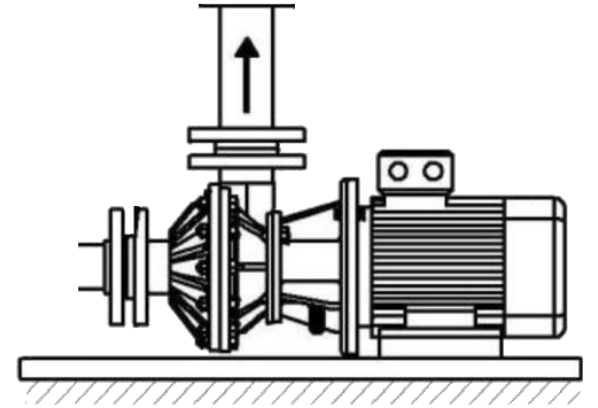


Pumps

**An introductory guide to Pumps
for Chemical Engineers**



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2. Introduction

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Get Ready !

Part 1



1. Key Terms

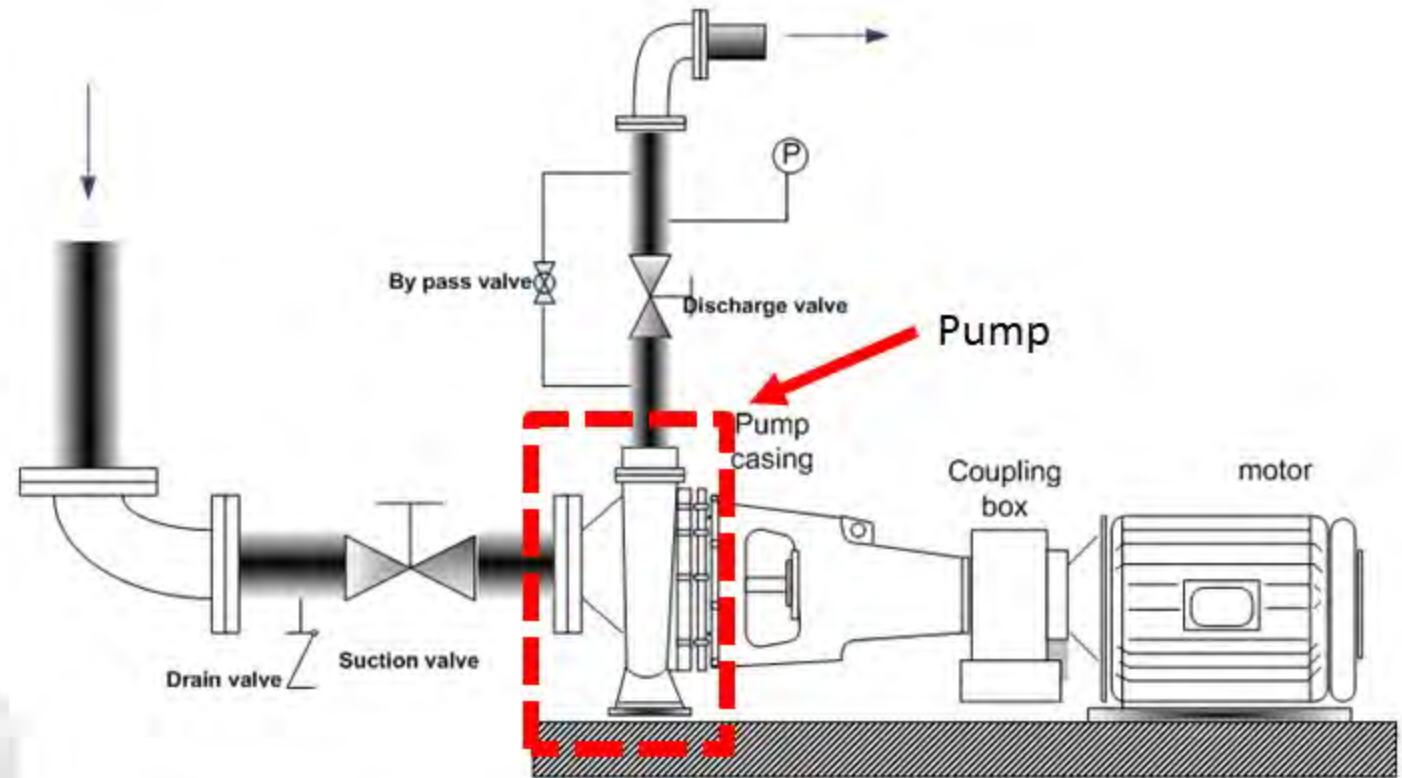
- Pump
- Head

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

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

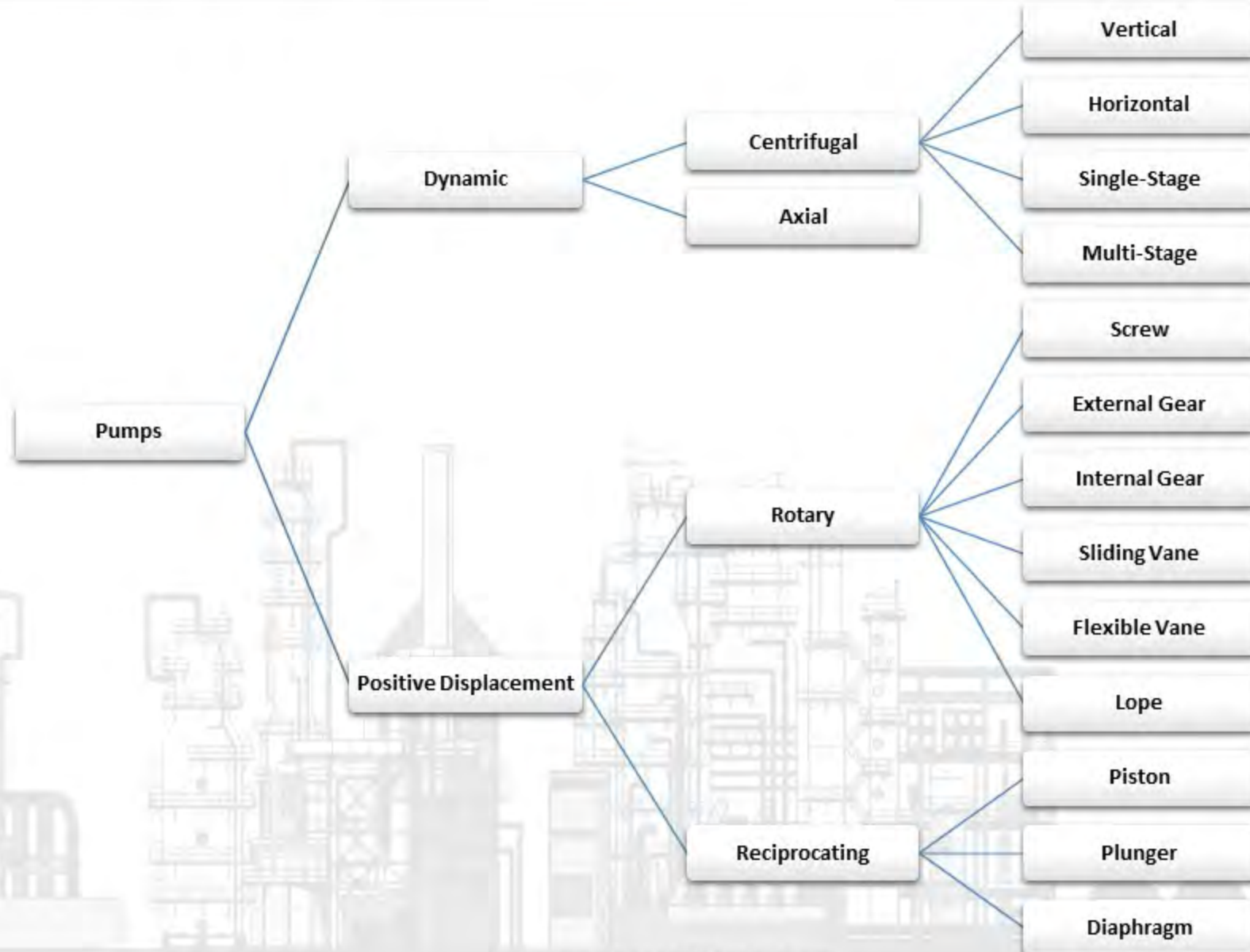
Refrigeration

Automobiles

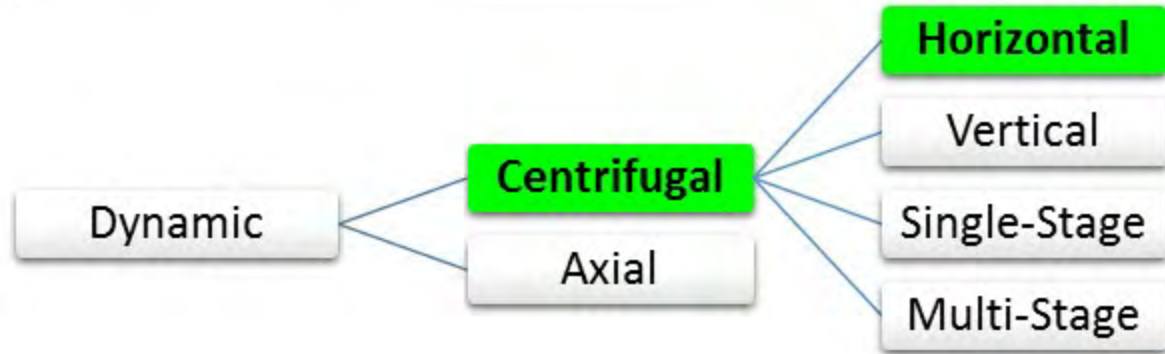
Home Heating Systems

Water Wells.

