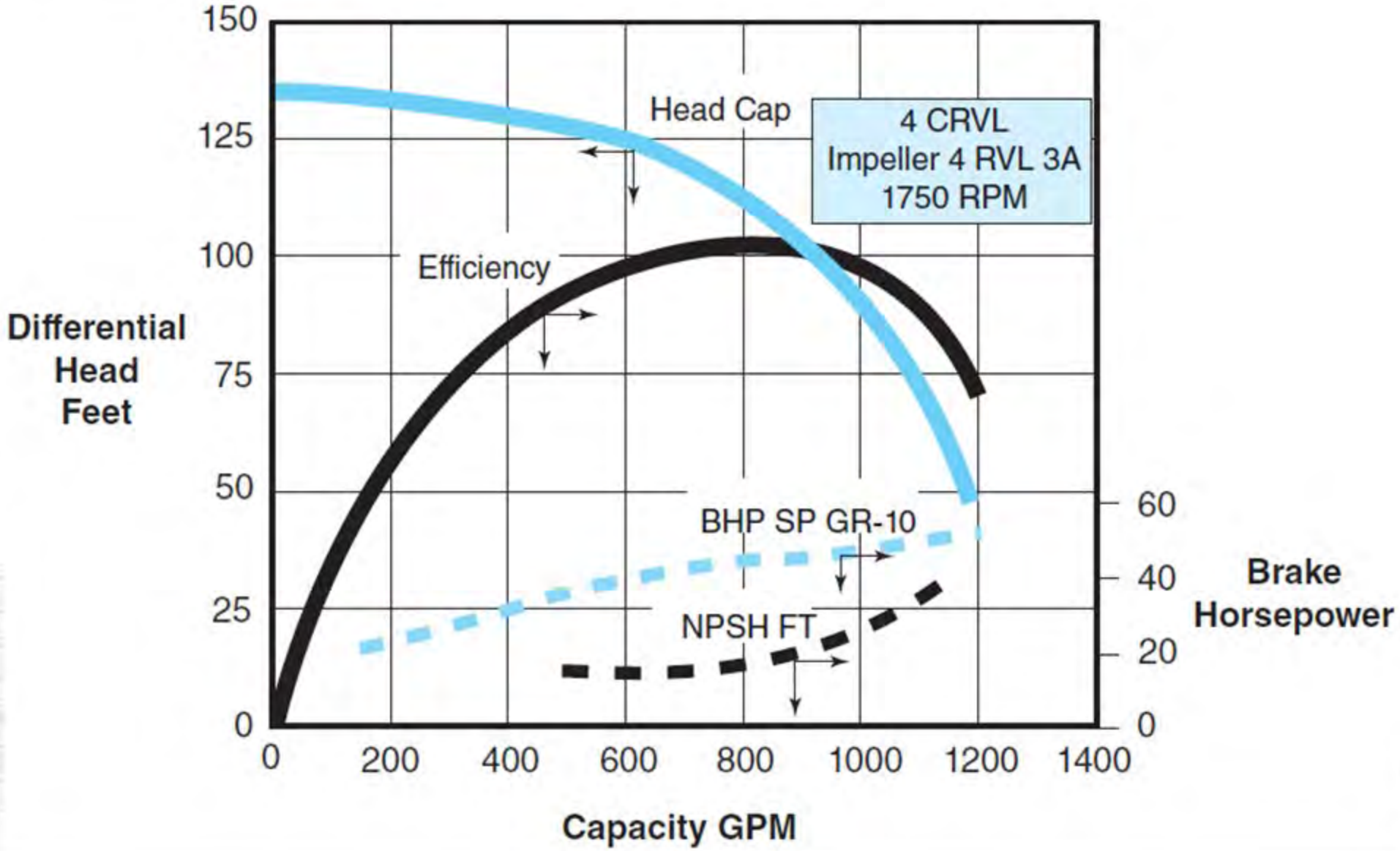


4. Basic Principles

- **Affinity Laws**

$$\frac{Q_2}{Q_1} = \left(\frac{D_2}{D_1}\right)^1 \qquad \frac{Q_2}{Q_1} = \left(\frac{N_2}{N_1}\right)^1$$

$$\frac{H_2}{H_1} = \left(\frac{D_2}{D_1}\right)^2 \qquad \frac{H_2}{H_1} = \left(\frac{N_2}{N_1}\right)^2$$

$$\frac{BHP_2}{BHP_1} = \left(\frac{D_2}{D_1}\right)^3 \qquad \frac{BHP_2}{BHP_1} = \left(\frac{N_2}{N_1}\right)^3$$

Where:
Q : Flow
D : Impeller Diameter
N : Speed
H : Head (TDH)
BHP :Brake Horsepower

