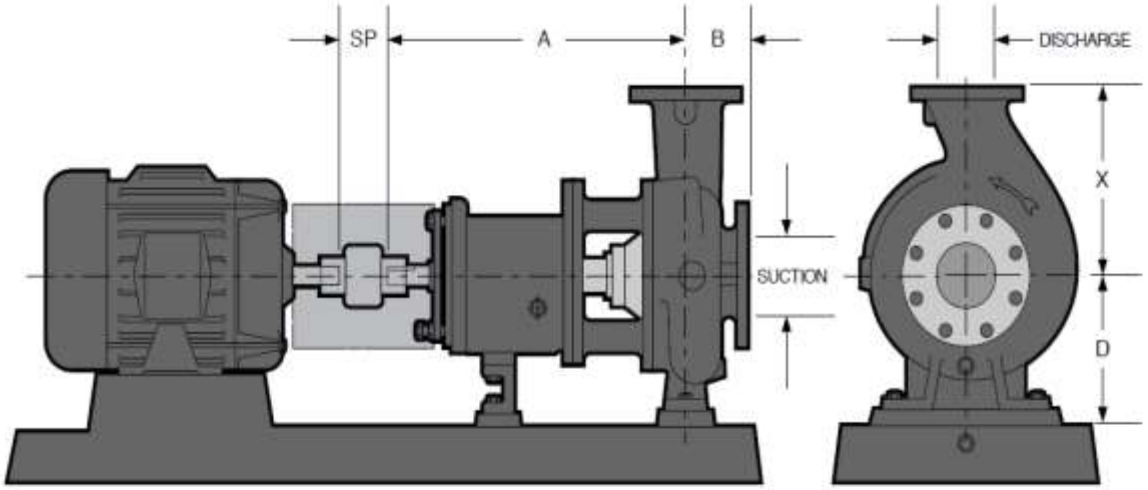
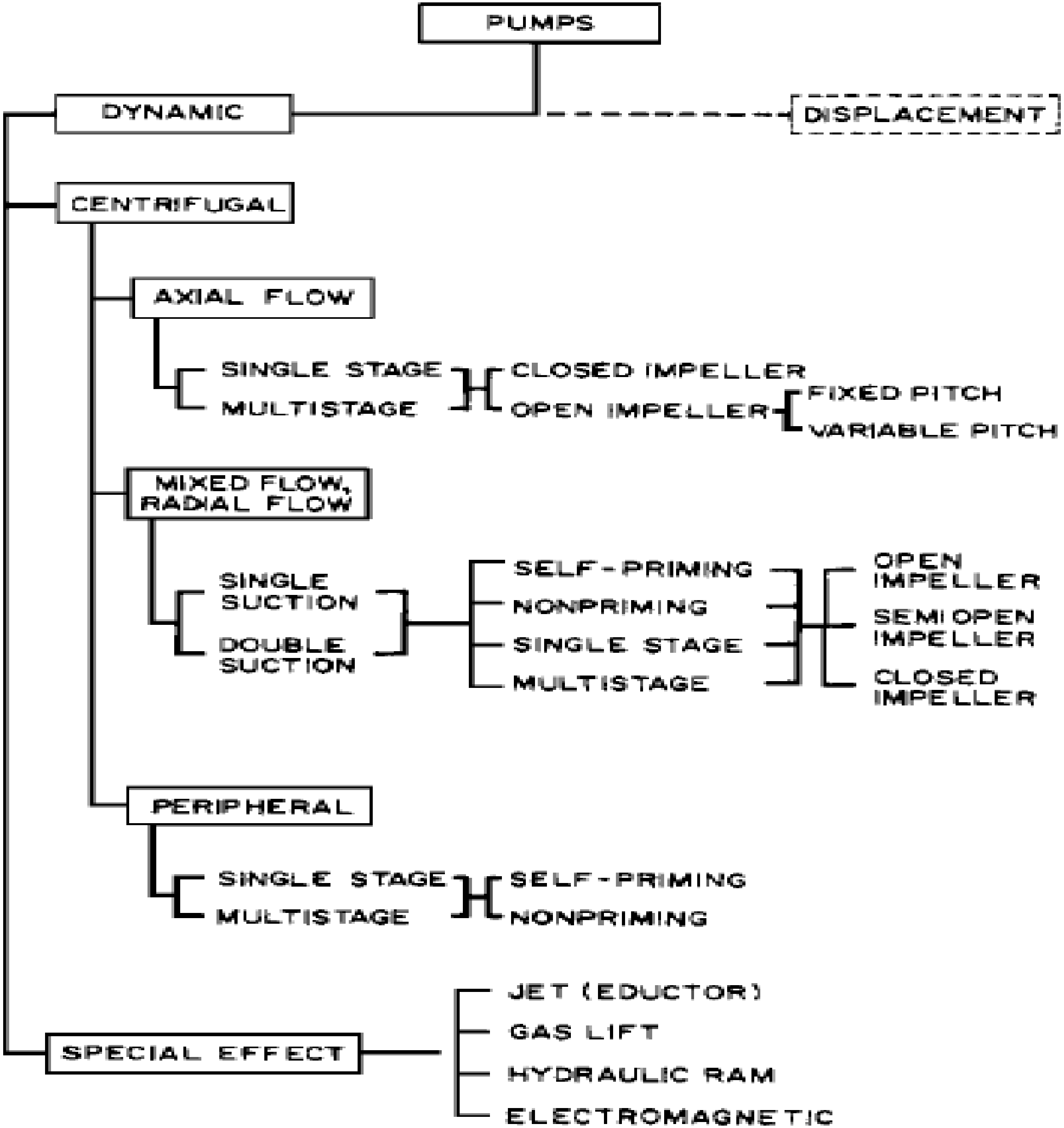