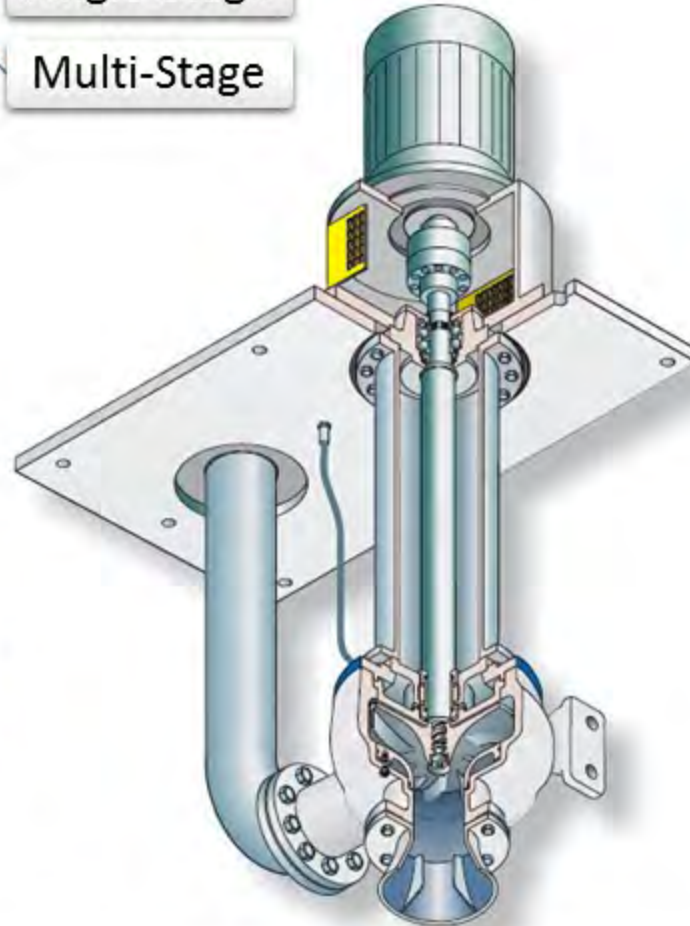
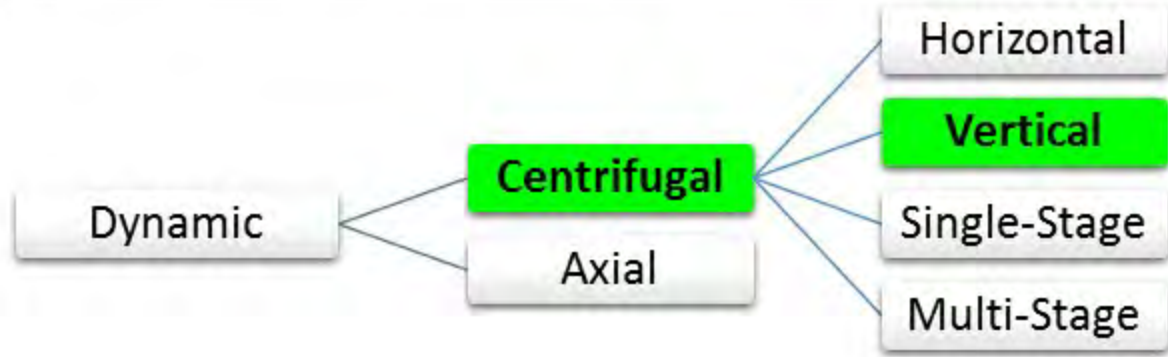
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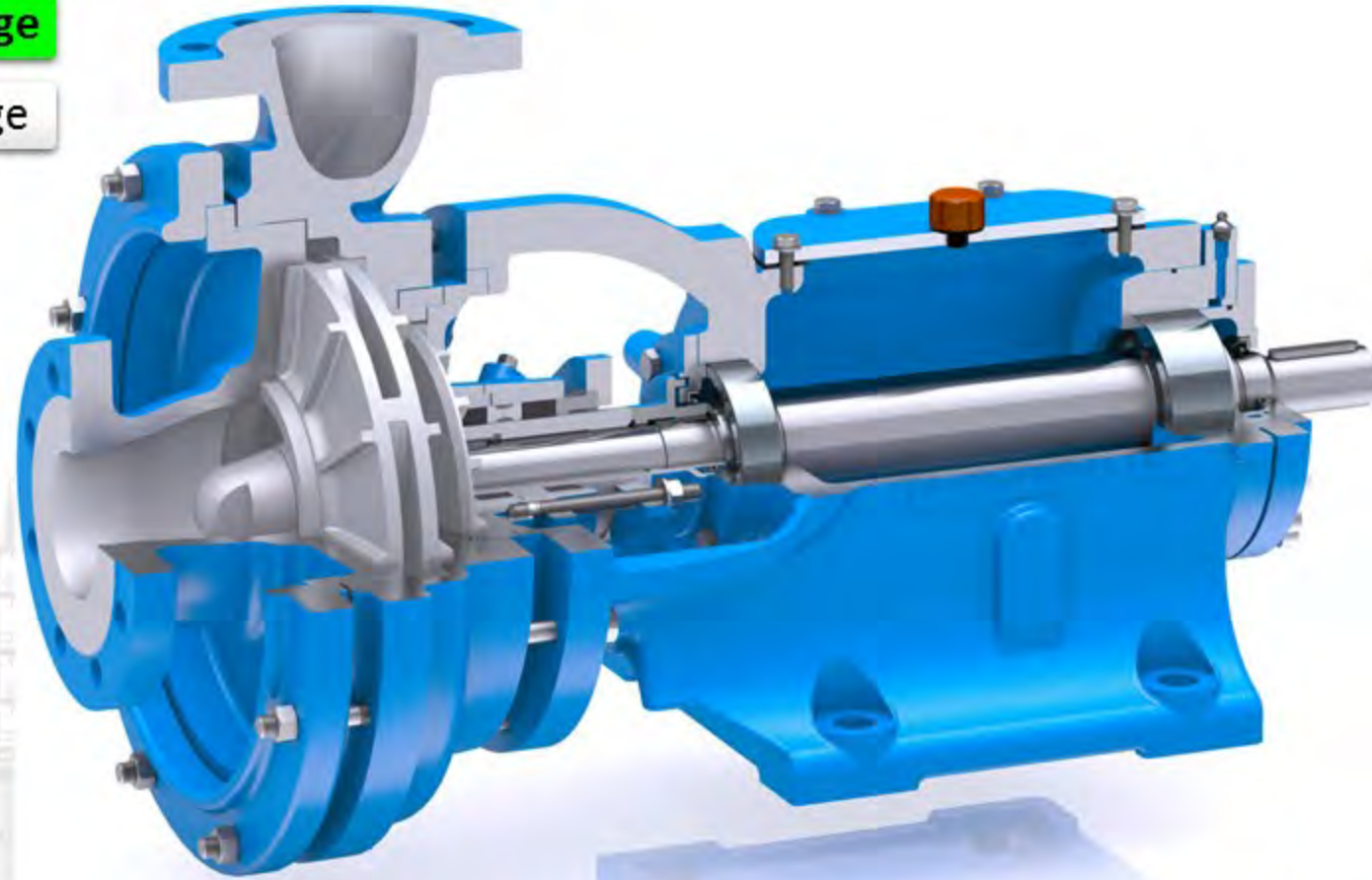
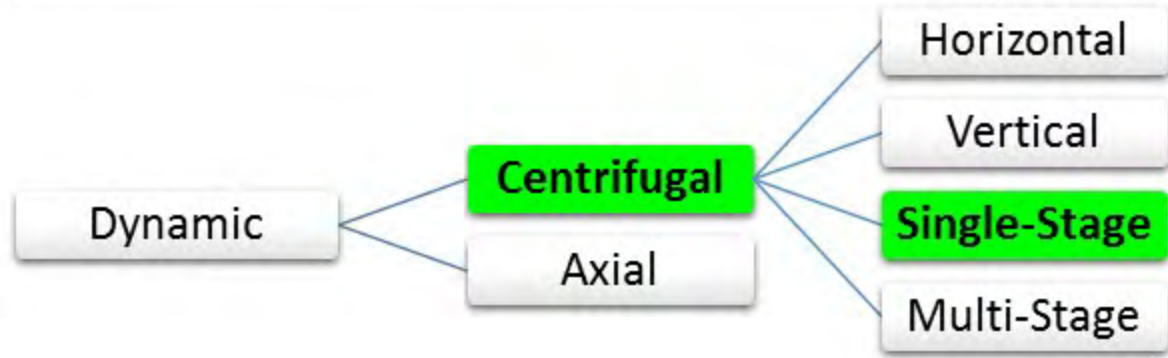
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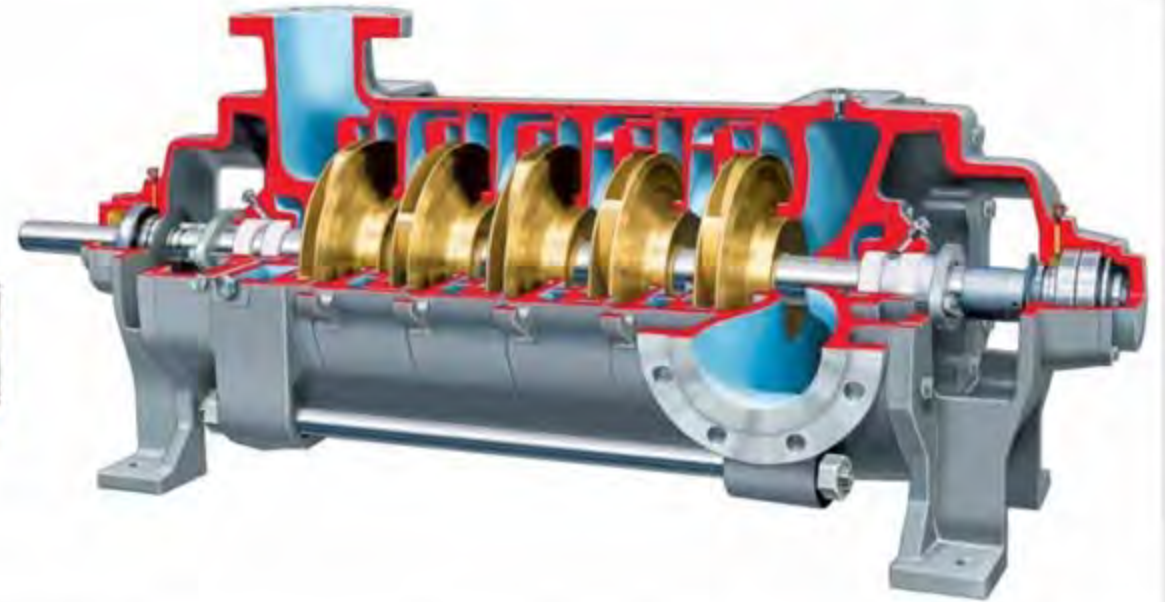
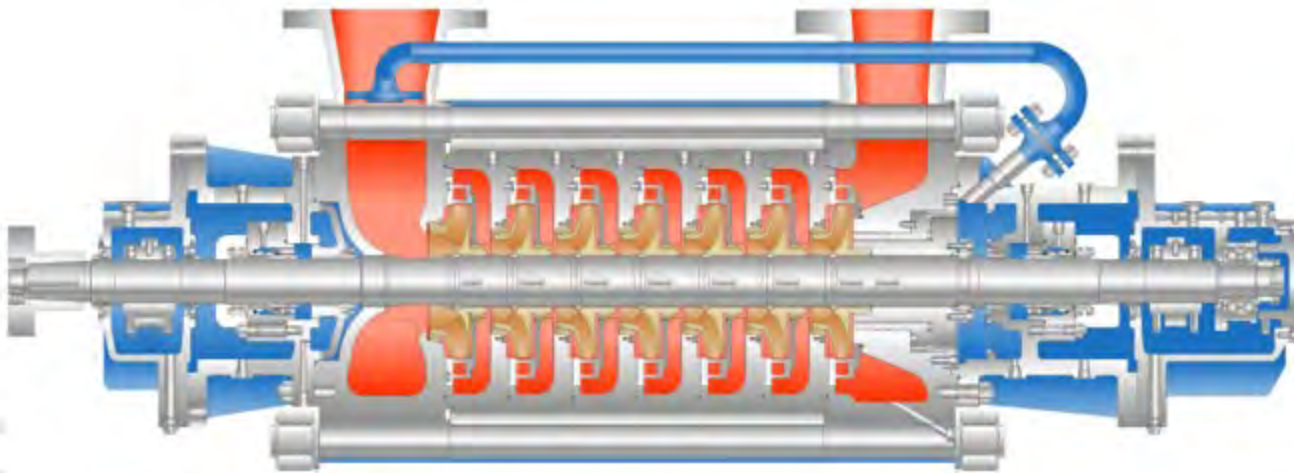
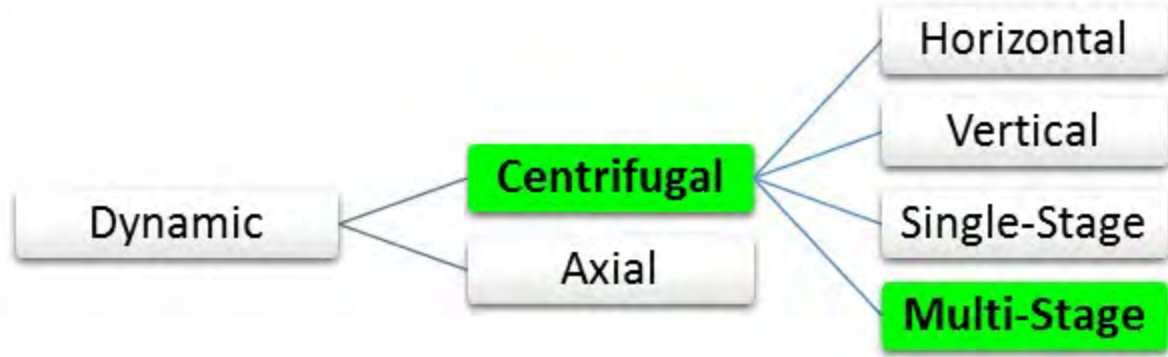
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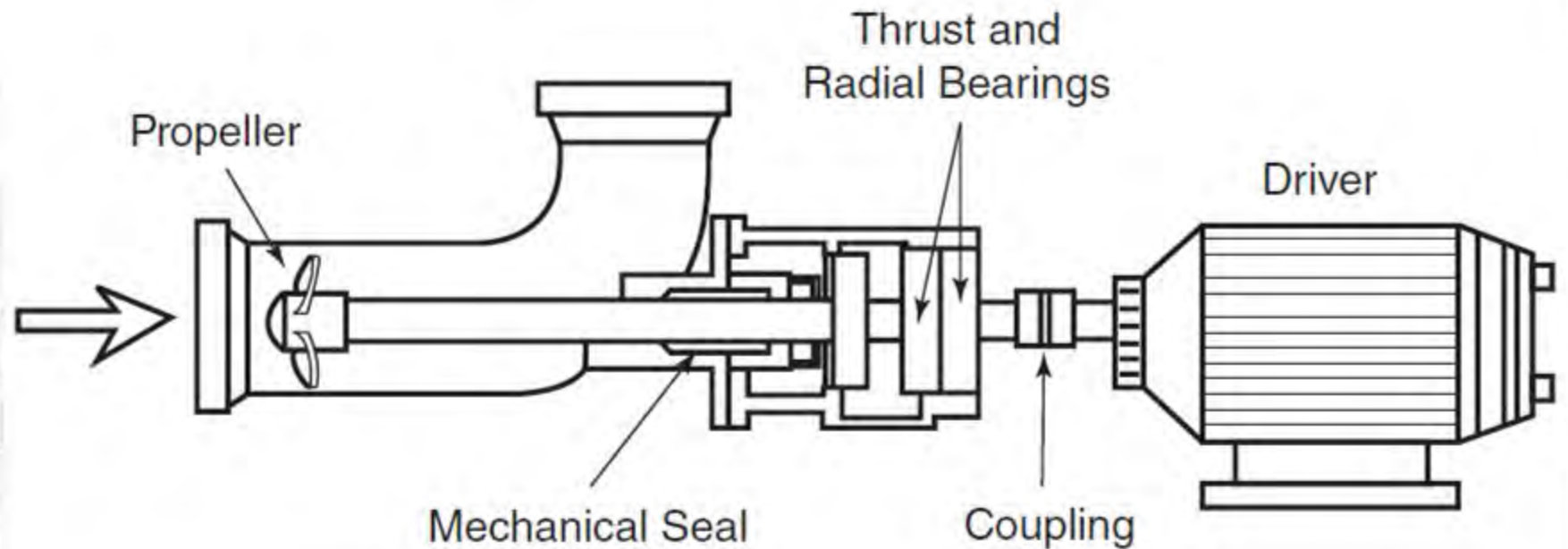
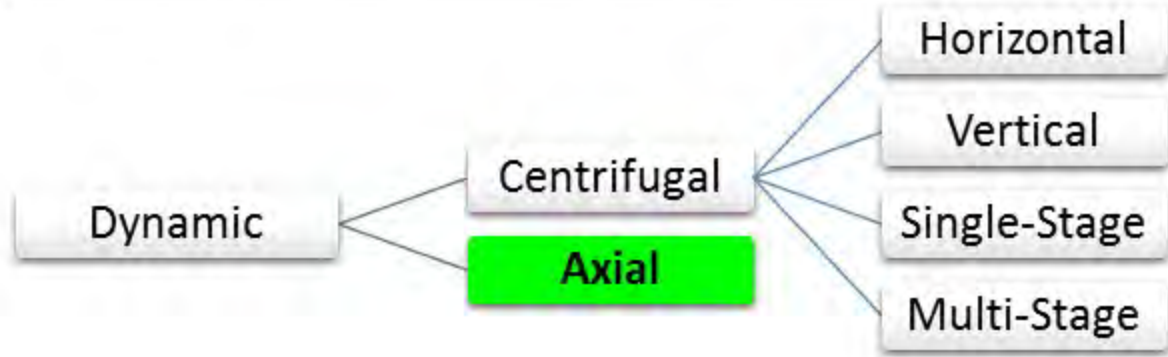
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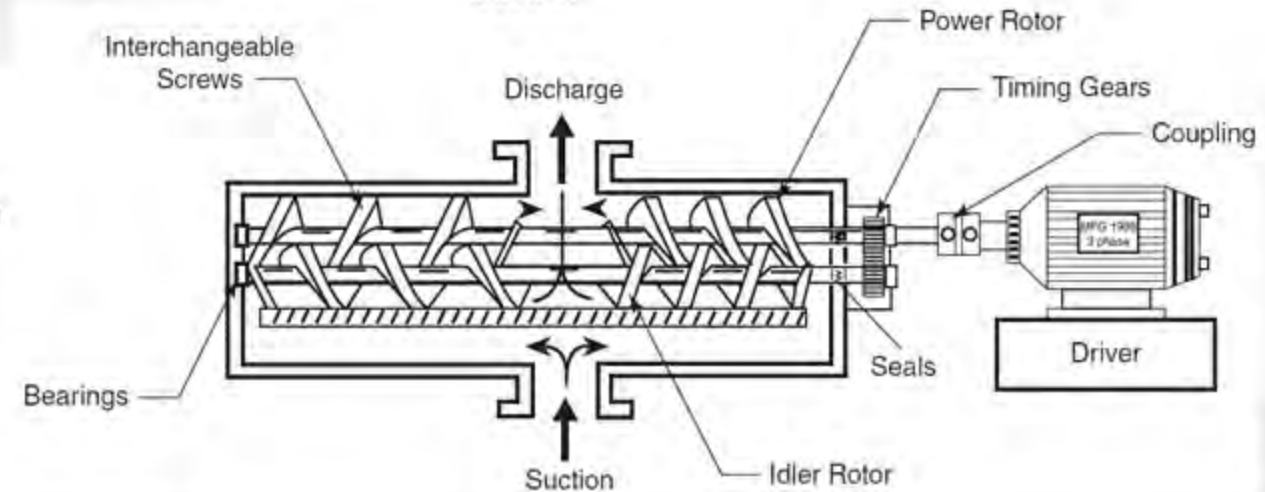
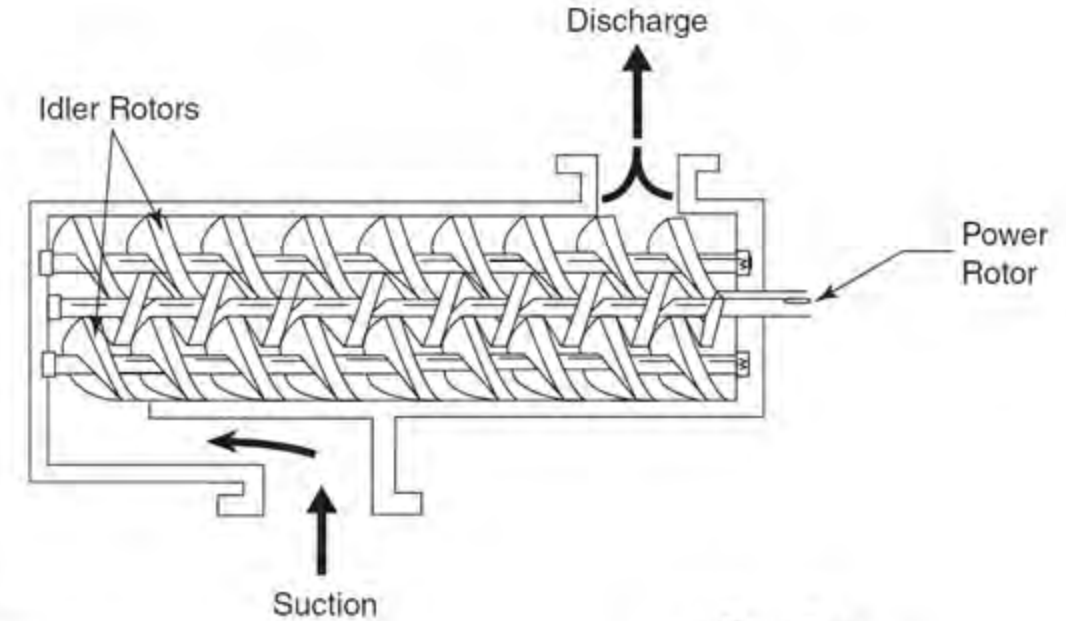