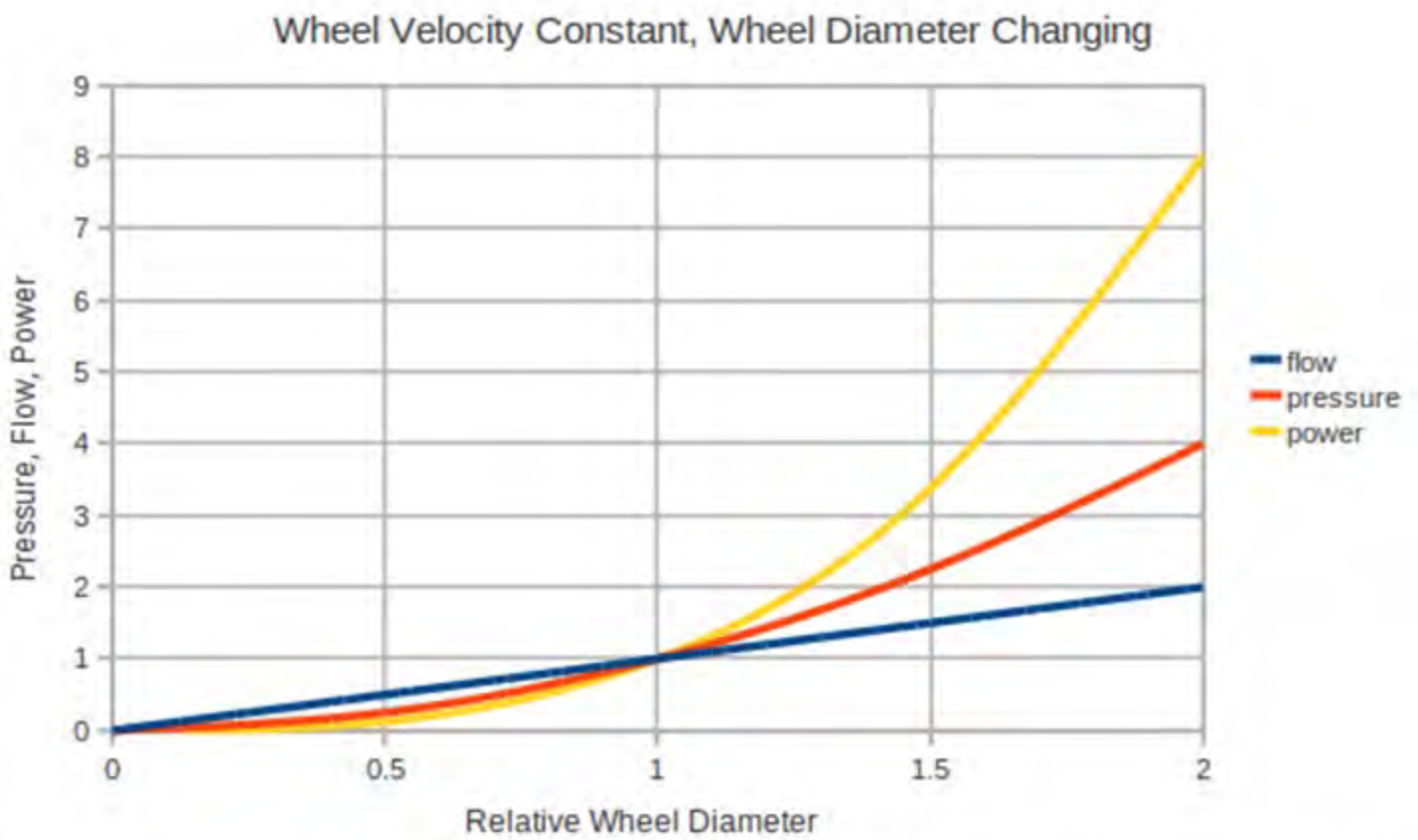
4. Basic Principles

- **Affinity Laws**

$$Q_2 = \left(\frac{D_2}{D_1}\right)^1 Q_1$$

$$H_2 = \left(\frac{D_2}{D_1}\right)^2 H_1$$

$$BHP_2 = \left(\frac{D_2}{D_1}\right)^3 BHP_1$$



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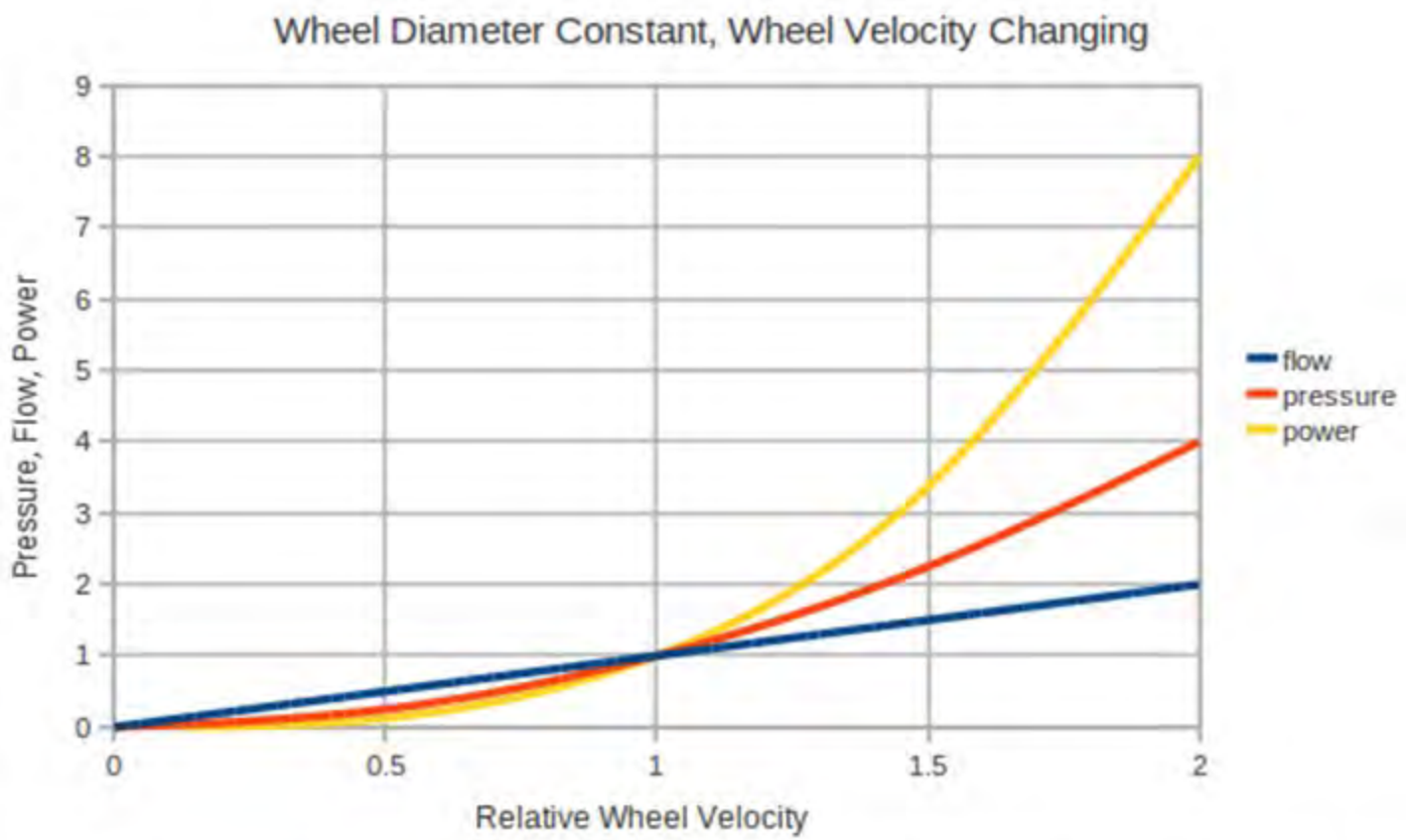