Pumps

Function : TO INCREASE MECHANICAL ENERGY OF FLUID

Principle : Bernoulli's Theorem


PUMPS
DYNAMIC
DISPLACEMENT
CENTRIFUGAL
AXIAL FLOW
SINGLE STAGE
MULTISTAGE
CLOSED IMPELLER
OPEN IMPELLER
FIXED PITCH
VARIABLE PITCH
MIXED FLOW, RADIAL FLOW
SINGLE SUCTION
DOUBLE SUCTION
SELF-PRIMING
NONPRIMING
SINGLE STAGE
MULTISTAGE
OPEN IMPELLER
SEMI OPEN IMPELLER
CLOSED IMPELLER
PERIPHERAL
SINGLE STAGE
MULTISTAGE
SELF-PRIMING
NONPRIMING
SPECIAL EFFECT
JET (EDUCTOR)
GAS LIFT
HYDRAULIC RAM
ELECTROMAGNETIC

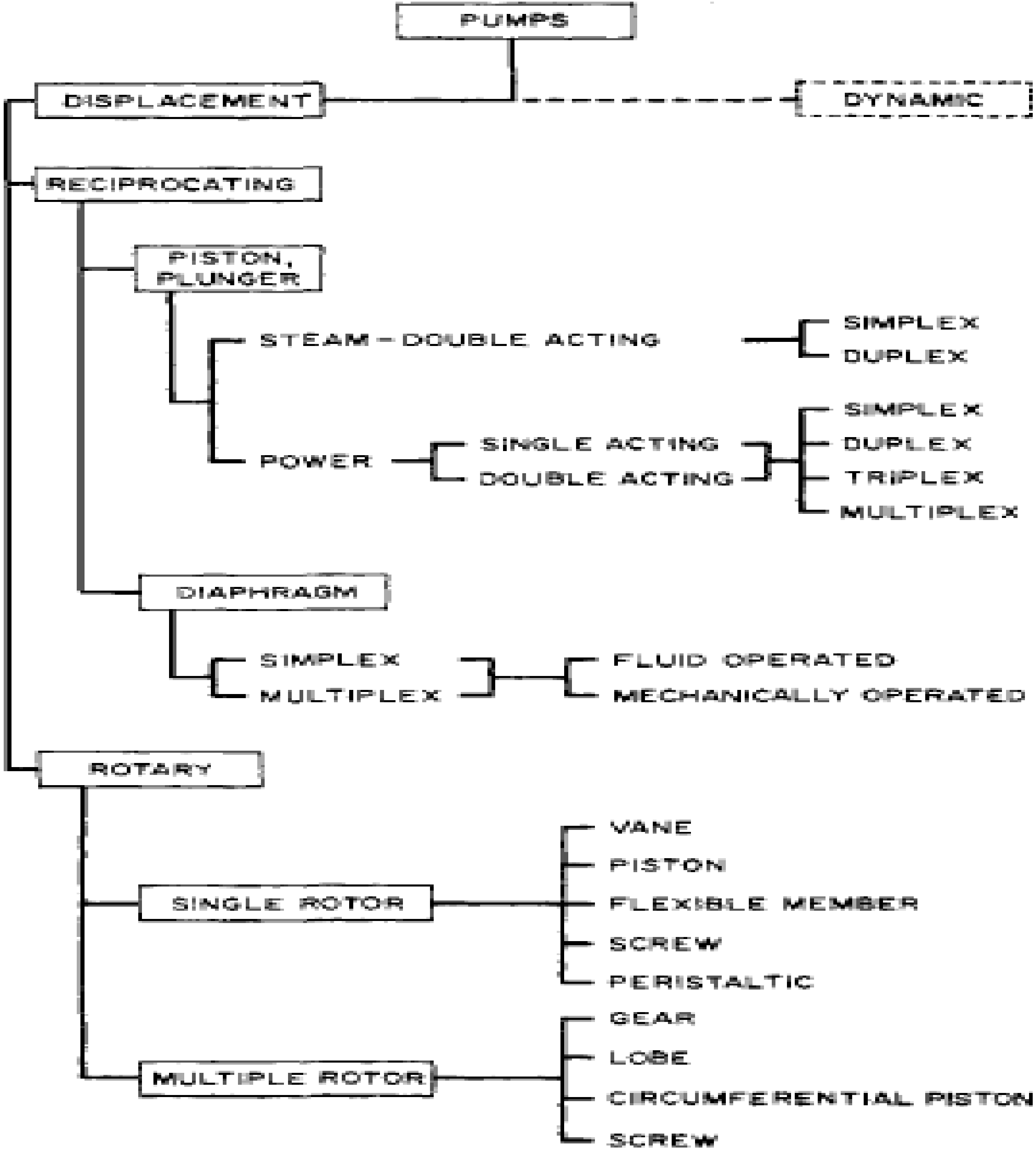


FIGURE 2 Classification of displacement pumps

TYPES

Centrifugal Pump

1. Type of energy conversion: (*a*) volute, (*b*) diffuser or turbine.
2. Number of stages: (*a*) single-stage, (*b*) multistage.
3. Impeller type: (*a*) single- or double-suction, (*b*) open, semi-open, or closed, (*c*) single- or double-curvature vanes.
4. Axis of rotation: (*a*) horizontal, (*b*) vertical, (*c*) inclined.
5. Casing: (*a*) solid or split, (*b*) location of suction and discharge nozzles.
6. Method of drive: (*a*) direct-connected (coupled or close-coupled), (*b*) geared, (*c*) chain-driven or belted.

Pump Selection

When selecting a pump for a circuit, factors that must be considered are:

- Nature of Pumpage (Corrosive, Temperature, Abrasive, Non-Abrasive viscosity, toxicity, abrasiveness)
- System requirements(Head , Velocity etc)
- Expected length of service
- Environmental conditions
- Cost

Impeller Selection

Depending upon type of Fluid Handled, Efficiency, Power etc

General steps selection & purchase of the equipment

Engineering the pumping system

Defining the pumping requirements

Designing the pumping system