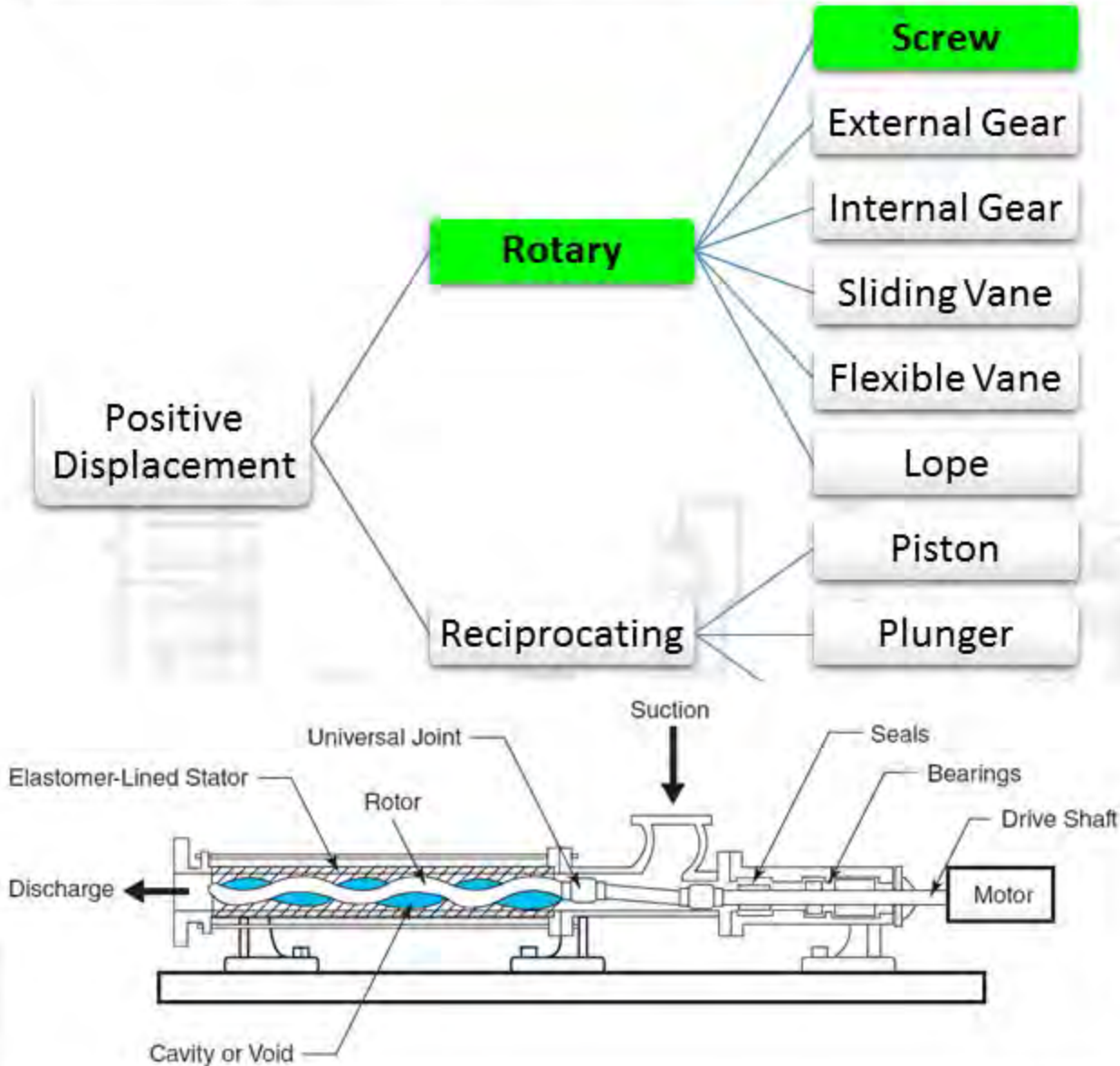
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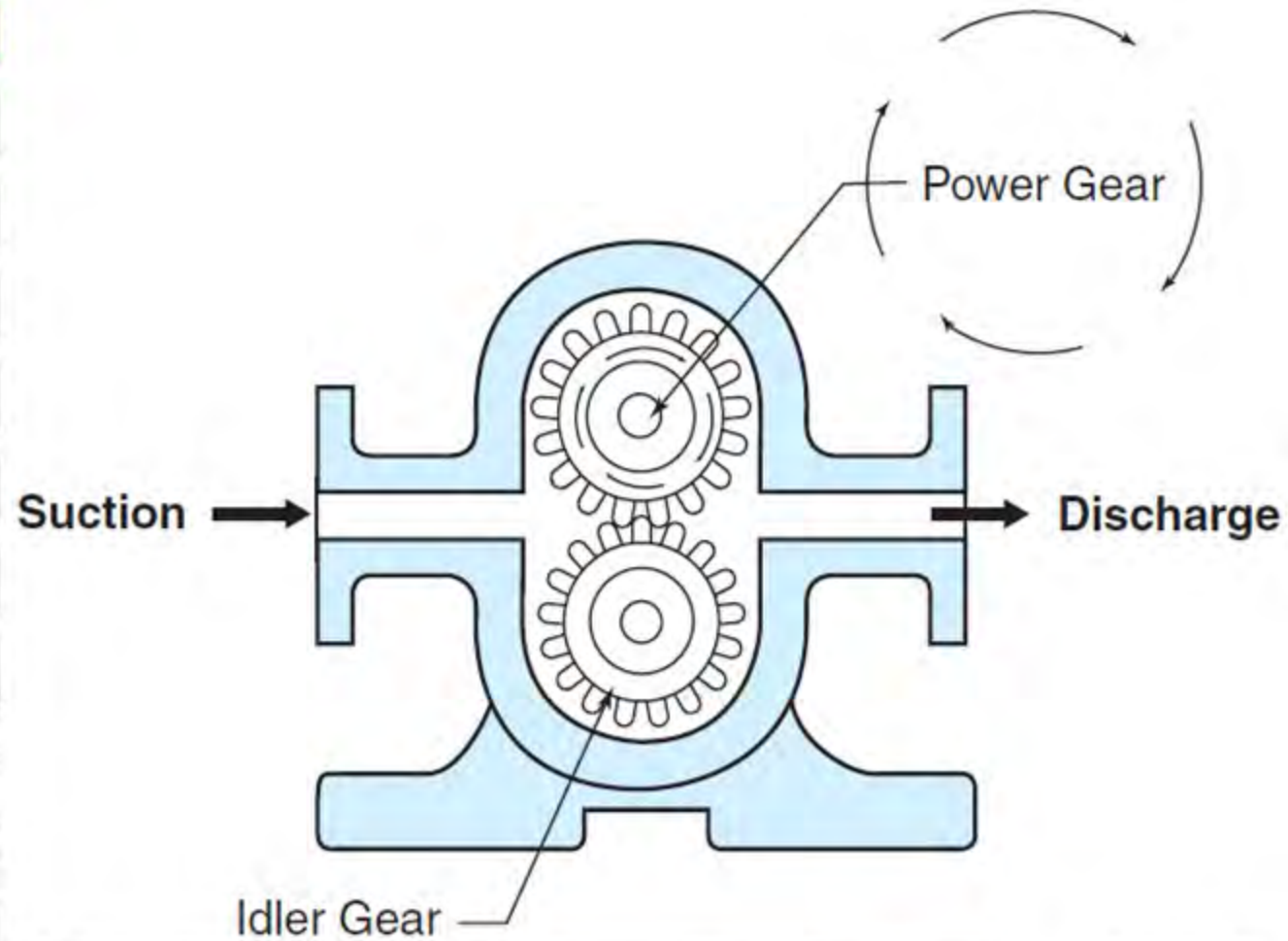
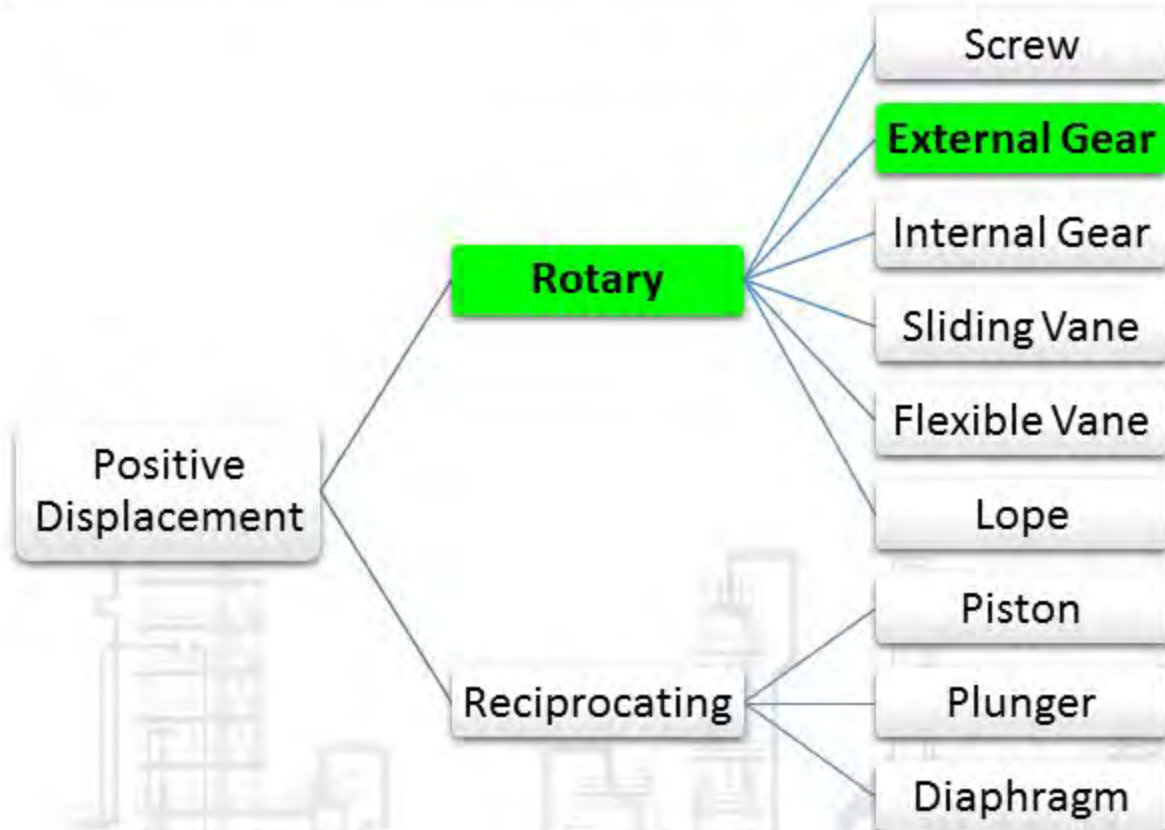
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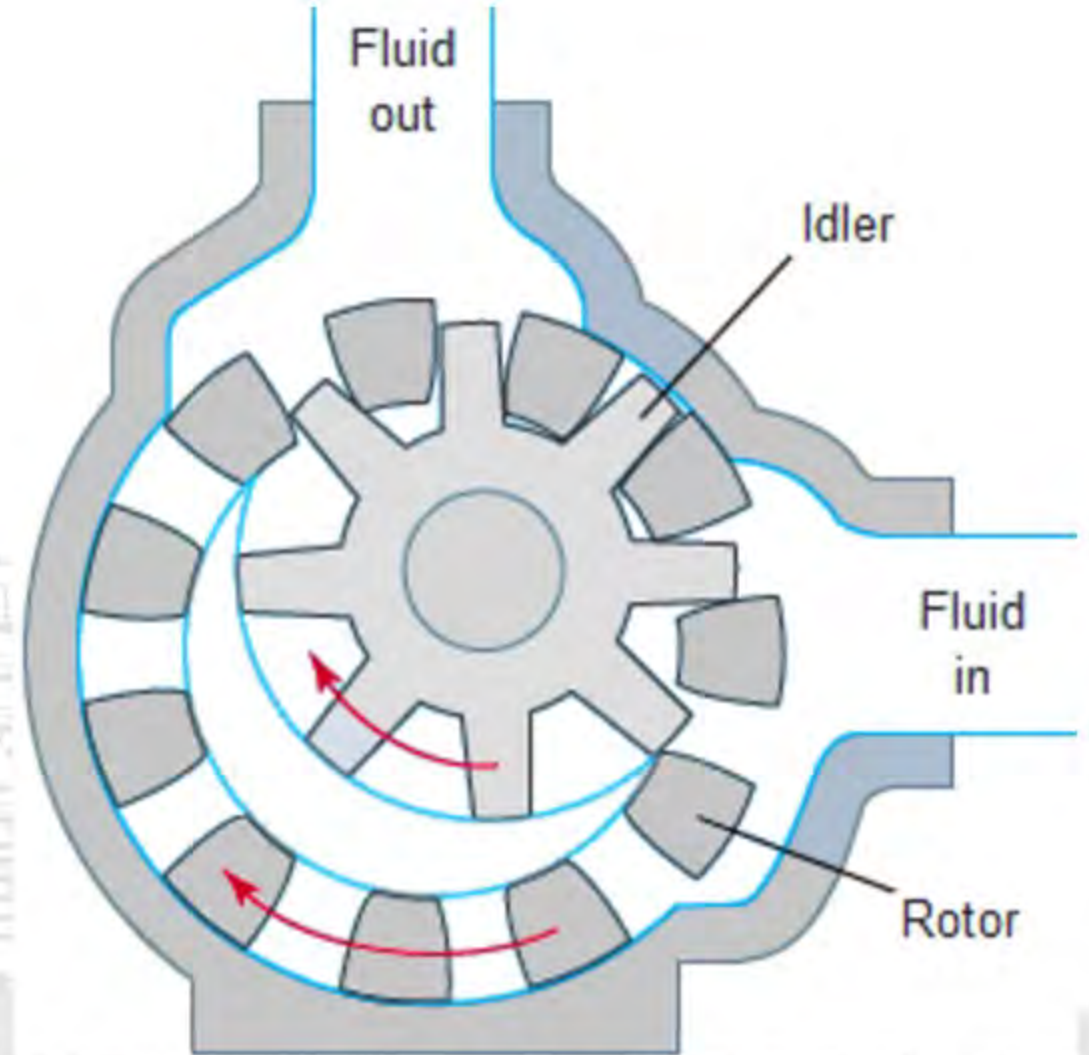
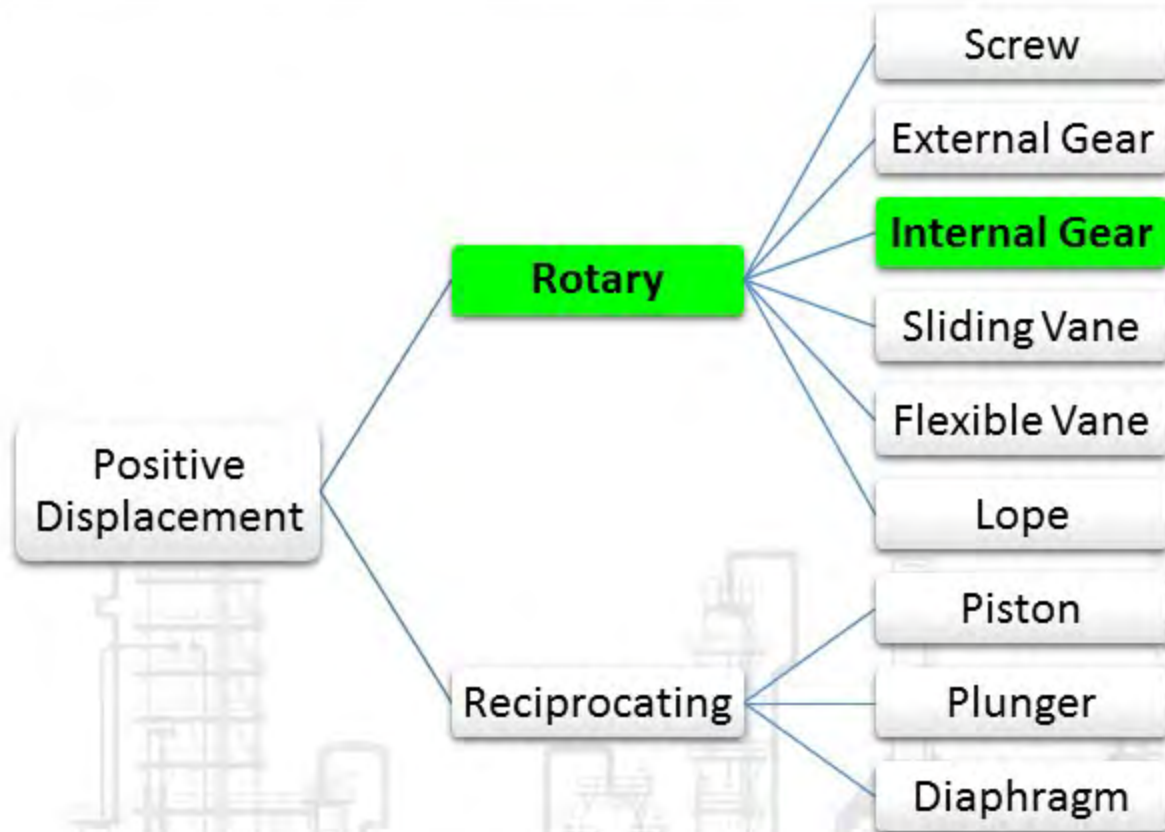
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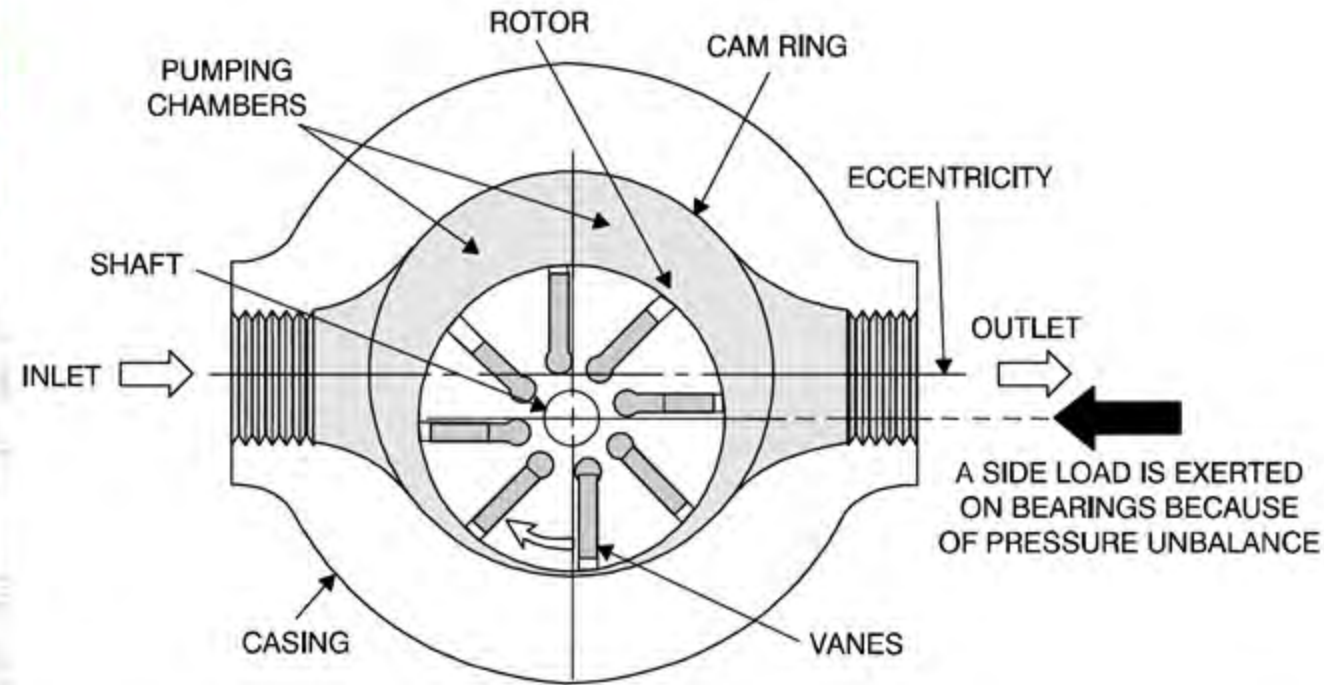
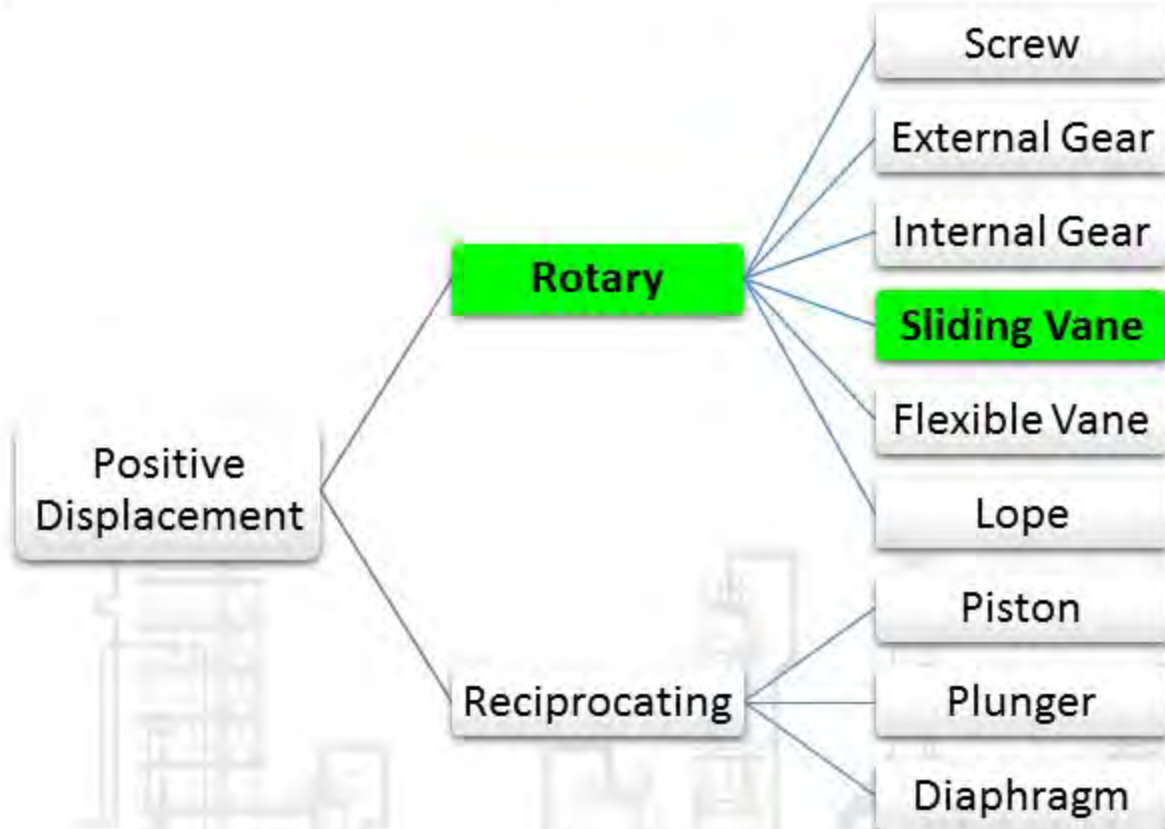
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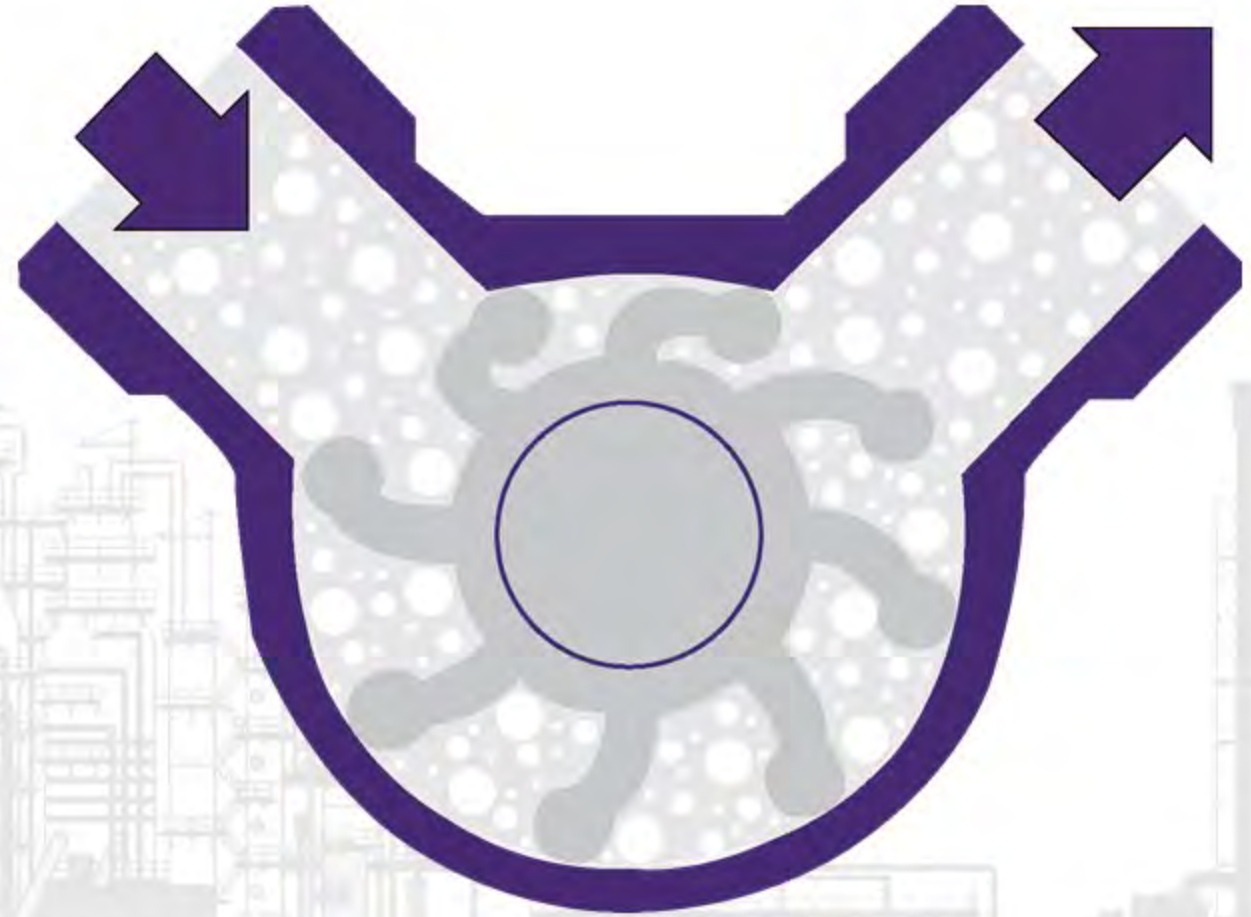
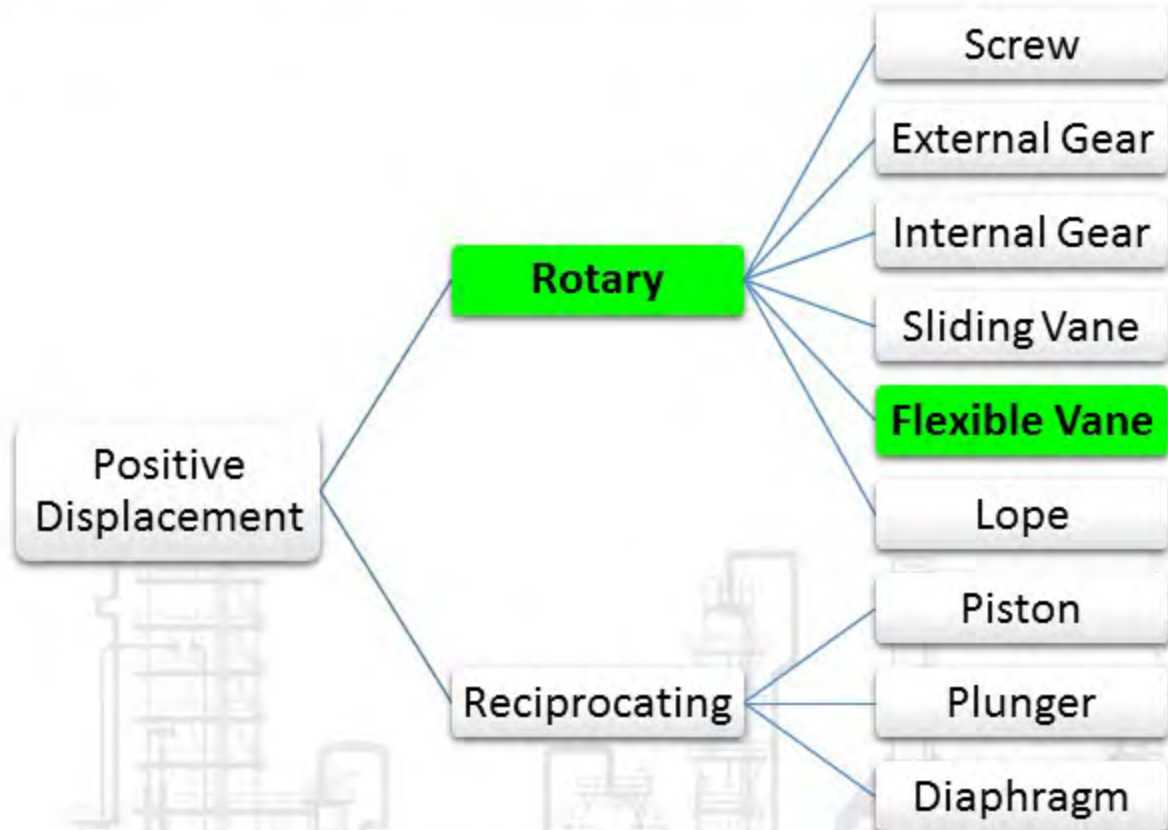
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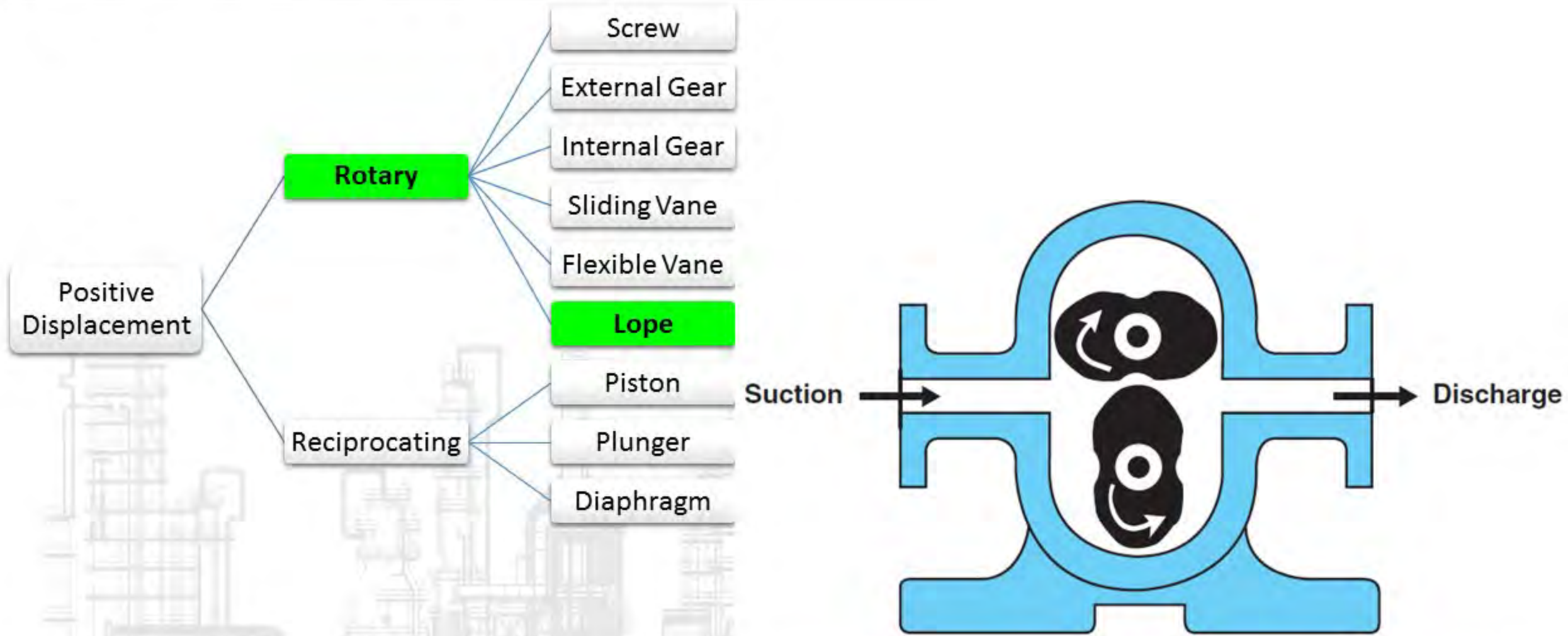