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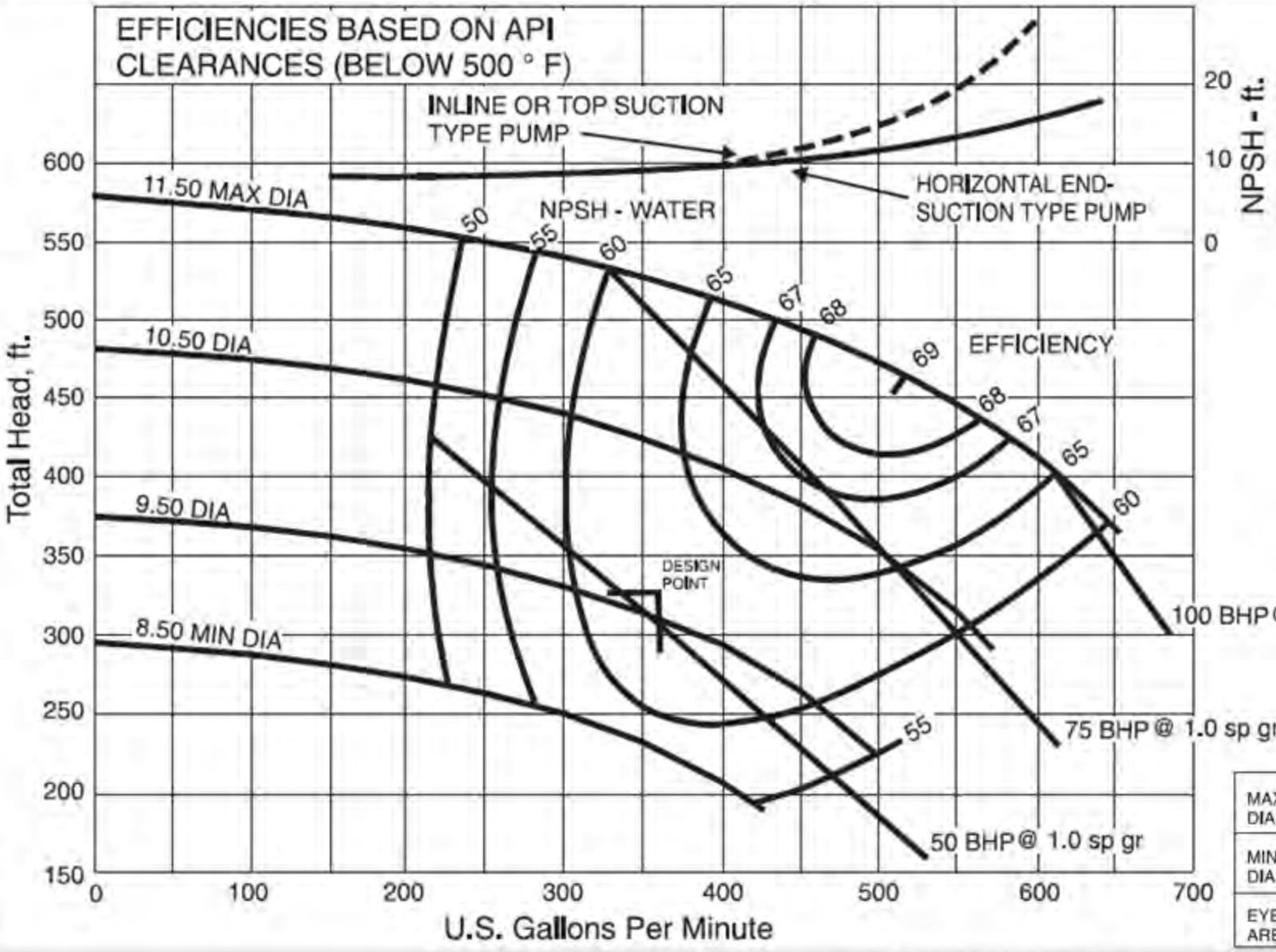
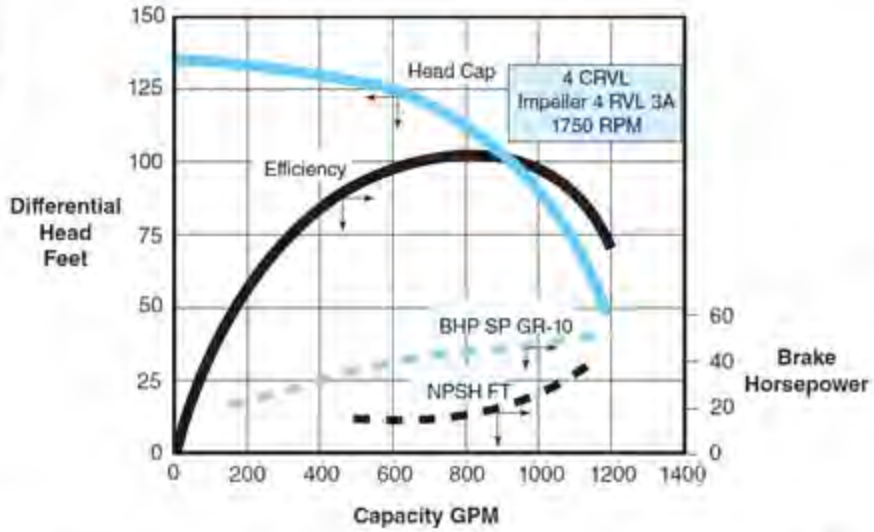
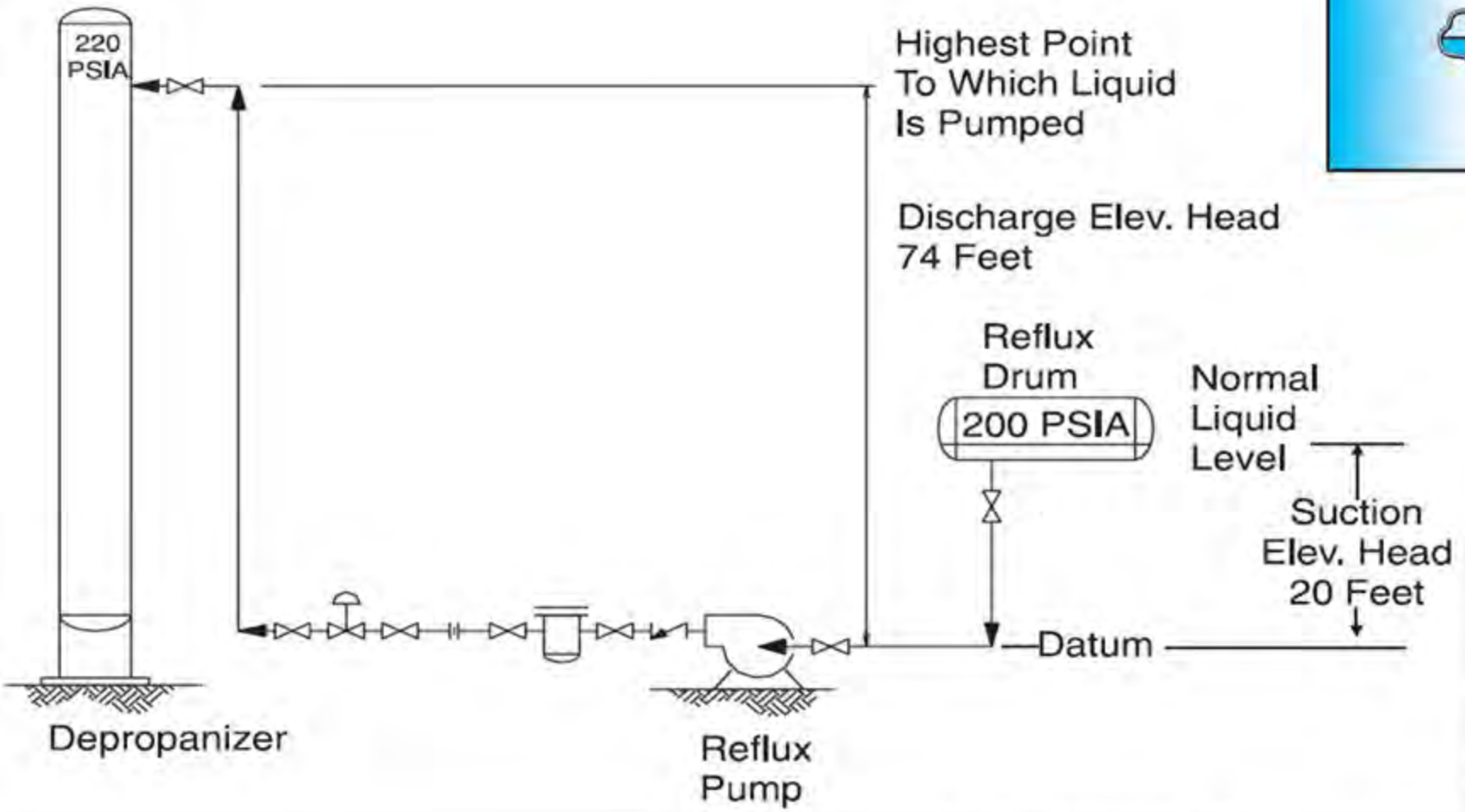
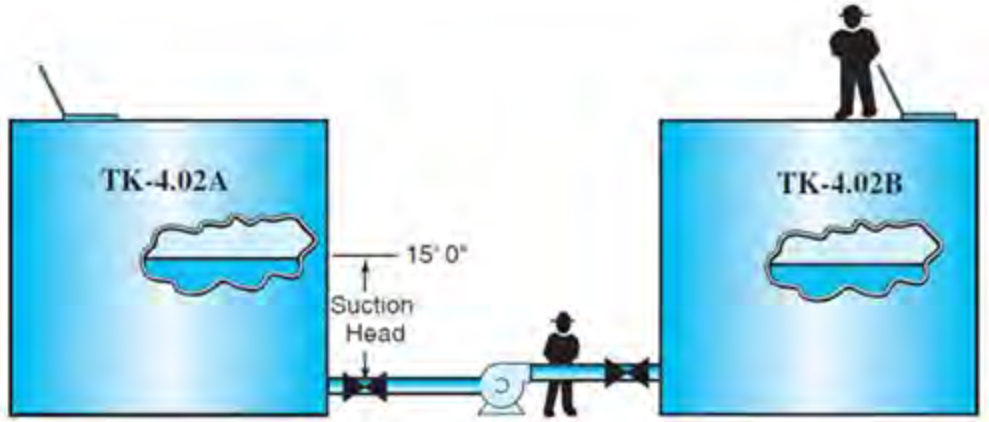




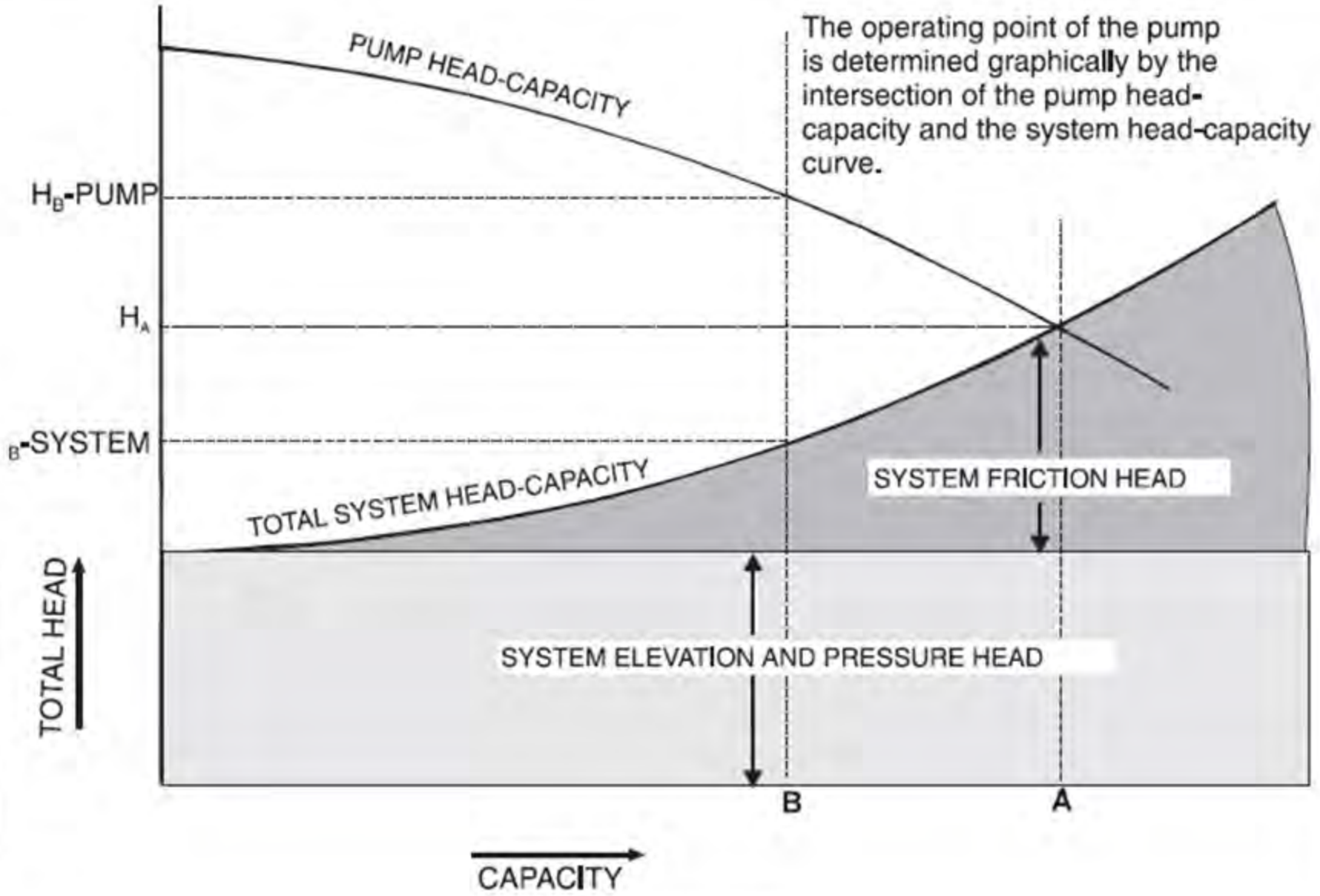
IMPELLER				
MAX DIA	11.50 IN	3 X 4 X 11.5 SINGLE STAGE PUMP		
MIN DIA	8.50 IN	DIA IMPELLER 9.75 IN	IMPELLER PATT	3,560 RPM
EYE AREA	14.2 SQ IN	NPSH REQUIRED 9 FT	REFERENCE	CURVE NO. CA-307-3

5. System


220
PSIA
Highest Point
To Which Liquid
Is Pumped
Discharge Elev. Head
74 Feet
Reflux
Drum
200 PSIA
Normal
Liquid
Level
Suction
Elev. Head
20 Feet
Datum
Depropanizer
Reflux
Pump

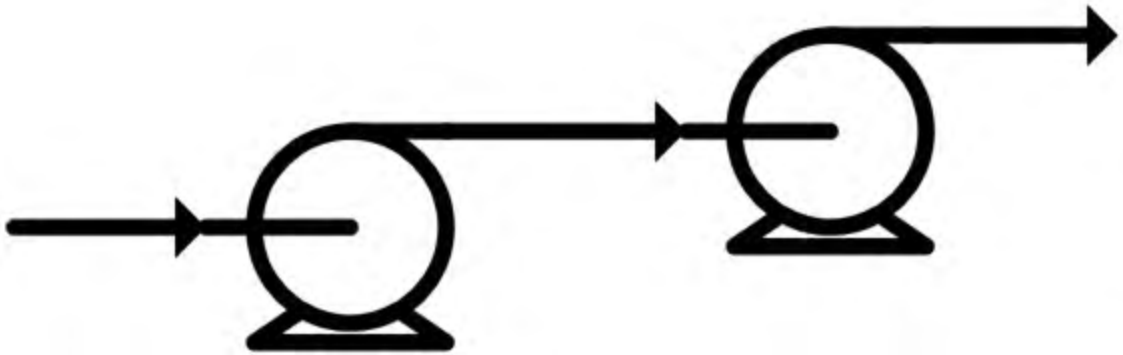

TK-4.02A
TK-4.02B
15' 0"
Suction
Head

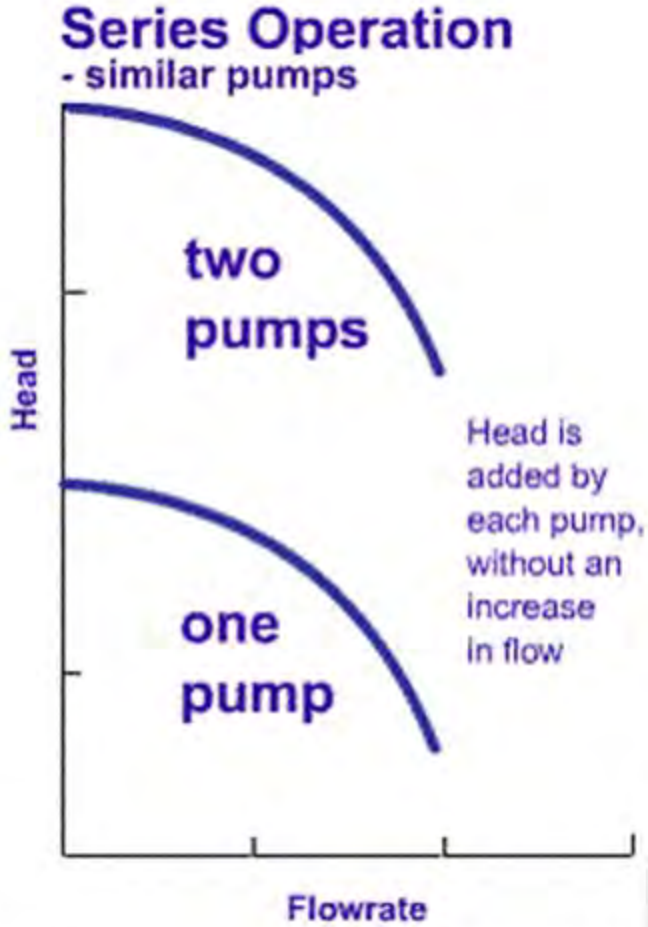
5. System


The operating point of the pump is determined graphically by the intersection of the pump head-capacity and the system head-capacity curve.
PUMP HEAD-CAPACITY
H_B-PUMP
H_A
$_B$-SYSTEM
TOTAL SYSTEM HEAD-CAPACITY
SYSTEM FRICTION HEAD
SYSTEM ELEVATION AND PRESSURE HEAD
TOTAL HEAD
B
A
CAPACITY