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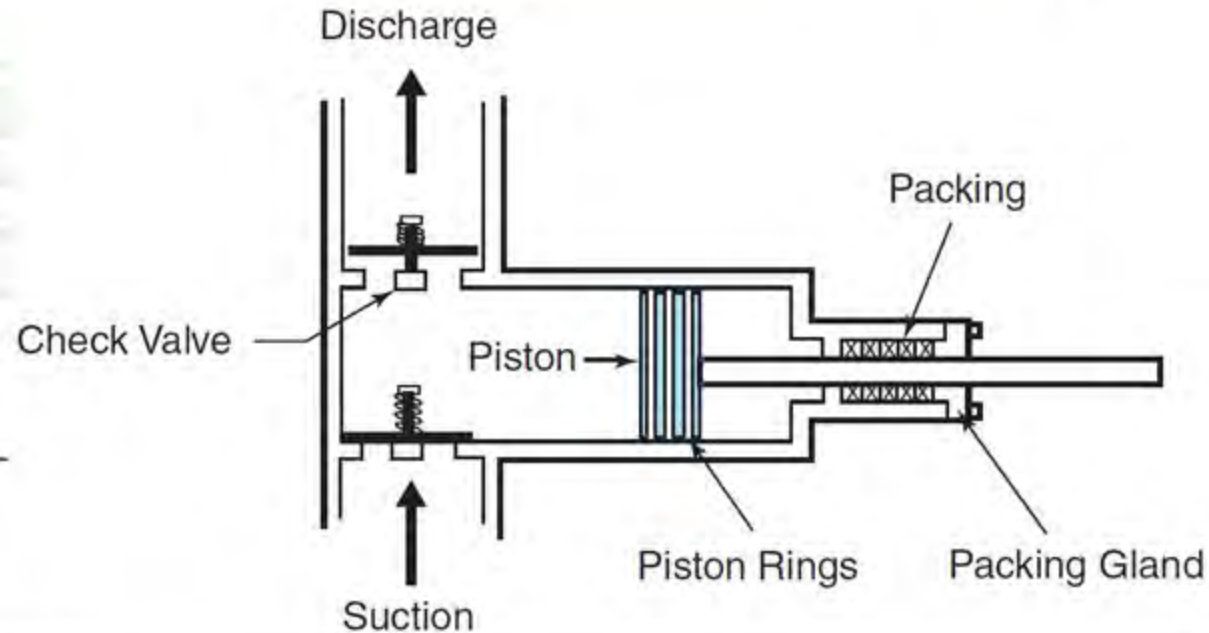
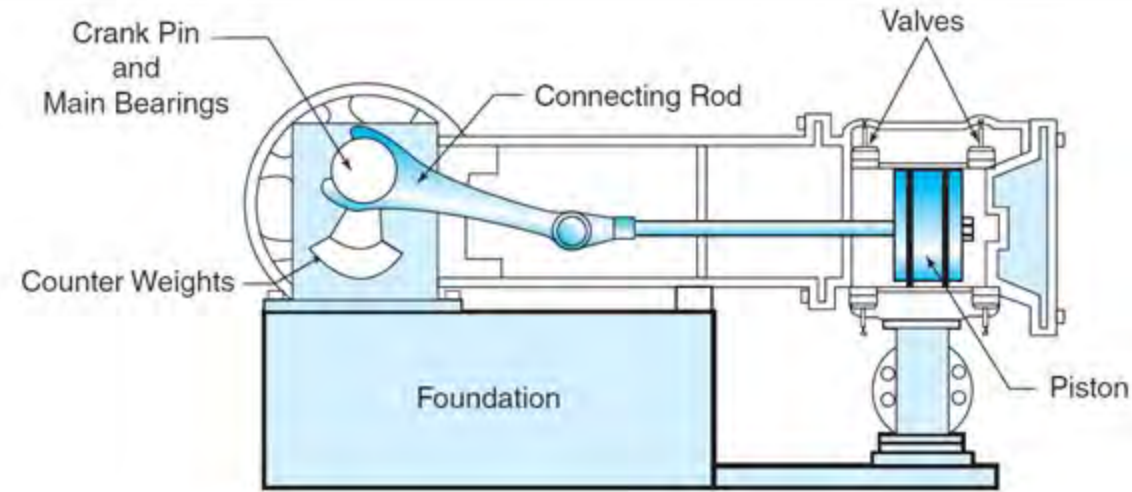
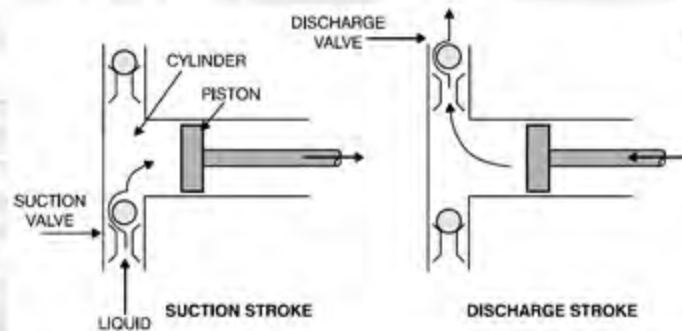
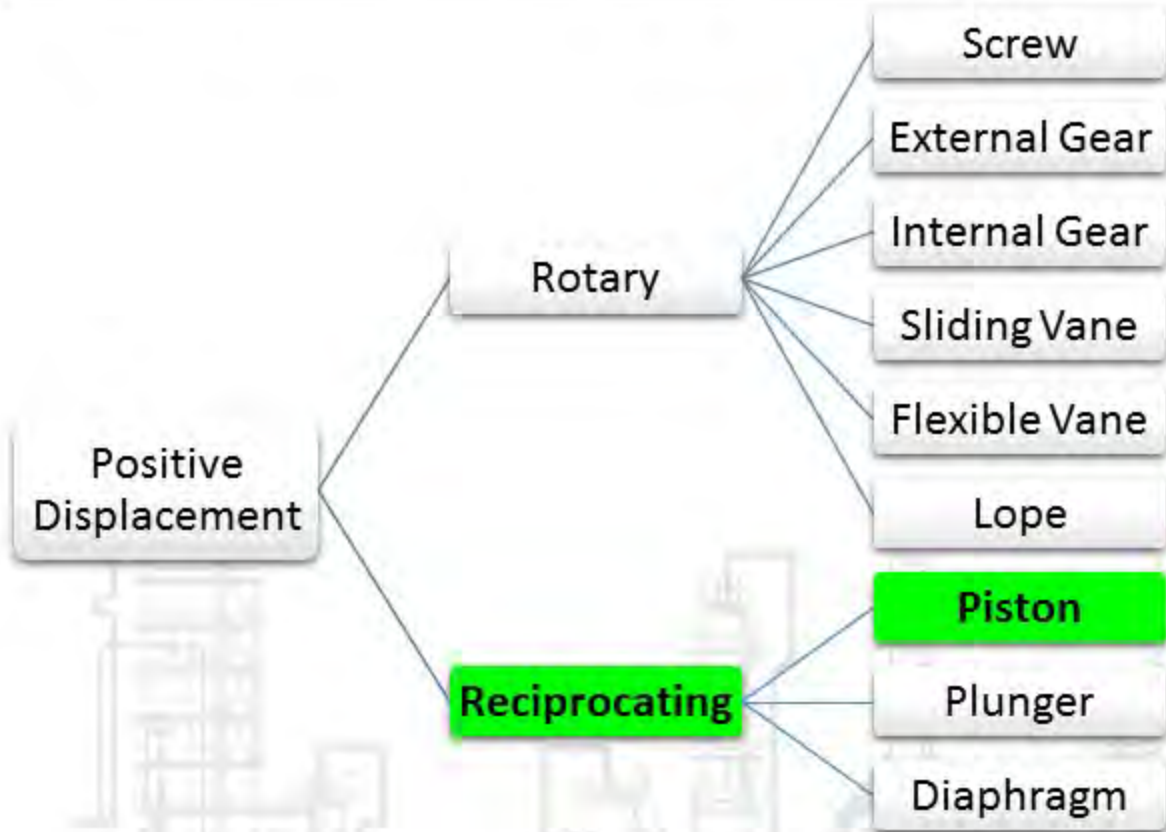
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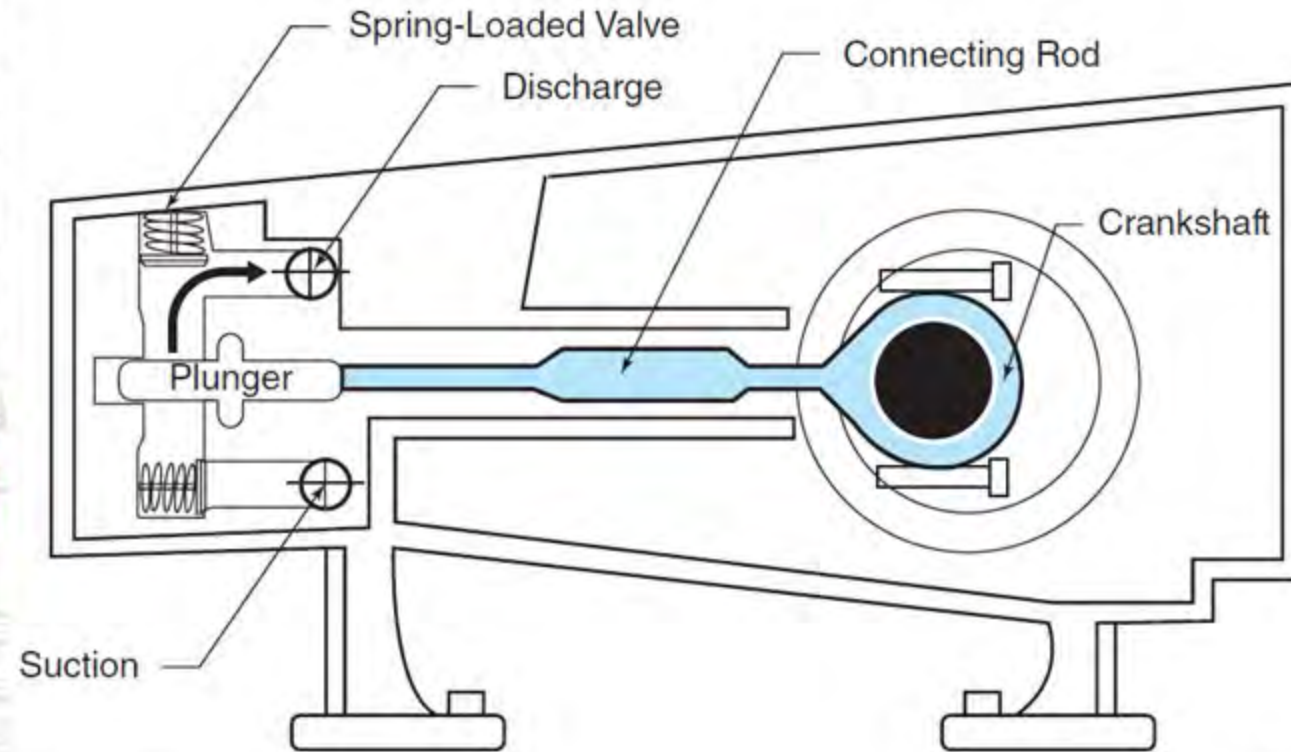
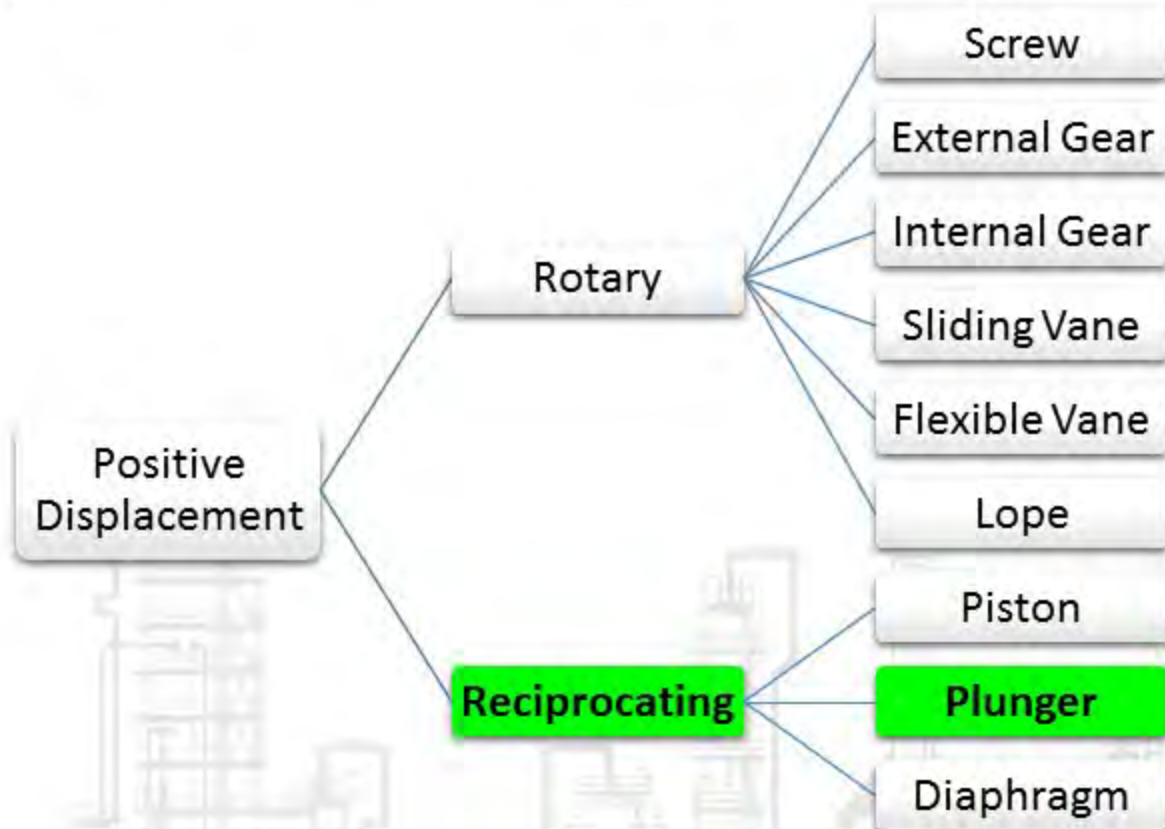
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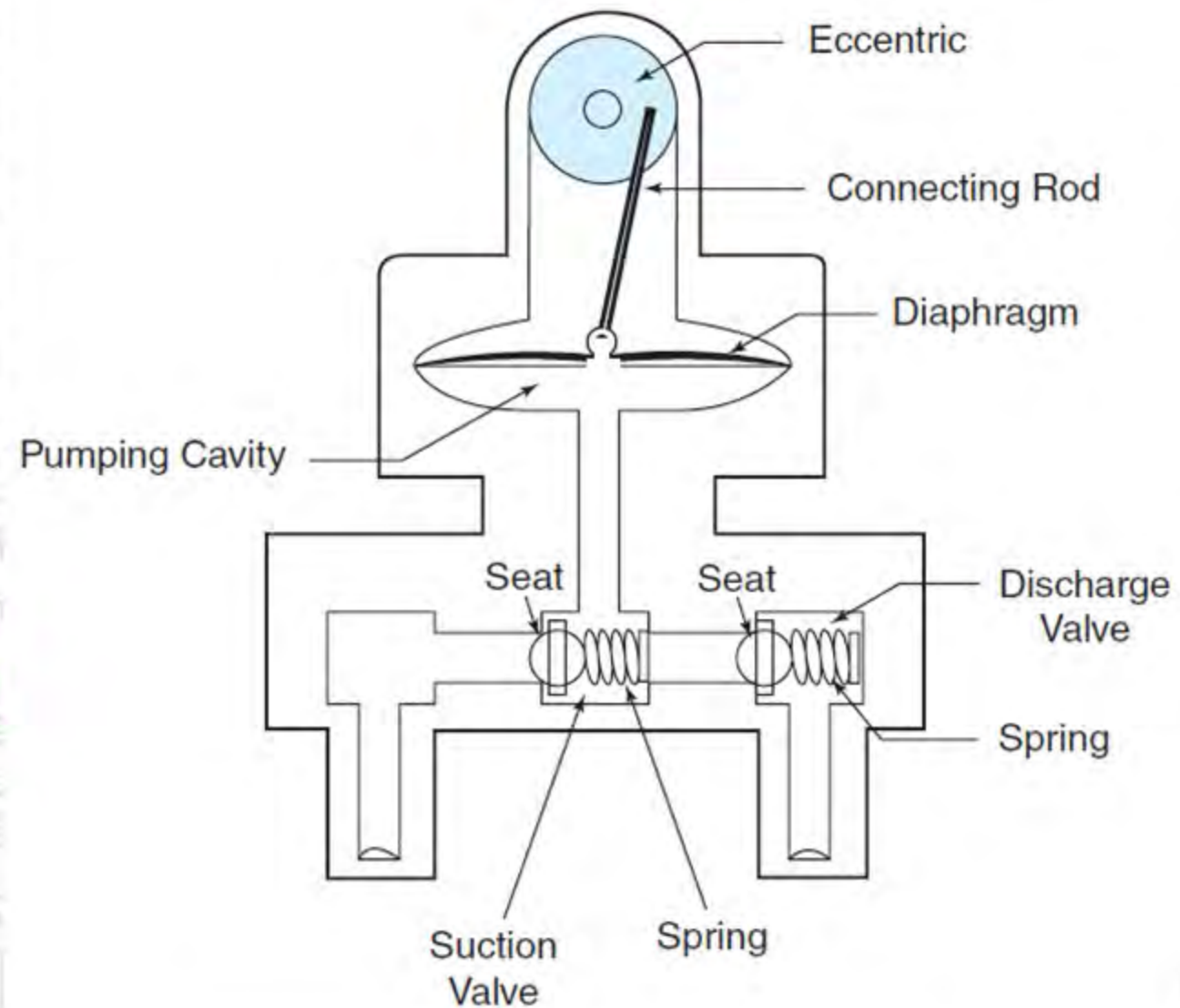
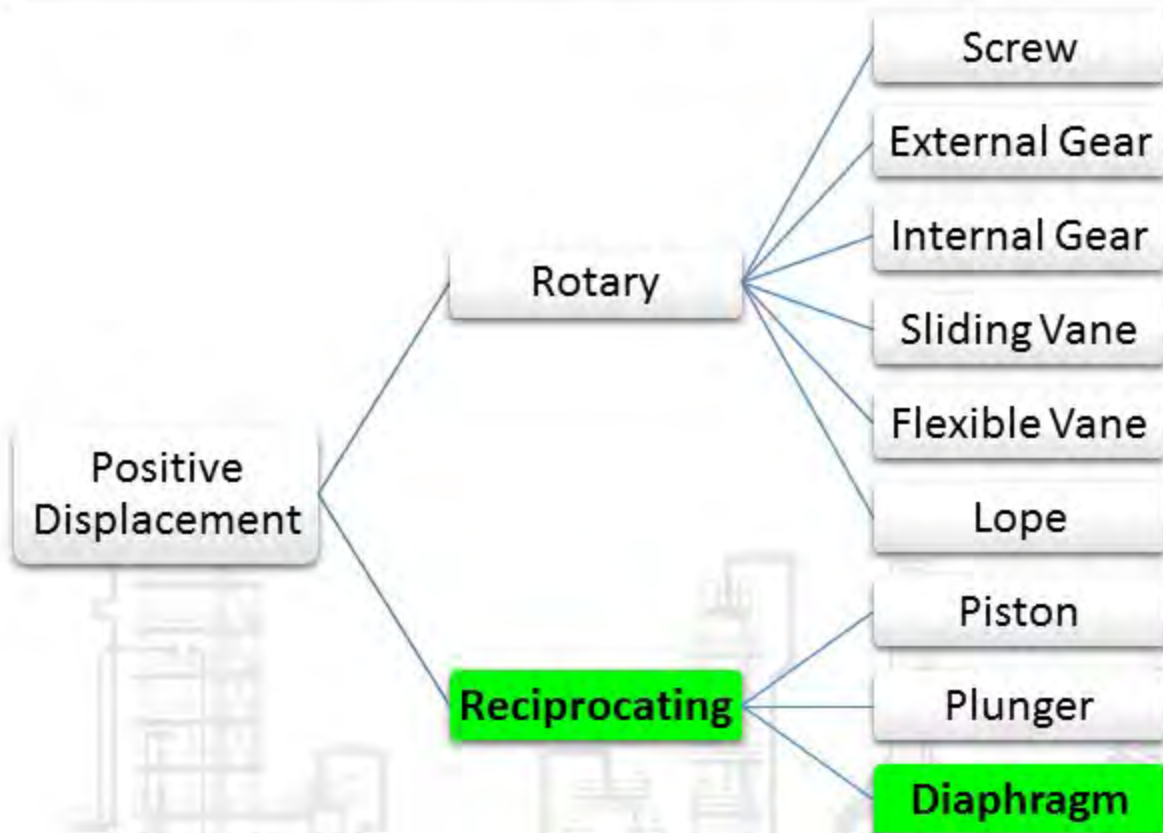
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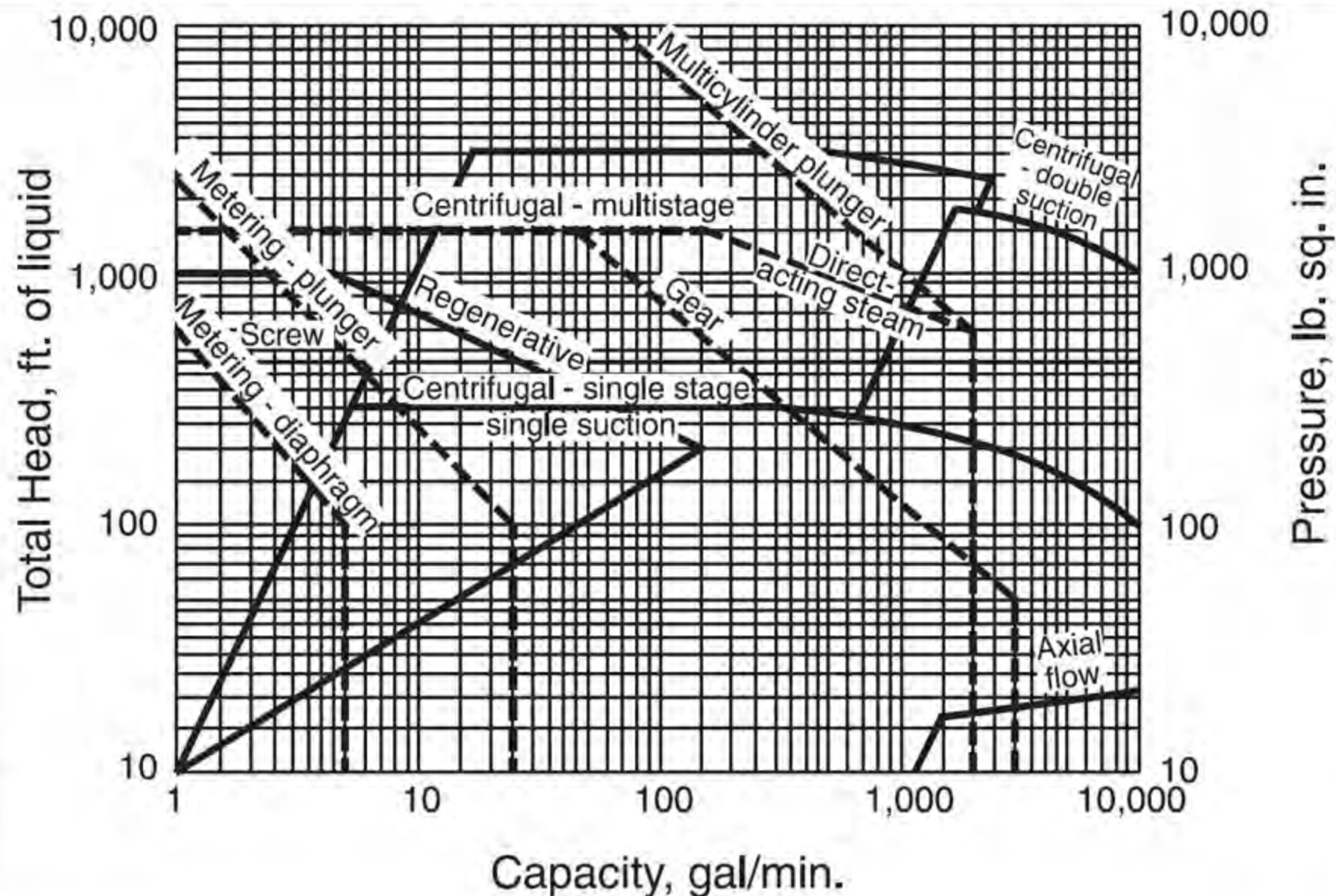
3. Classification



3. Classification



3. Classification



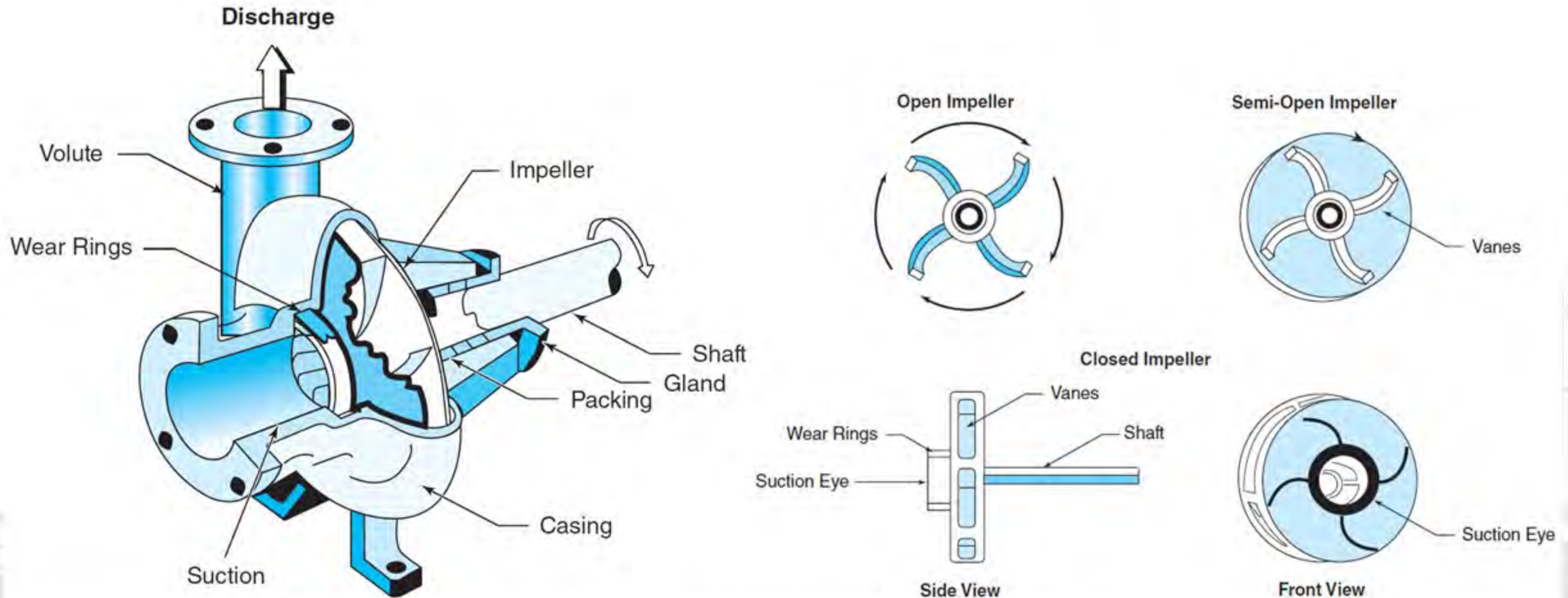
Get Ready !

Part 2

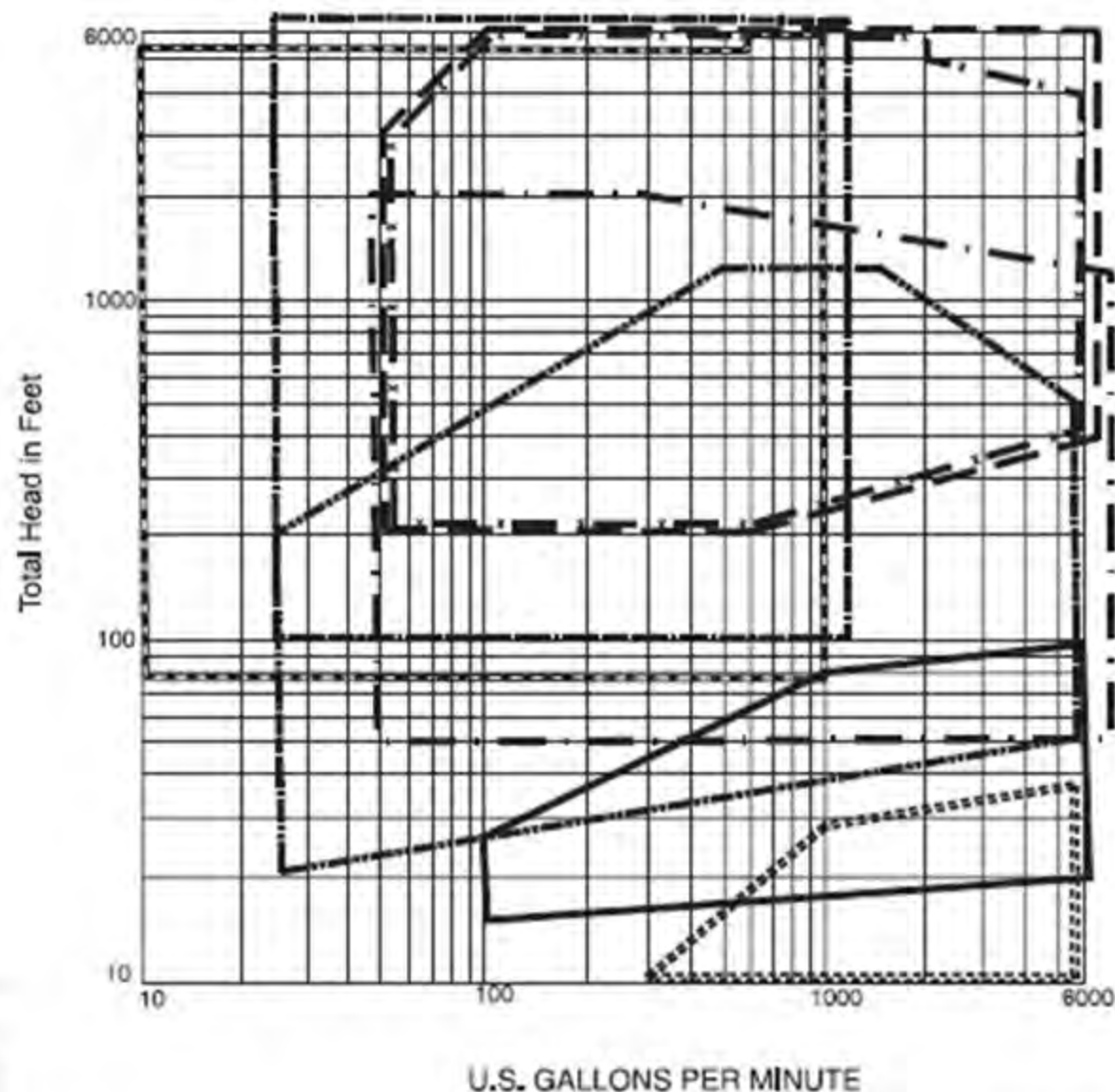


4. Basic Principles

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 — Wilamette Ltd.