5. System

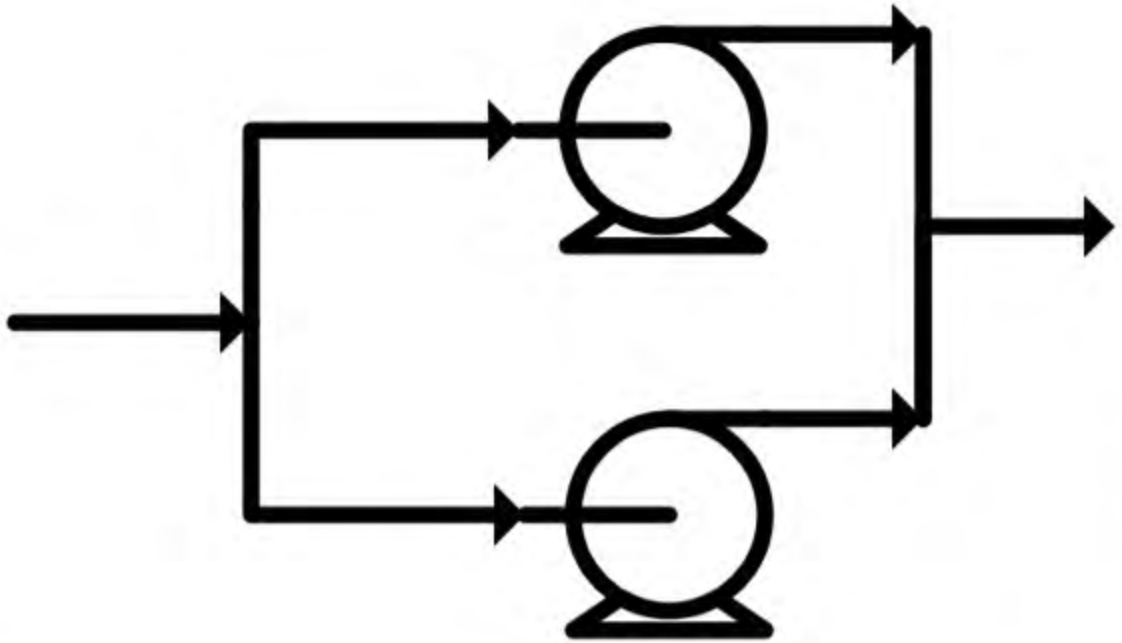
- Series Pumps

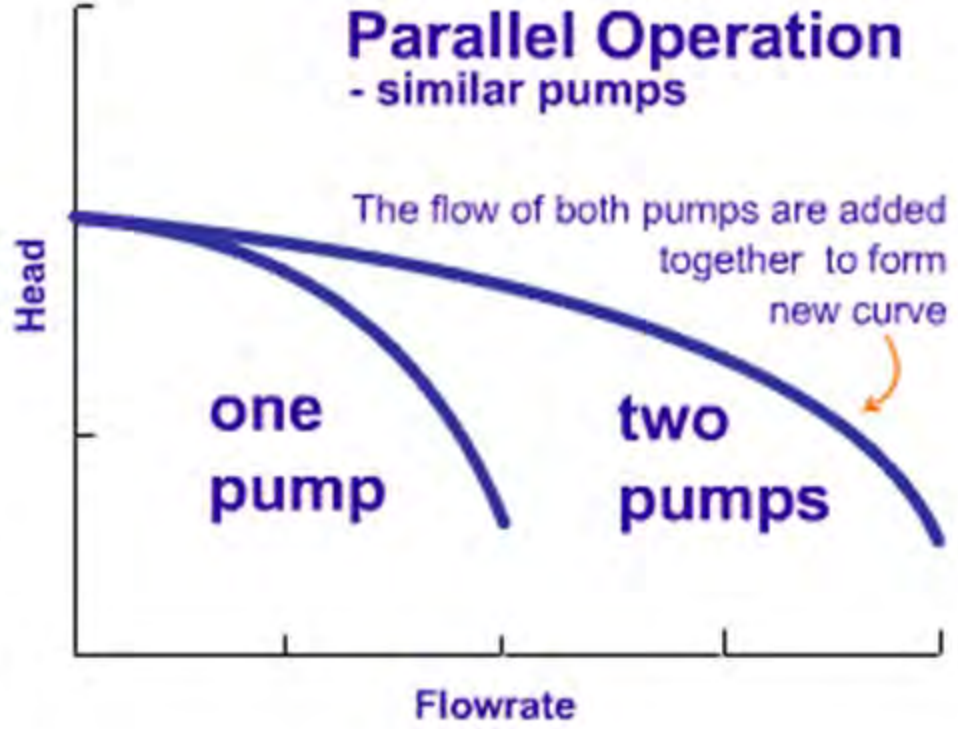




5. System

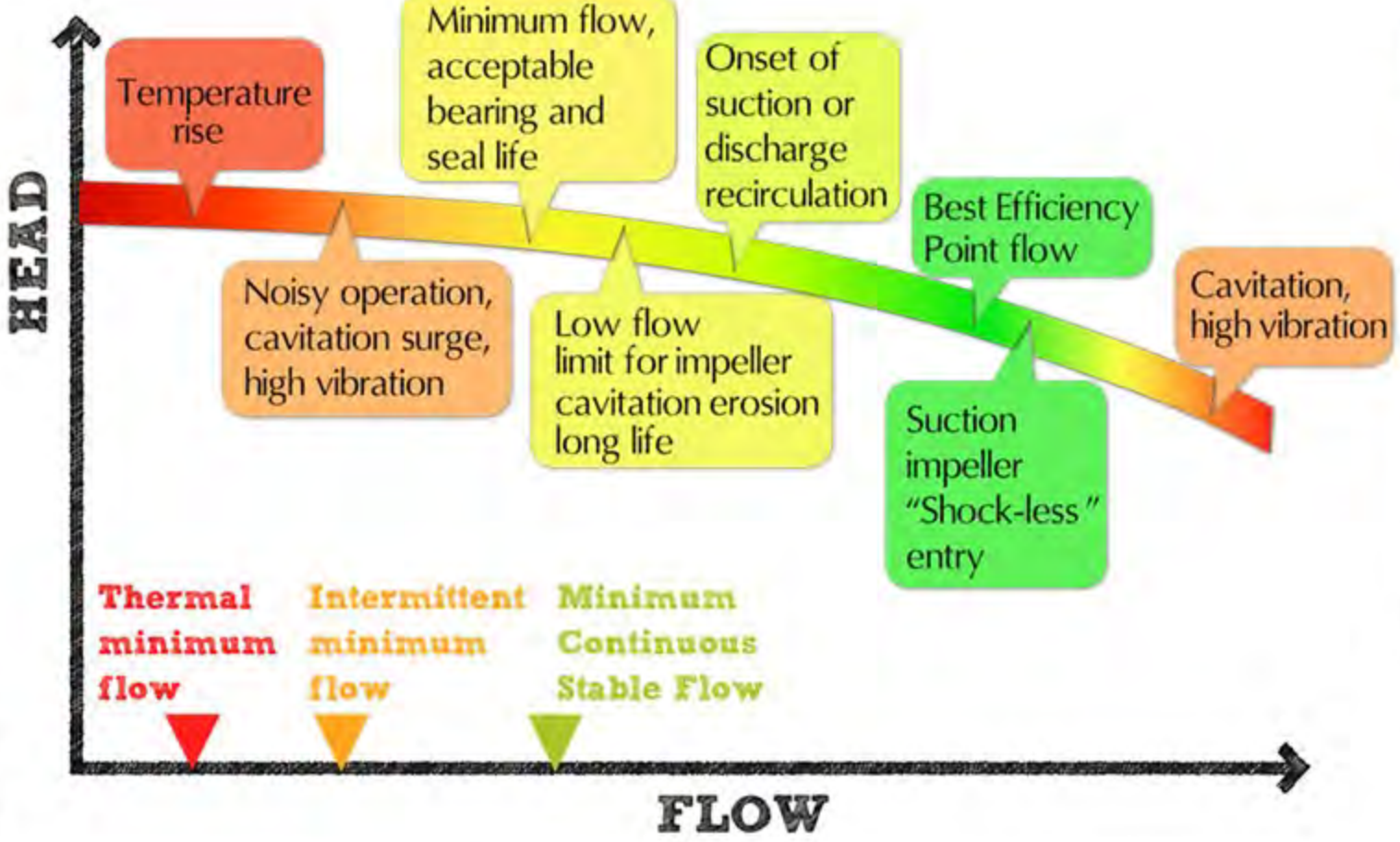
- **Parallel Pumps**

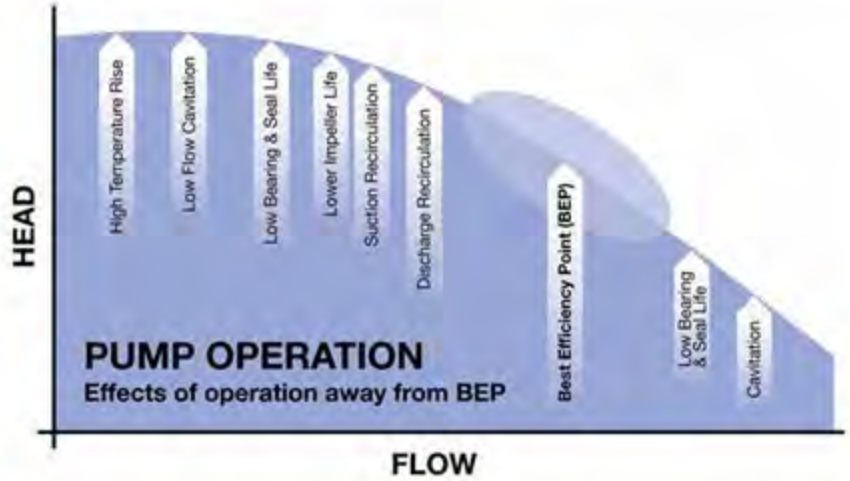


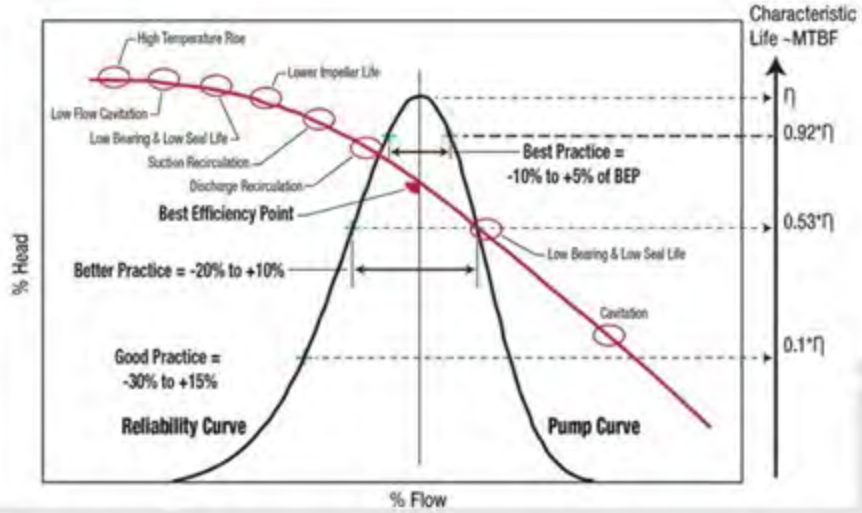


5. System

- **Minimum Flow**

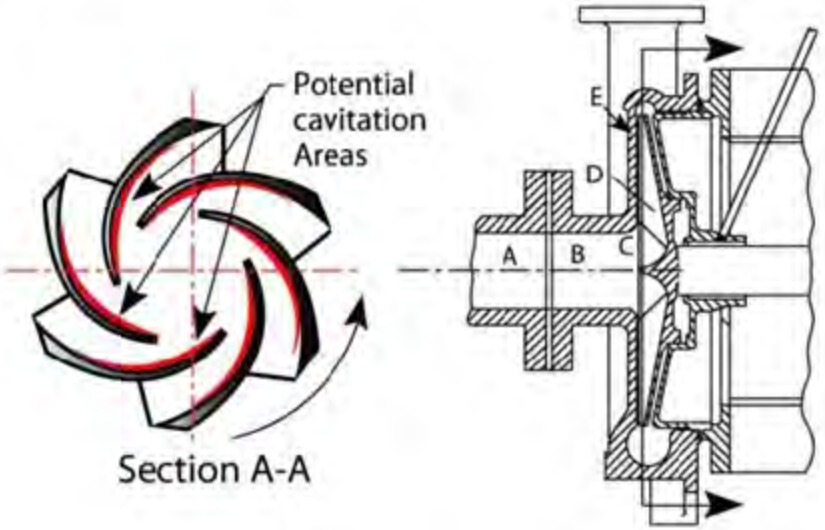


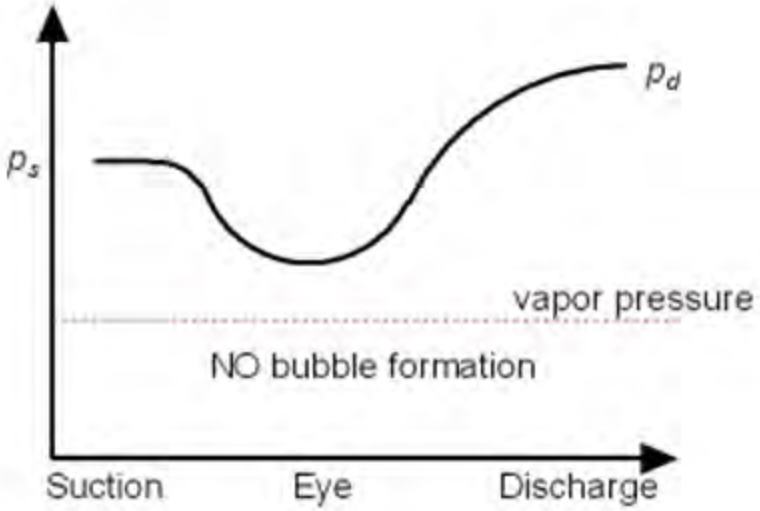