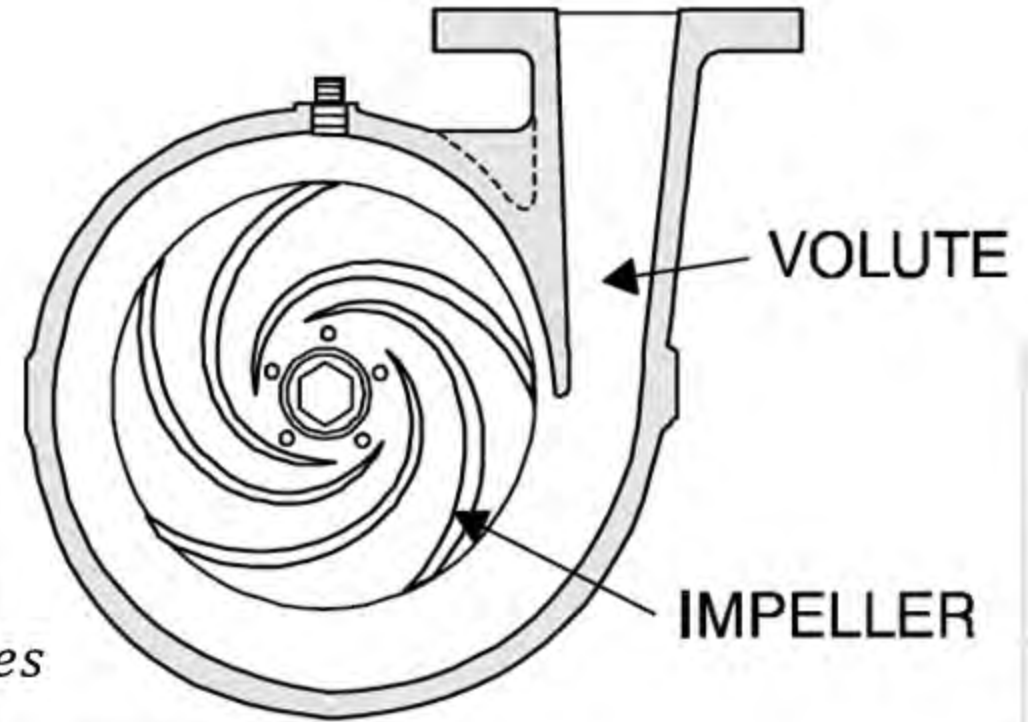
4. Basic Principles

- **Continuity Equation**

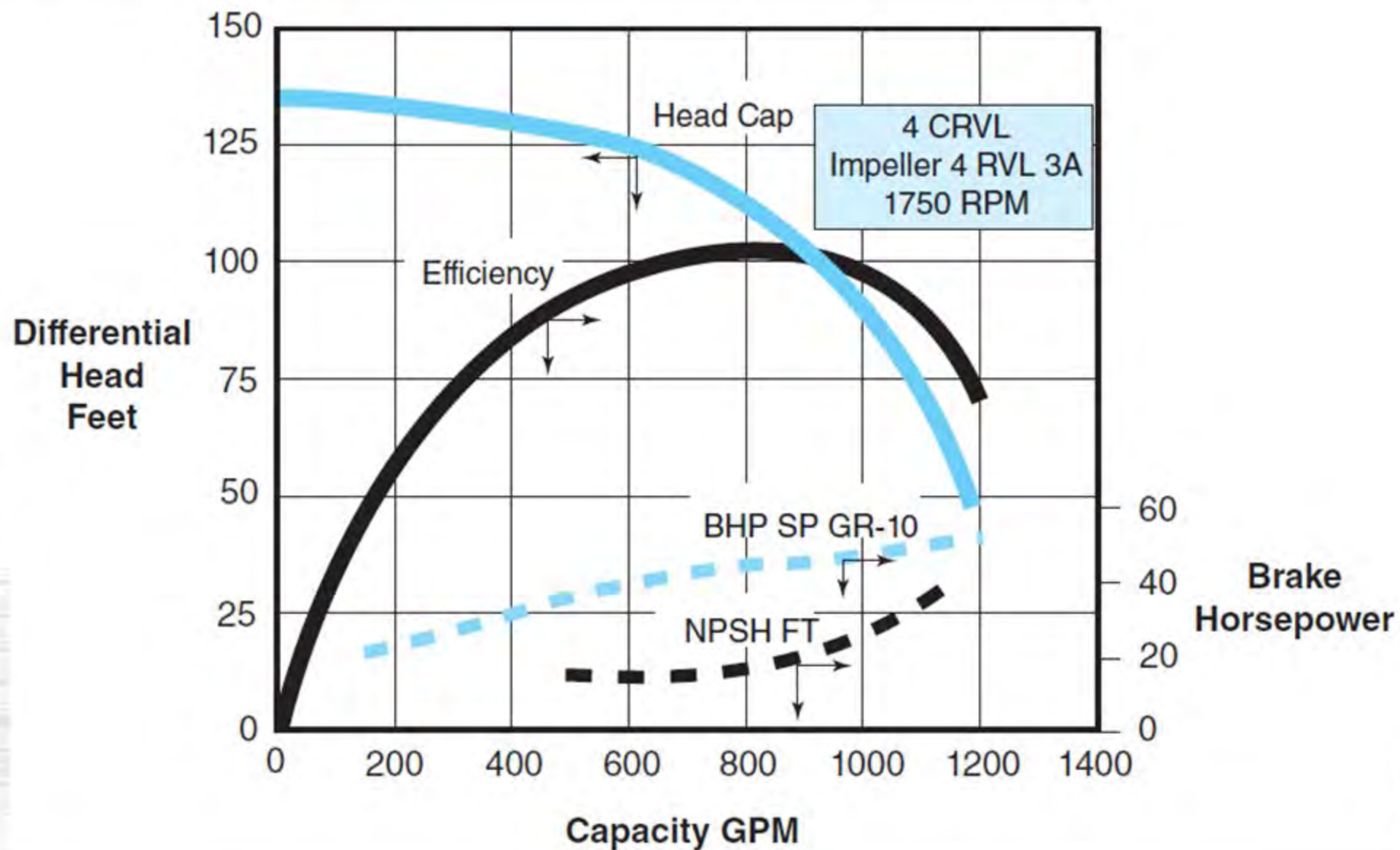
$$A_1V_1 = A_2V_2 = \text{Constant}$$

- **Bernoulli Equation**

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



4. Basic Principles



4. Basic Principles

• Affinity Laws

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

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

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

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

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

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

Where:

Q : Flow

D : Impeller Diameter

N : Speed

H : Head (TDH)

BHP : Brake Horsepower

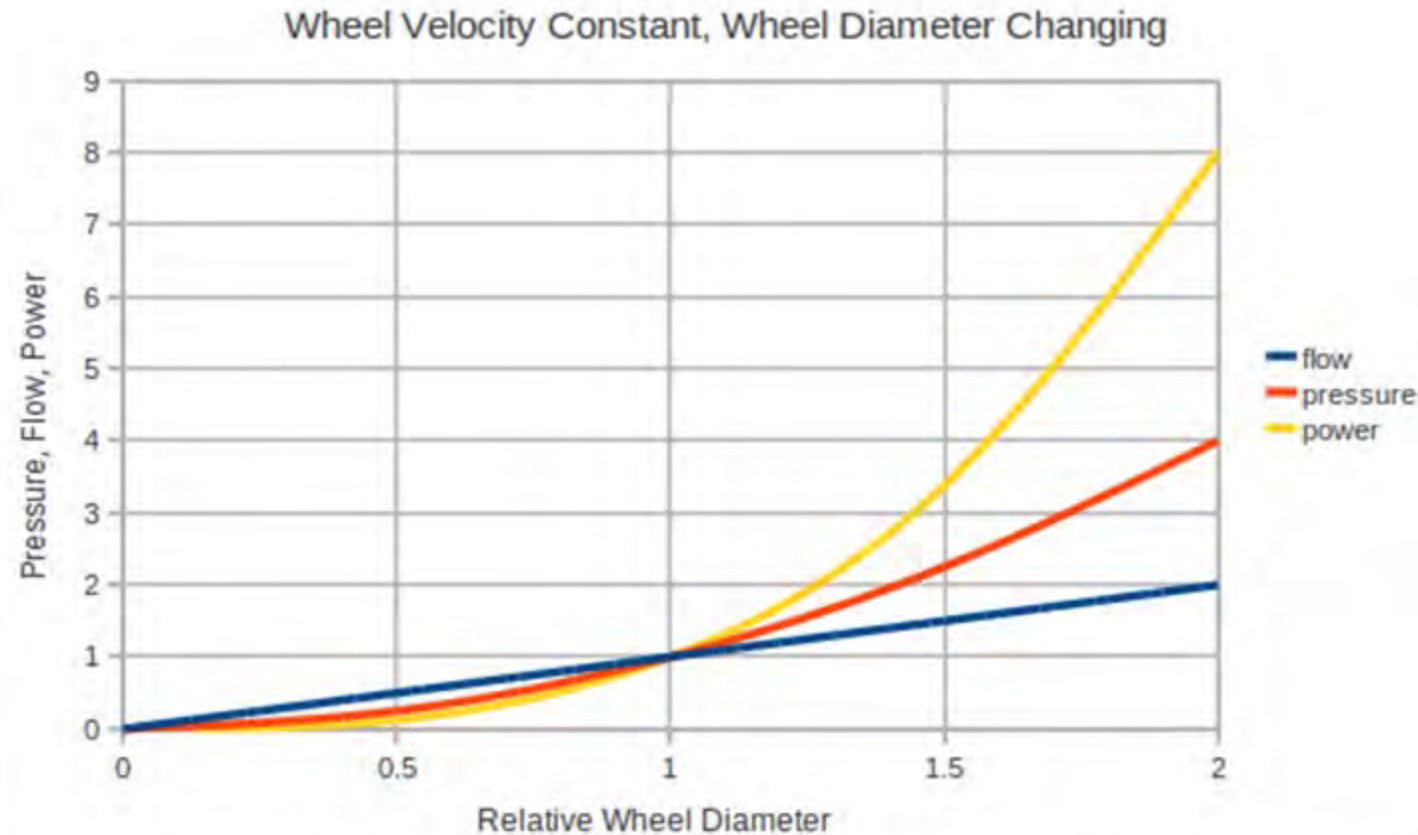
4. Basic Principles

- Affinity Laws

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

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

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



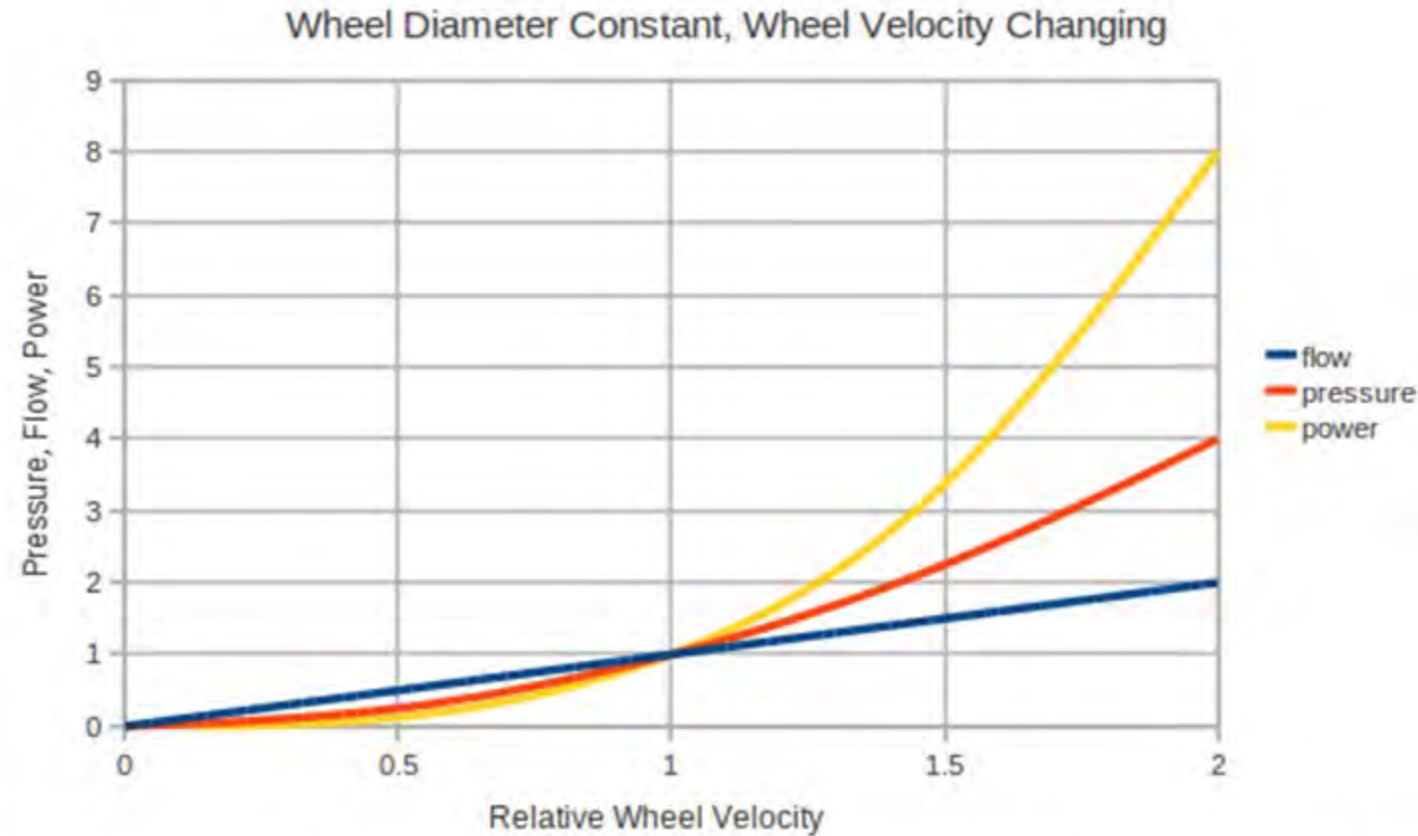
4. Basic Principles

- Affinity Laws

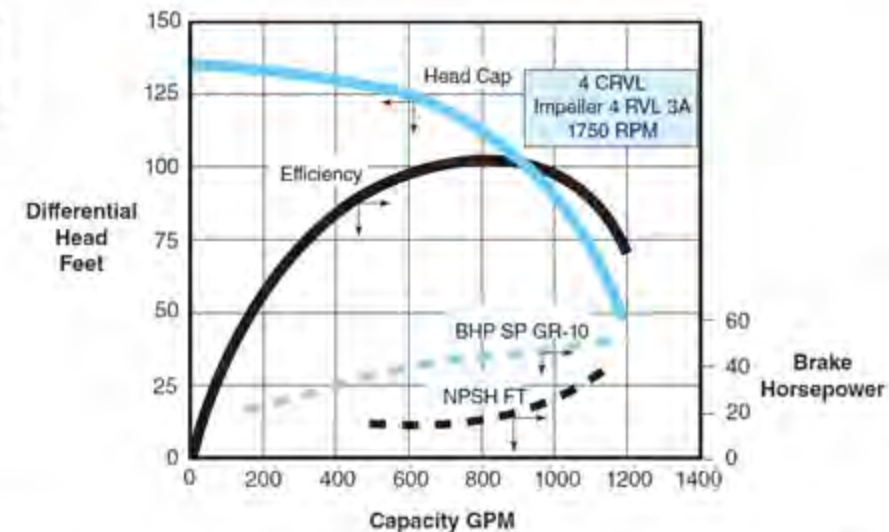
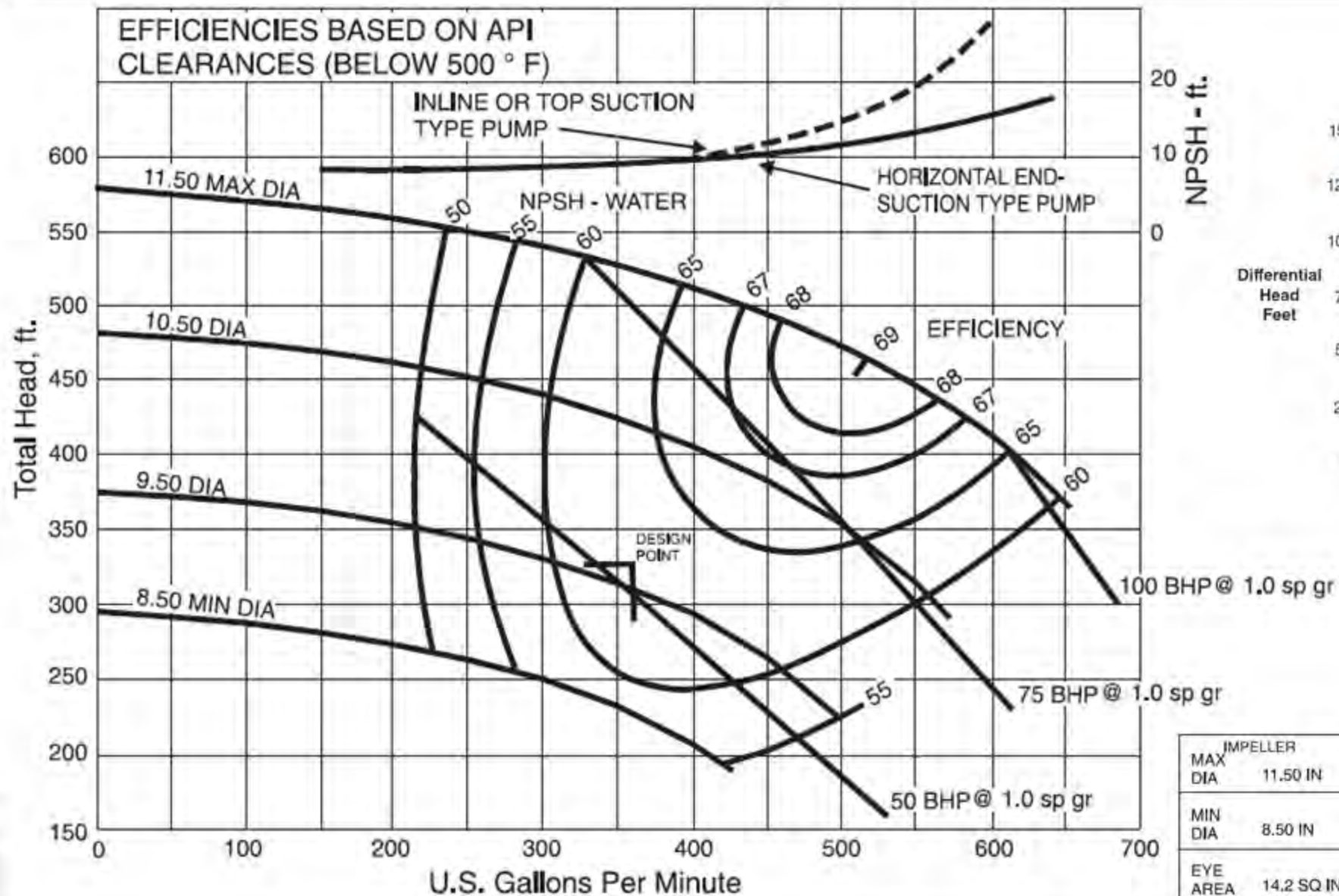
$$Q_2 = \left(\frac{N_2}{N_1} \right)^1 Q_1$$

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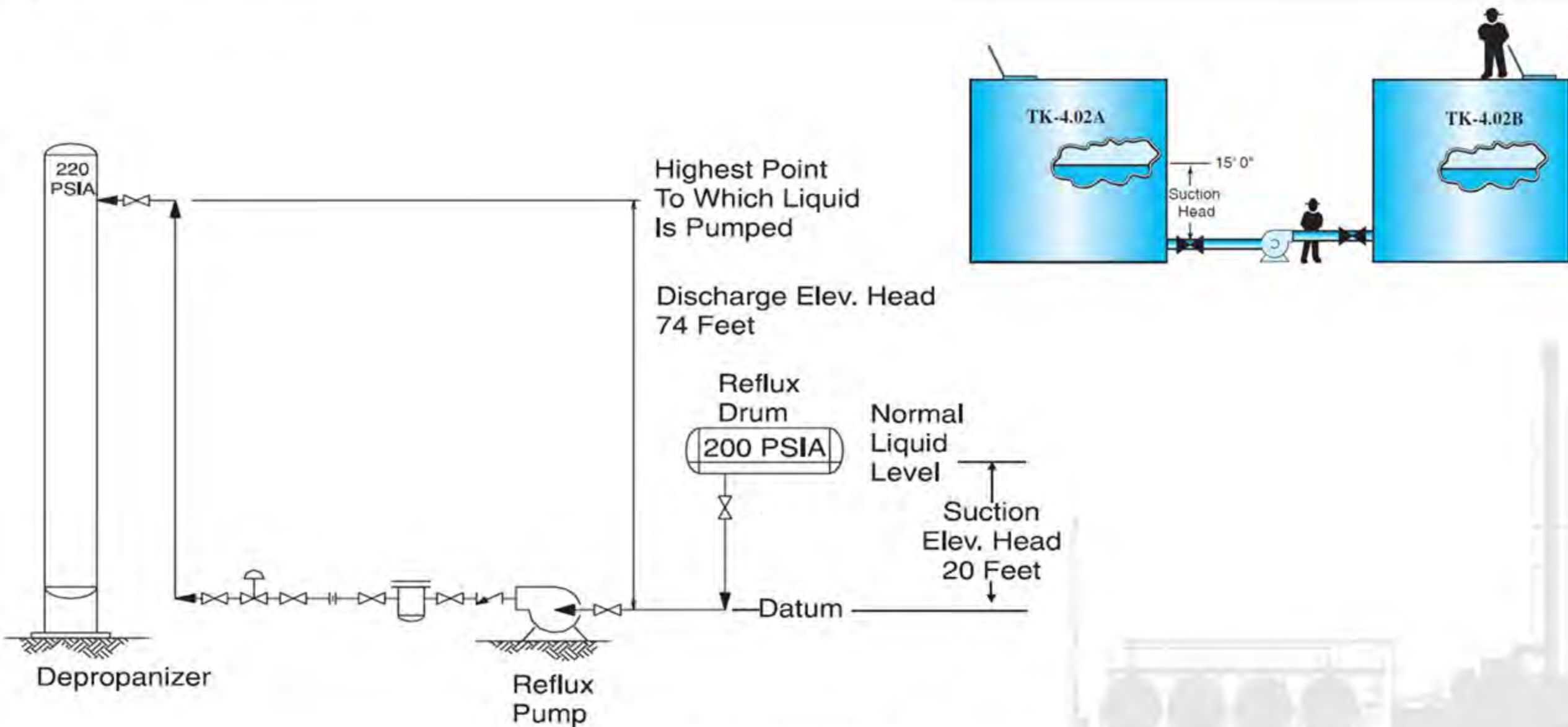


4. Basic Principles

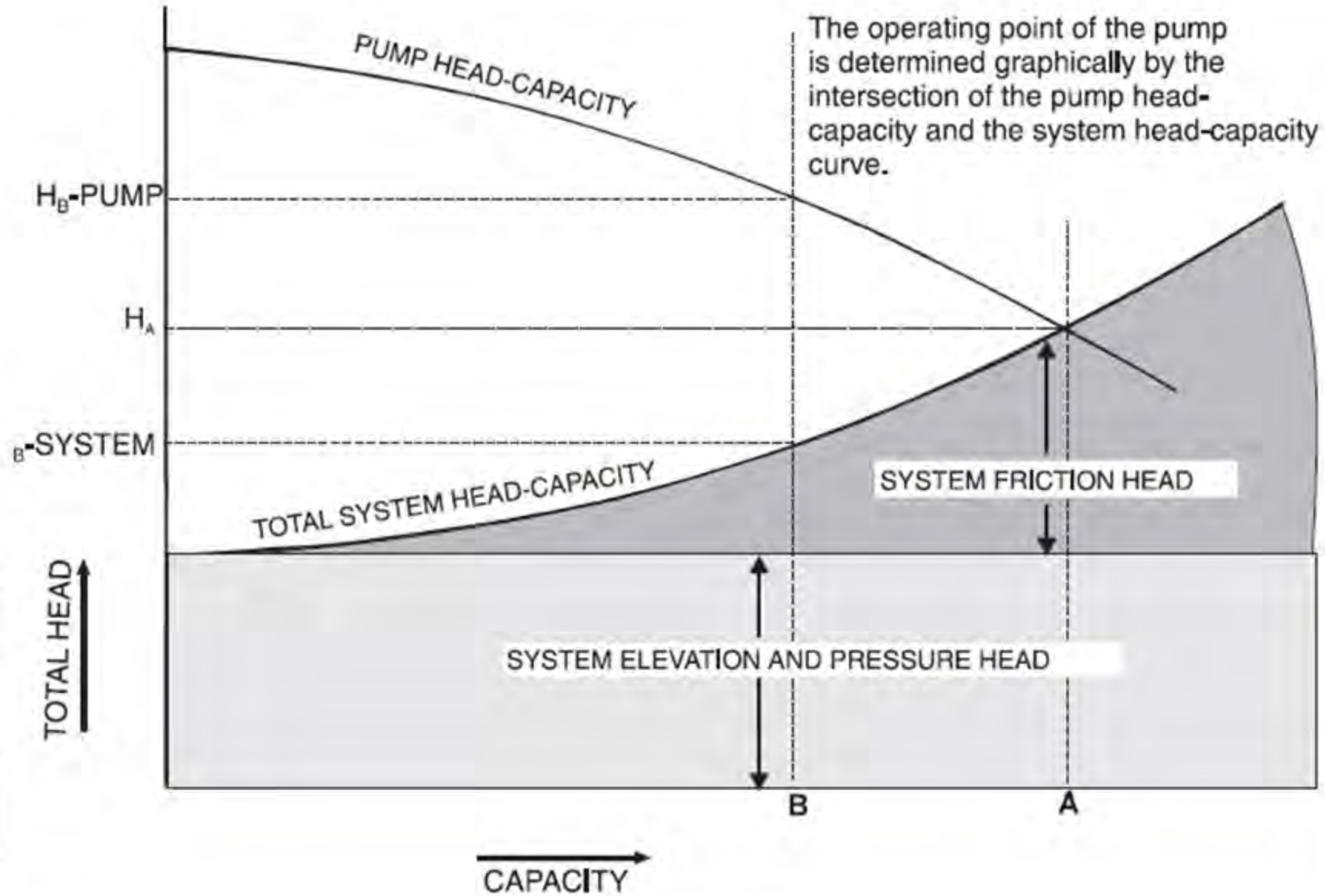


IMPELLER		3 X 4 X 11.5 SINGLE STAGE PUMP		
MAX DIA	11.50 IN	DIA IMPELLER	IMPELLER PATT	3,560 RPM
MIN DIA	8.50 IN	9.75 IN		
EYE AREA	14.2 SQ IN	NPSH REQUIRED	REFERENCE	CURVE NO. CA-307-3
		9 FT		

5. System

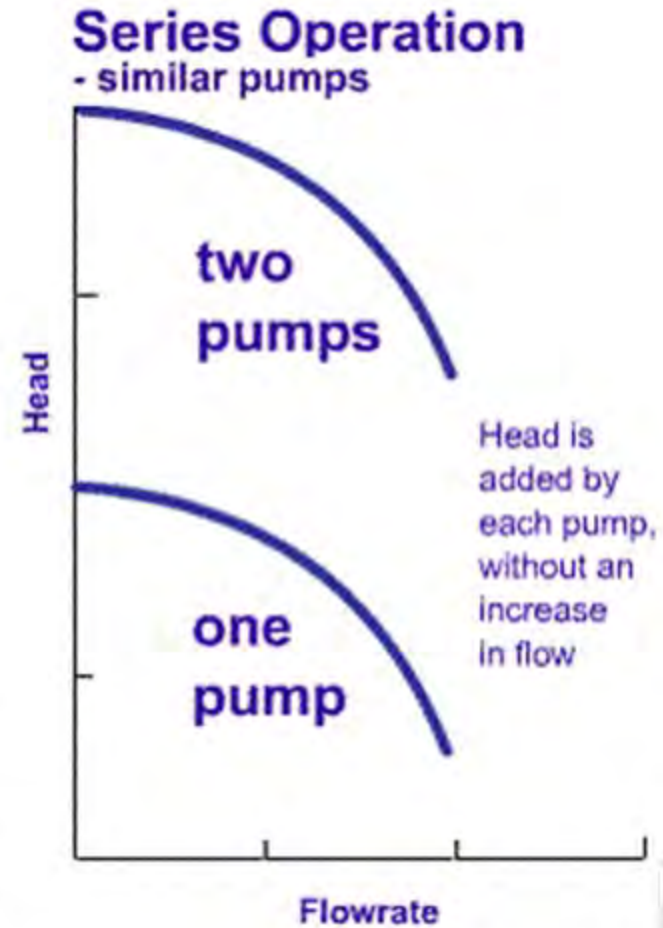
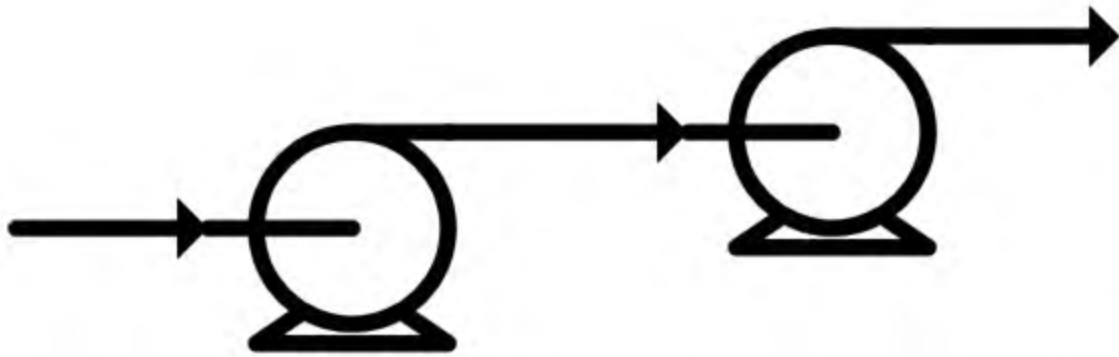


5. System



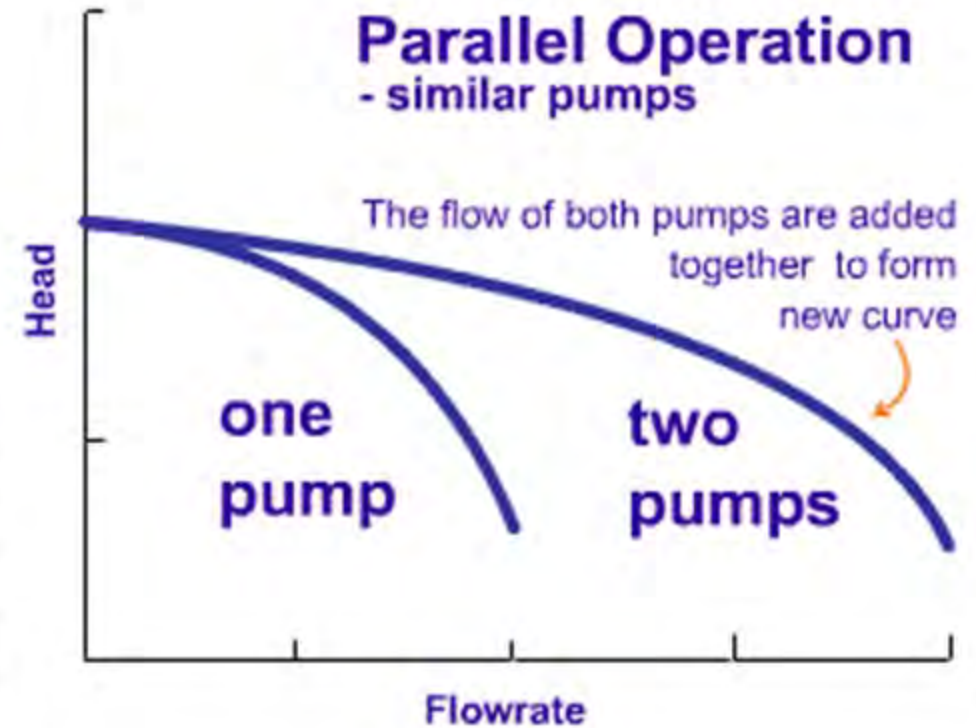
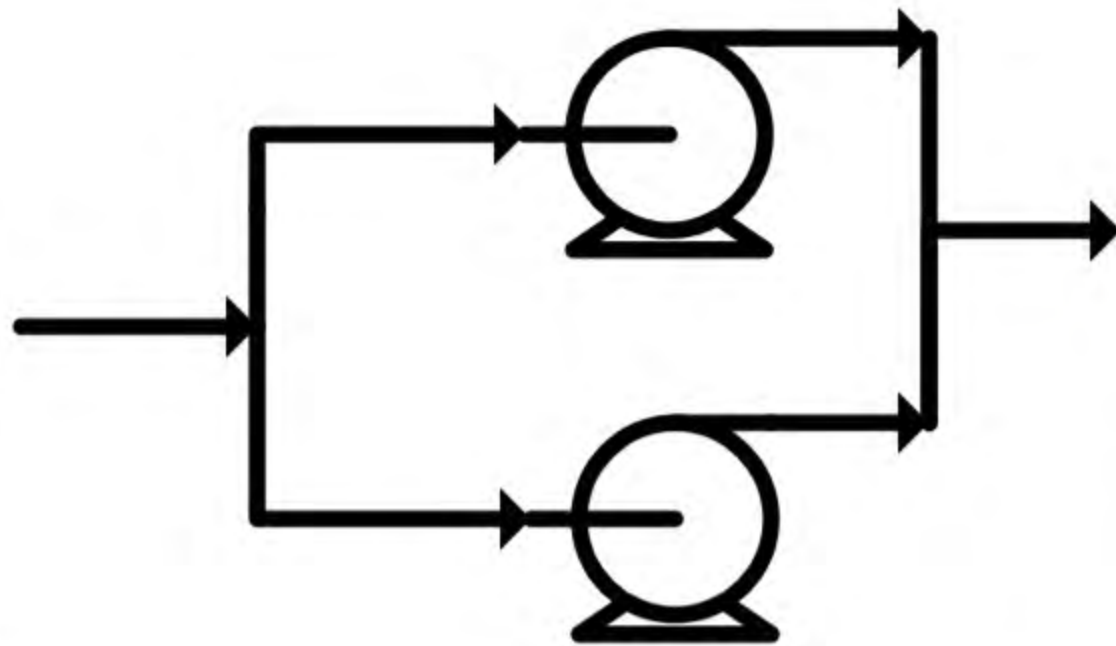
5. System