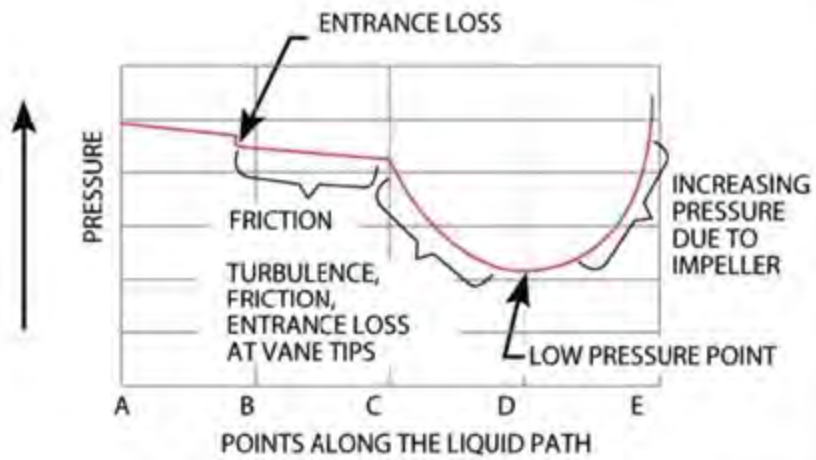


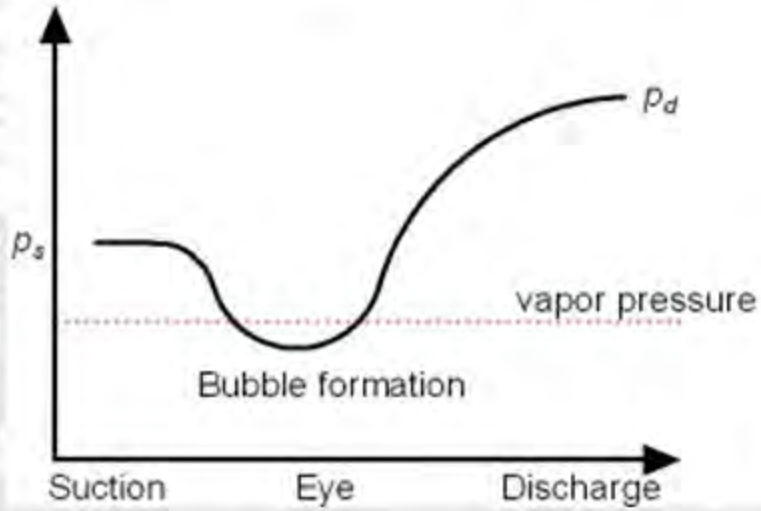
5. System

- **NPSH**

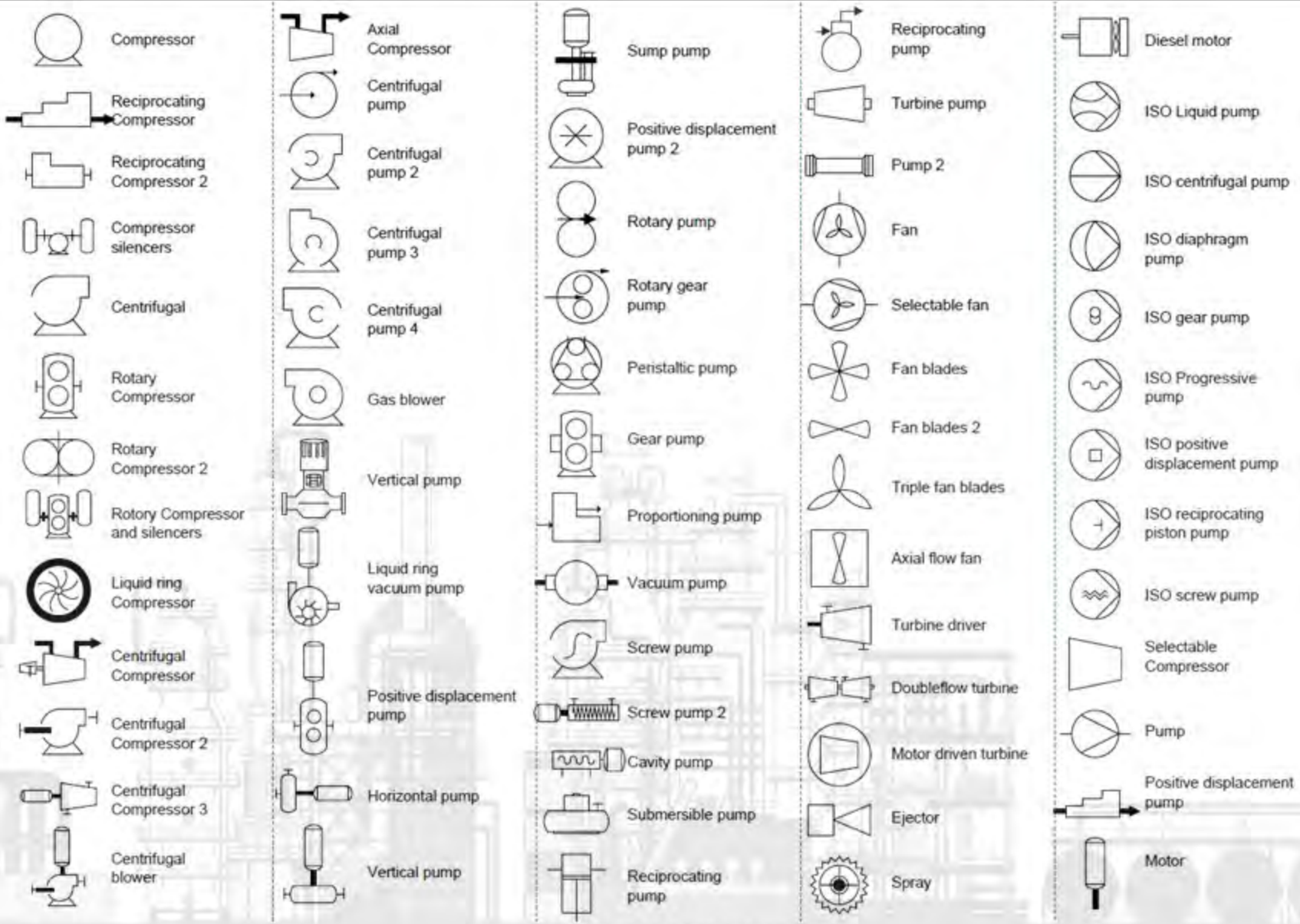








6. P&ID Symbols



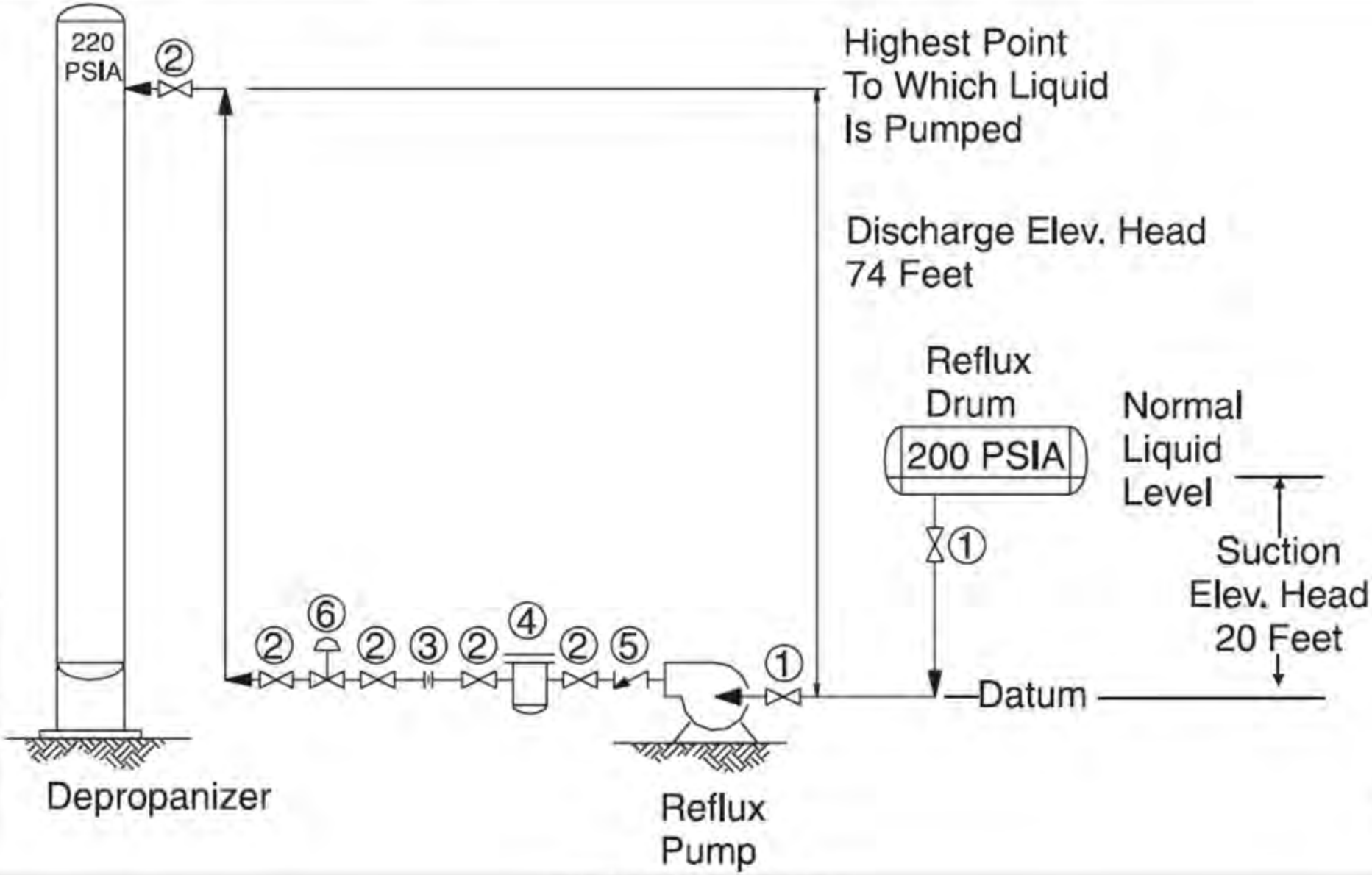
Get Ready !

Part 3

7. Worked Example

Assume Liquid propane, at its bubble point, is to be pumped from a reflux drum to a depropanizer (use the previous system). The maximum flow rate is expected to be 360 gpm. The pressures in the vessels are 200 and 220 psia respectively. The specific gravity of propane at the pumping temperature (100°F) is 0.485. The elevations and estimated frictional pressure losses are shown on the next figure. The pump nozzles elevations are zero and the velocity head at nozzles is negligible. The previous pump curve can be used as The pump curves for this example.