- Series Pumps



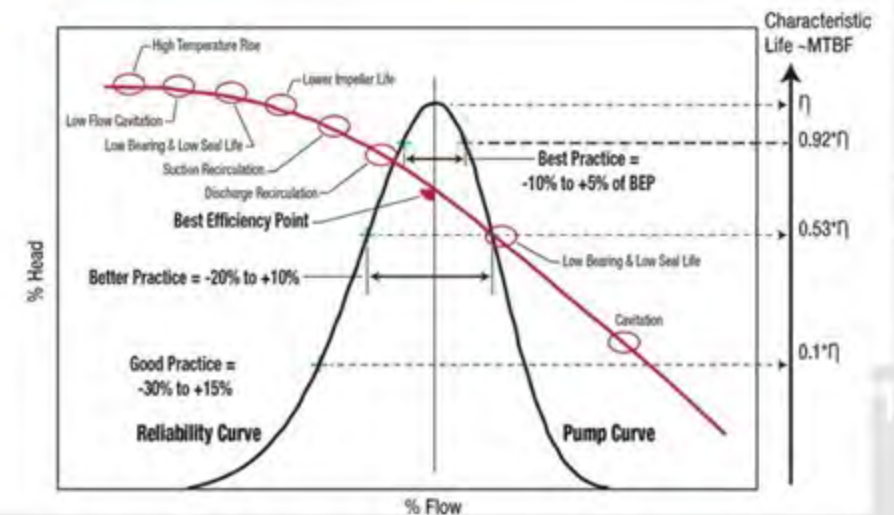
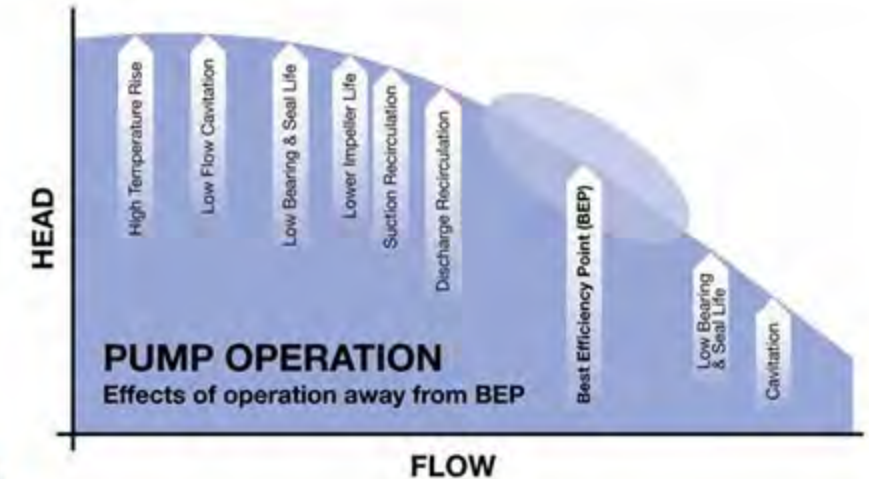
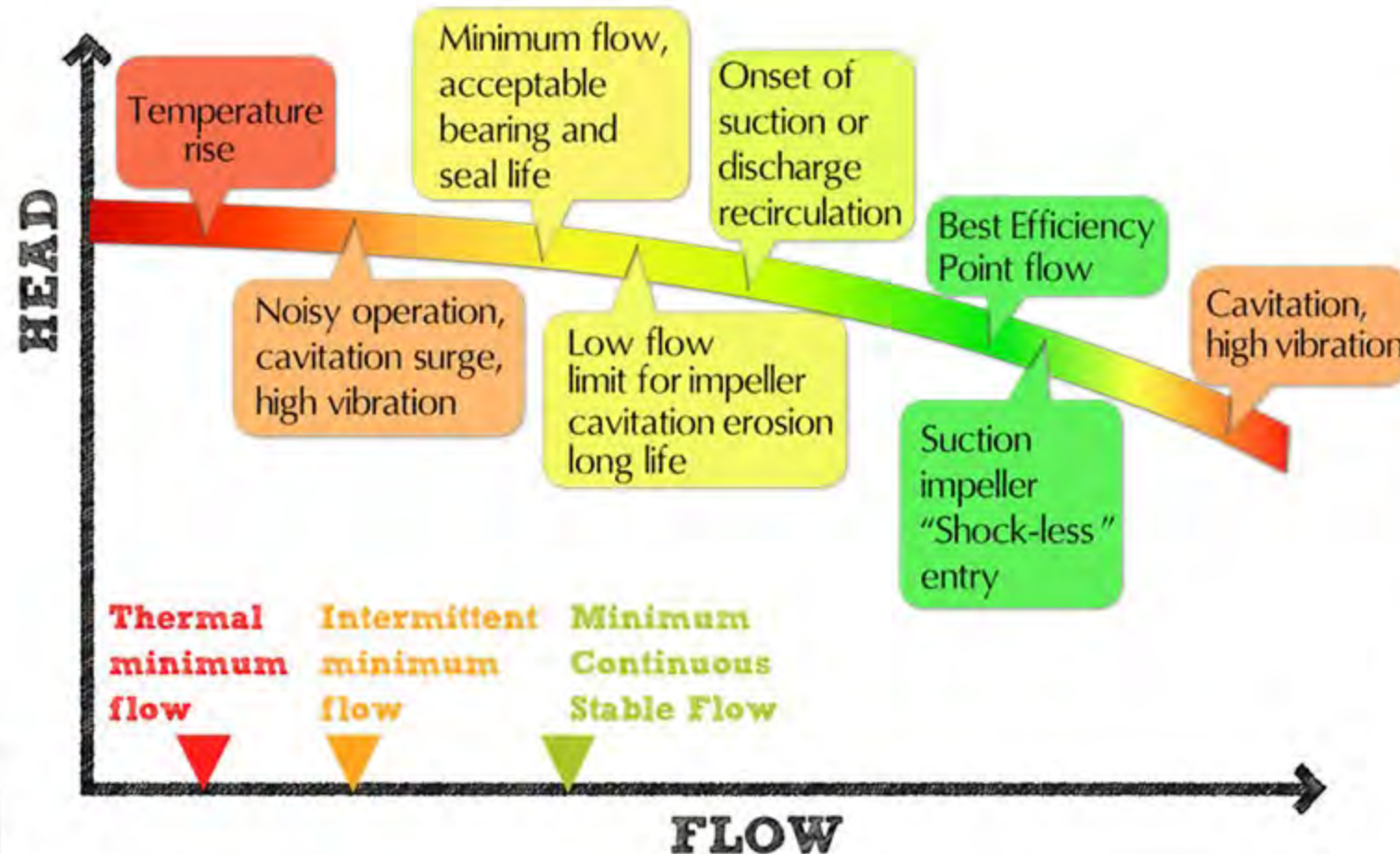
5. System

- Parallel Pumps



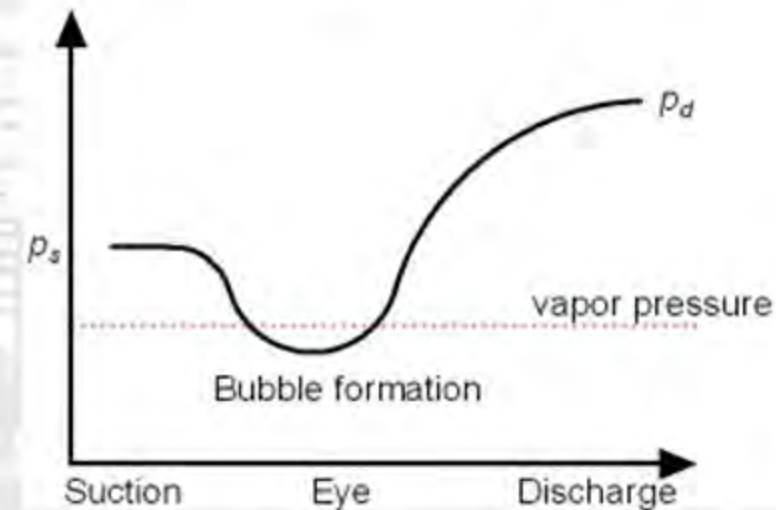
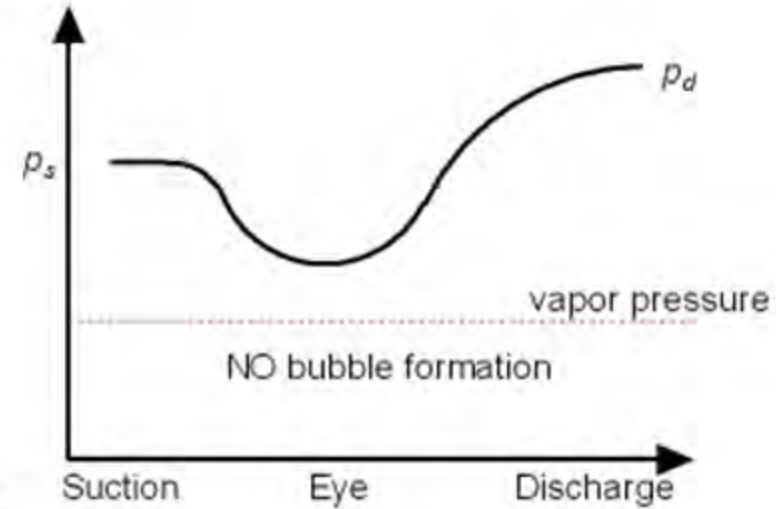
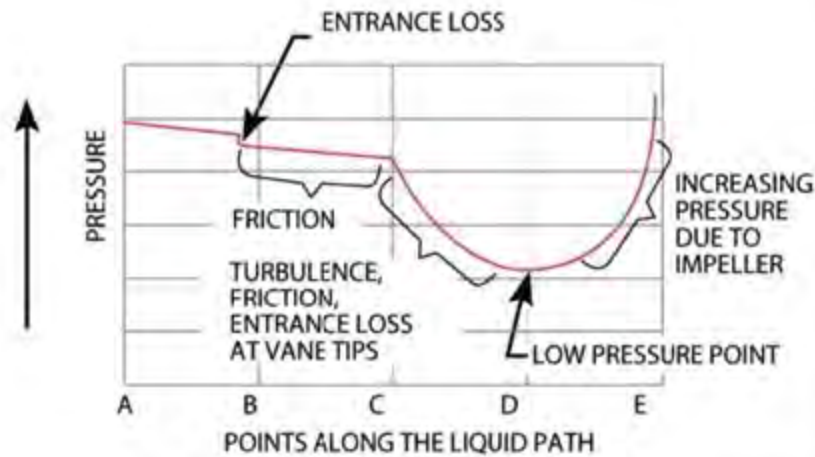
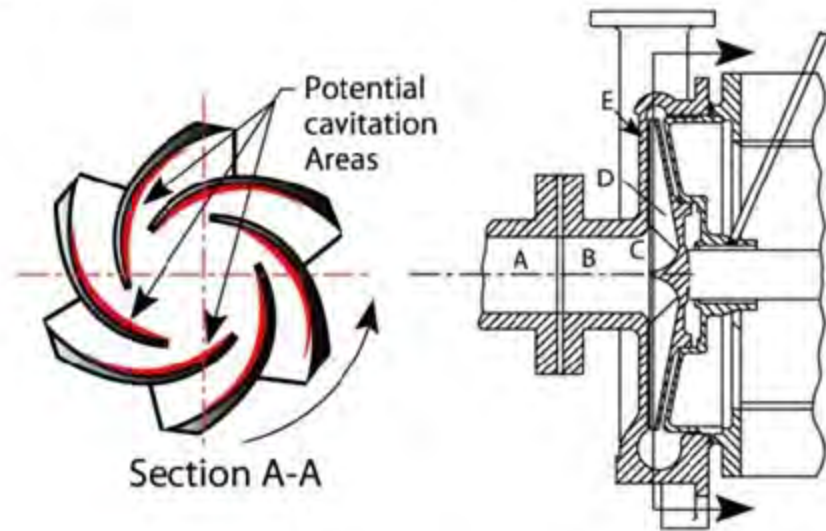
5. System

• Minimum Flow

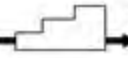


5. System

• NPSH



6. P&ID Symbols

	Compressor		Axial Compressor		Sump pump		Reciprocating pump		Diesel motor
	Reciprocating Compressor		Centrifugal pump		Positive displacement pump 2		Turbine pump		ISO Liquid pump
	Reciprocating Compressor 2		Centrifugal pump 2		Rotary pump		Pump 2		ISO centrifugal pump
	Compressor silencers		Centrifugal pump 3		Rotary gear pump		Fan		ISO diaphragm pump
	Centrifugal		Centrifugal pump 4		Peristaltic pump		Selectable fan		ISO gear pump
	Rotary Compressor		Gas blower		Gear pump		Fan blades		ISO Progressive pump
	Rotary Compressor 2		Vertical pump		Proportioning pump		Fan blades 2		ISO positive displacement pump
	Rotary Compressor and silencers		Liquid ring vacuum pump		Vacuum pump		Triple fan blades		ISO reciprocating piston pump
	Liquid ring Compressor		Positive displacement pump		Screw pump		Axial flow fan		ISO screw pump
	Centrifugal Compressor		Horizontal pump		Screw pump 2		Turbine driver		Selectable Compressor
	Centrifugal Compressor 2		Vertical pump		Cavity pump		Doubleflow turbine		Pump
	Centrifugal Compressor 3		Horizontal pump		Submersible pump		Motor driven turbine		Positive displacement pump
	Centrifugal blower		Vertical pump		Reciprocating pump		Ejector		Motor
							Spray		

Get Ready !

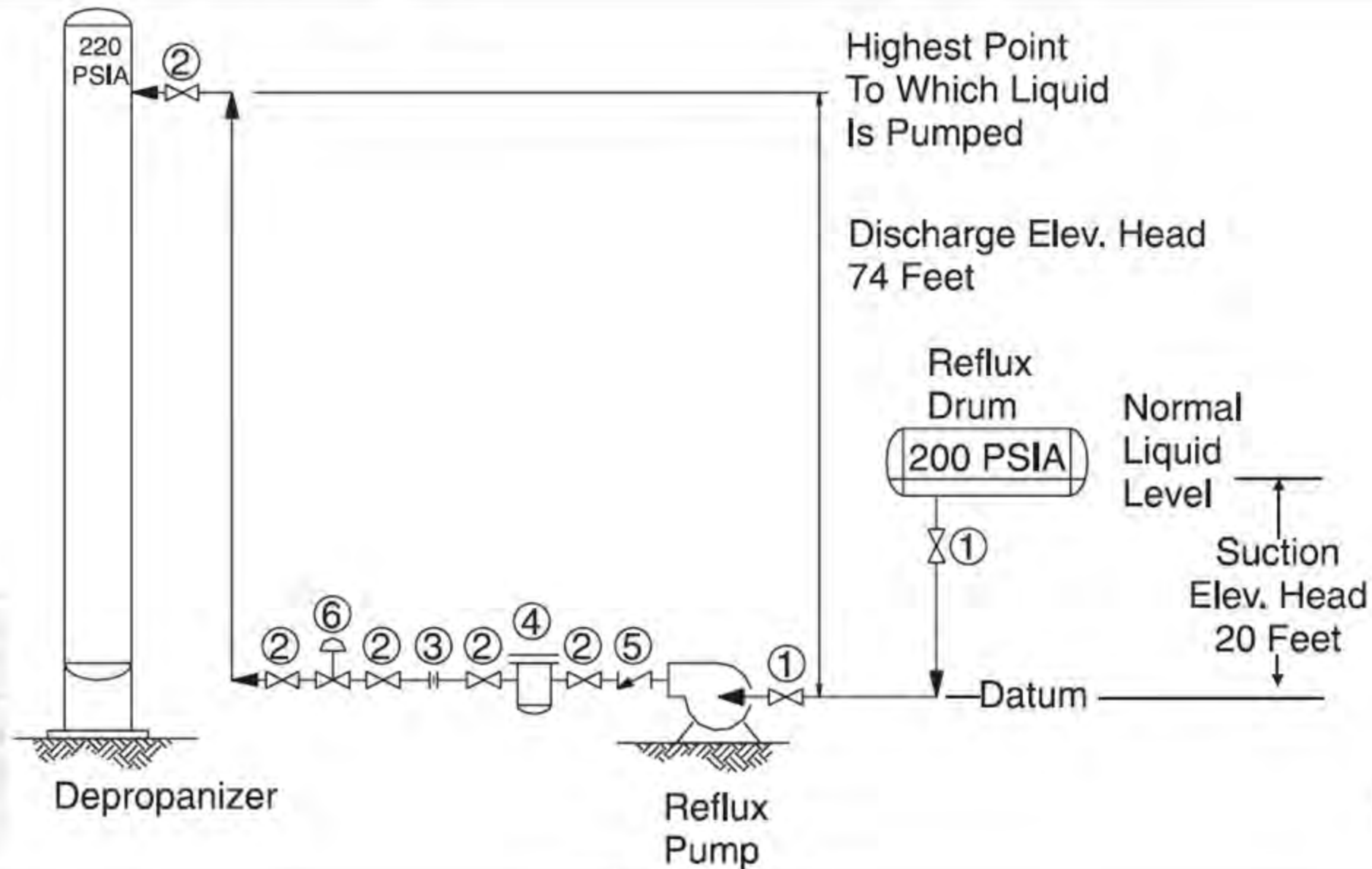
Part 3



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.

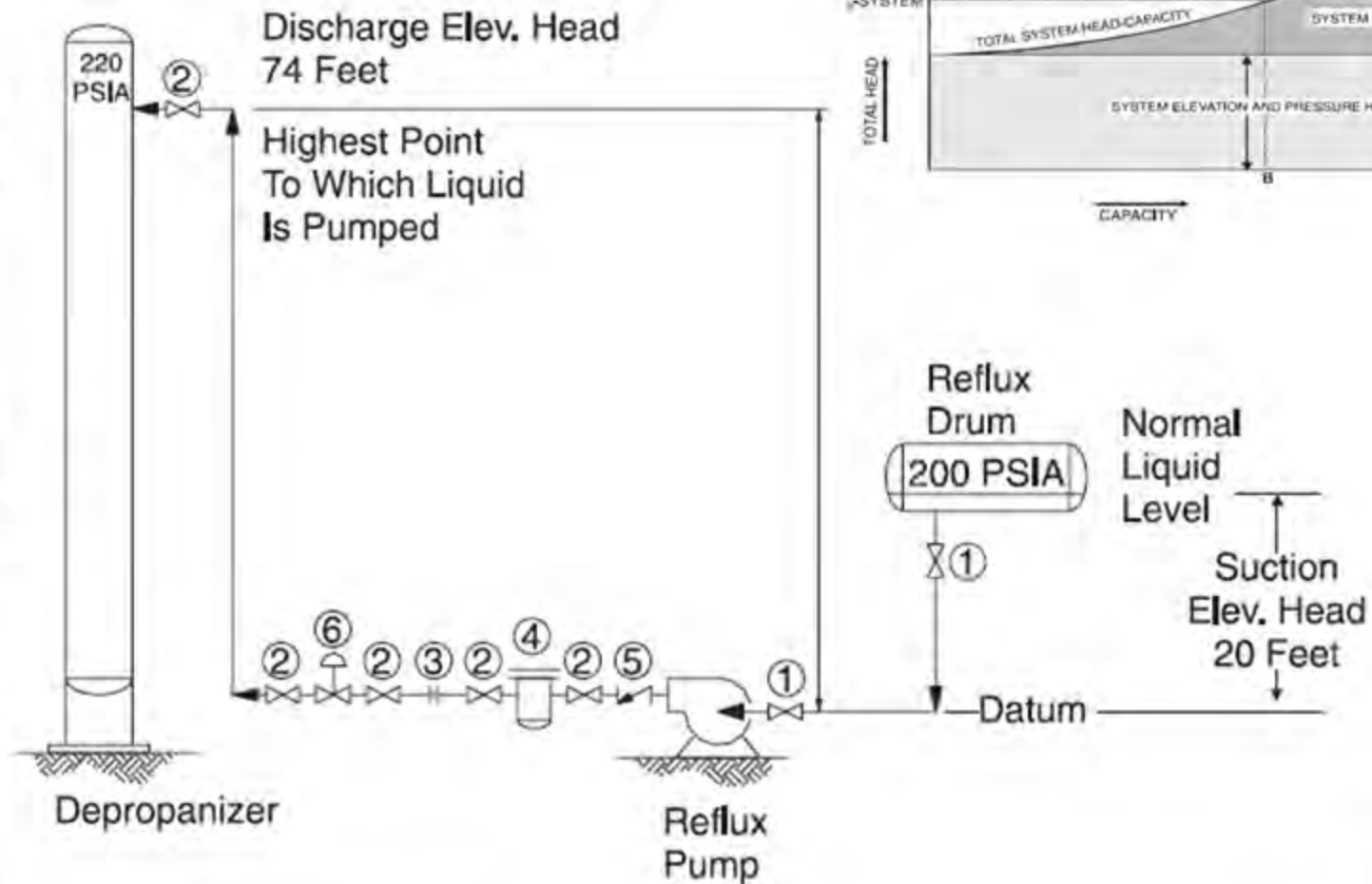
7. Worked Example



7. Worked Example

SUCTION FRICTION		
PIPING		
①- VALVES	0.5 PSI	
	0.2 PSI	

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



7. Worked Example

Absolute Total Pressure at Pump Suction

Reflux drum	200.0 psia
Elevation	$20 \text{ ft.} \cdot 0.485/2.31 = + 4.2 \text{ psi}$
Friction	
piping	- 0.5 psi
valves	<u>- 0.2 psi</u>
	203.5 psia
	= 188.8 psig

7. Worked Example

Absolute Total Pressure at Pump Discharge

Tower		220.0 psia
Elevation	$74 \text{ ft} \cdot 0.485/2.31 =$	$+15.5 \text{ psi}$
Friction	piping	$+3.0 \text{ psi}$
	valves	$+2.0 \text{ psi}$
	orifice	$+1.2 \text{ psi}$
	filter	$+13.0 \text{ psi}$
	check valve	$+1.0 \text{ psi}$
	control valve	<u>$+9.0 \text{ psi}$</u>
		264.7 psia
		= 250.0 psig

7. Worked Example

$$\text{Differential pressure} = 250.0 - 188.8 = 61.2 \text{ psi}$$

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

$$10\% \text{ safety factor} \quad \quad \quad \underline{+30 \text{ ft}}$$

$$\text{Required differential head (H)} \quad \quad \quad 322 \text{ ft}$$

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.](#)