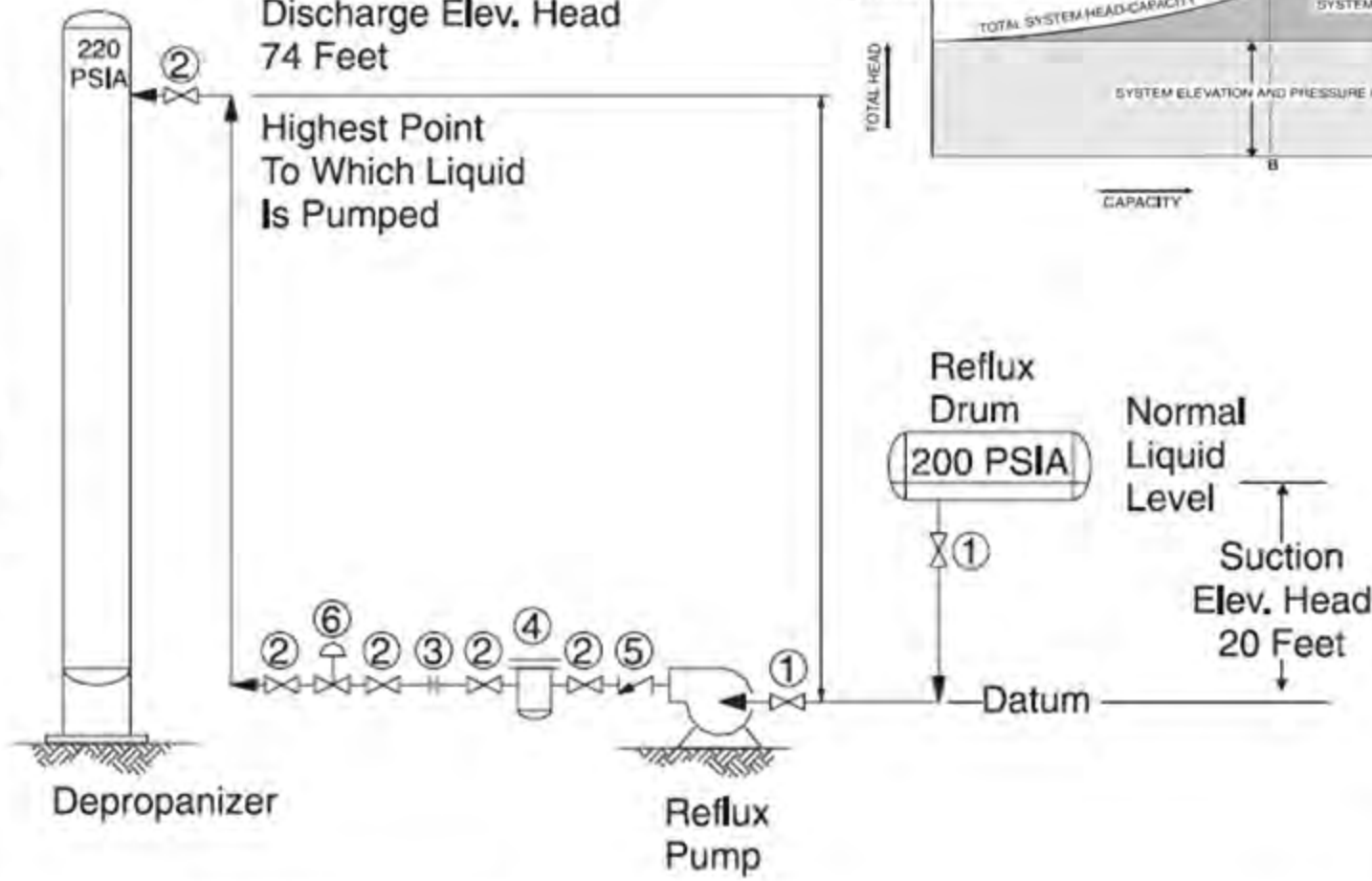
7. Worked Example

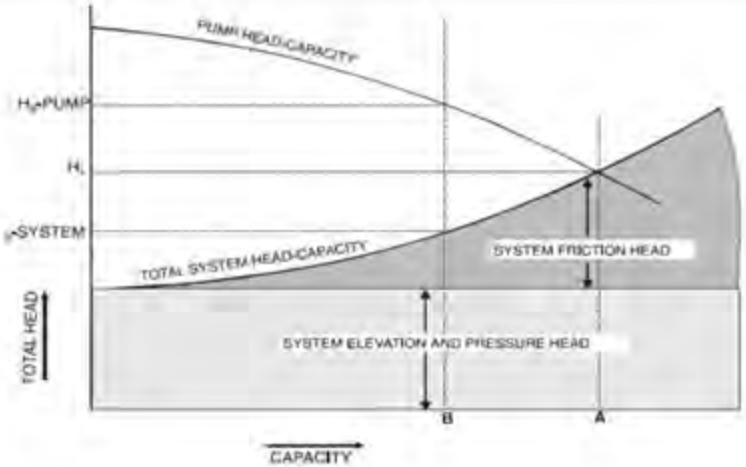


7. Worked Example

SUCTION FRICTION	
PIPING	0.5 PSI
①- VALVES	0.2 PSI

DISCHARGE FRICTION	
PIPING	3.0 PSI
②- VALVES	2.0 PSI
③- ORIFICE	1.2 PSI
④- FILTER	13.0 PSI
⑤- CHECK VALVE	1.0 PSI
⑥- CONTROL VALVE	9.0 PSI





7. Worked Example

Absolute Total Pressure at Pump Suction

Reflux drum		200.0 psia
Elevation	20 ft. • 0.485/2.31 =	+ 4.2 psi
Friction	piping	- 0.5 psi
	valves	- 0.2 psi
		203.5 psia
		= 188.8 psig

7. Worked Example

Absolute Total Pressure at Pump Discharge

Tower		220.0 psia
Elevation	74 ft • 0.485/2.31 =	+15.5 psi
Friction	piping	+3.0 psi
	valves	+2.0 psi
	orifice	+1.2 psi
	filter	+13.0 psi
	check valve	+1.0 psi
	control valve	+9.0 psi
		264.7 psia
		= 250.0 psig

7. Worked Example

Differential pressure = 250.0 – 188.8 = 61.2 psi

Differential head = H = $\frac{(61.2)(2.31)}{0.485}$ = 292 ft

10% safety factor +30 ft

Required differential head (H) 322 ft

7. Worked Example

Calculation of Hydraulic Power

$$\text{hyd hp} = \frac{(Q)(H)(\text{sp.gr.})}{3960}$$

$$\text{hyd hp} = \frac{(360)(322)(0.485)}{3960} = 14.2 \text{ hp}$$

Calculation of Actual Horsepower

$$\text{bhp} = \frac{\text{hyd hp}}{e}$$

The efficiency at rated capacity and required head is 62%.

$$\text{bhp} = \frac{14.2}{0.62} = 22.9 \text{ bhp}$$

7. Worked Example

Motor Sizing

The motor is selected for the pump to provide "full curve" protection (i.e., end of head curve).

The maximum flow is 500 gpm with a head of 240 feet for this particular pump impeller size, which results in a brake horsepower requirement of 26.2 bhp at end of head curve. Therefore, a 30 hp motor is selected.

8. Resources

- **Excel Tools**
  1. Pump Calculation Tool - Hassan Elbanhawi.
  2. Pump Energy Efficiency Calculation Tool - SEAI & WS WG.
  3. Pump Sizing Rev1A - myChemE.

- **Professional Experience**
  - Process Engineer at GAP Tech.
  - Process Engineer at Assiut Oil Refinery.
  - Process Engineer at Abu Zaable Fertilizers.

- **Academic Background**
  - M.Sc. in Chemical Engineering.
  - B.Sc. in Petroleum Refining and Petrochemical Engineering.

Hassan M. ElBanhawi

Process Engineer | M.Sc.

- **Other Topics**
  - Compressors
  - Steam Turbines
  - Gas Turbines
  - Electric Motors
  - Infographics
  - Pipeline Sizing
  - Heat Exchangers
  - Columns (Towers)
  - Fired Equipment
  - Storage
  - Valves

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Thank You

www.hassanelbanhawi.com