Pump specification and data sheet preparation

Pump selection and configuration

Pump selection

Pump configuration

Pump quotation

Evaluating and purchasing the pumping equipment

Evaluation of bids and negotiation

Purchase of the selected pump and driver

Defining the Pump System Requirements

Functional requirements :

- **SERVICE** is a general description of the particular pumping system. Examples
- might include booster pump, boiler feed pump, gasoline transfer pump, and ***so on***

- **OPERATING CONDITIONS** define the general fluid capacity, pressure,
- and elevation change required by the pumping system. At this point, the number of pumps required for the service may not be known, so the specific operating conditions **or each** pump in the system is not fully defined.

- **SITE CONDITIONS** These describe the location of the pumps, the altitude, and utility conditions for the driver (steam, electrical, and ***so on).***

- **FLUID TYPE AND PROPERTIES** : viscosity, density, vapor pressure, corrosiveness, erosiveness ,volatility, flammability, and toxicity.

The temperature, pressure, and corrosiveness MOC
fluid contains solids in suspension, suitable types of pump seal designs and brasion-resistant pump construction must be considered.

Erosion due to high particle content may cause premature performance decline. Large particles may favor open impeller design.

Fluid toxicity may necessitate the use of dual (tandem or double) mechanical seals due to government regulations **or safety considerations.**

Entrained gases may affect the pump's ability to produce the required differential
pressure.

Approximate upper limit of pressure & capacity by pump class

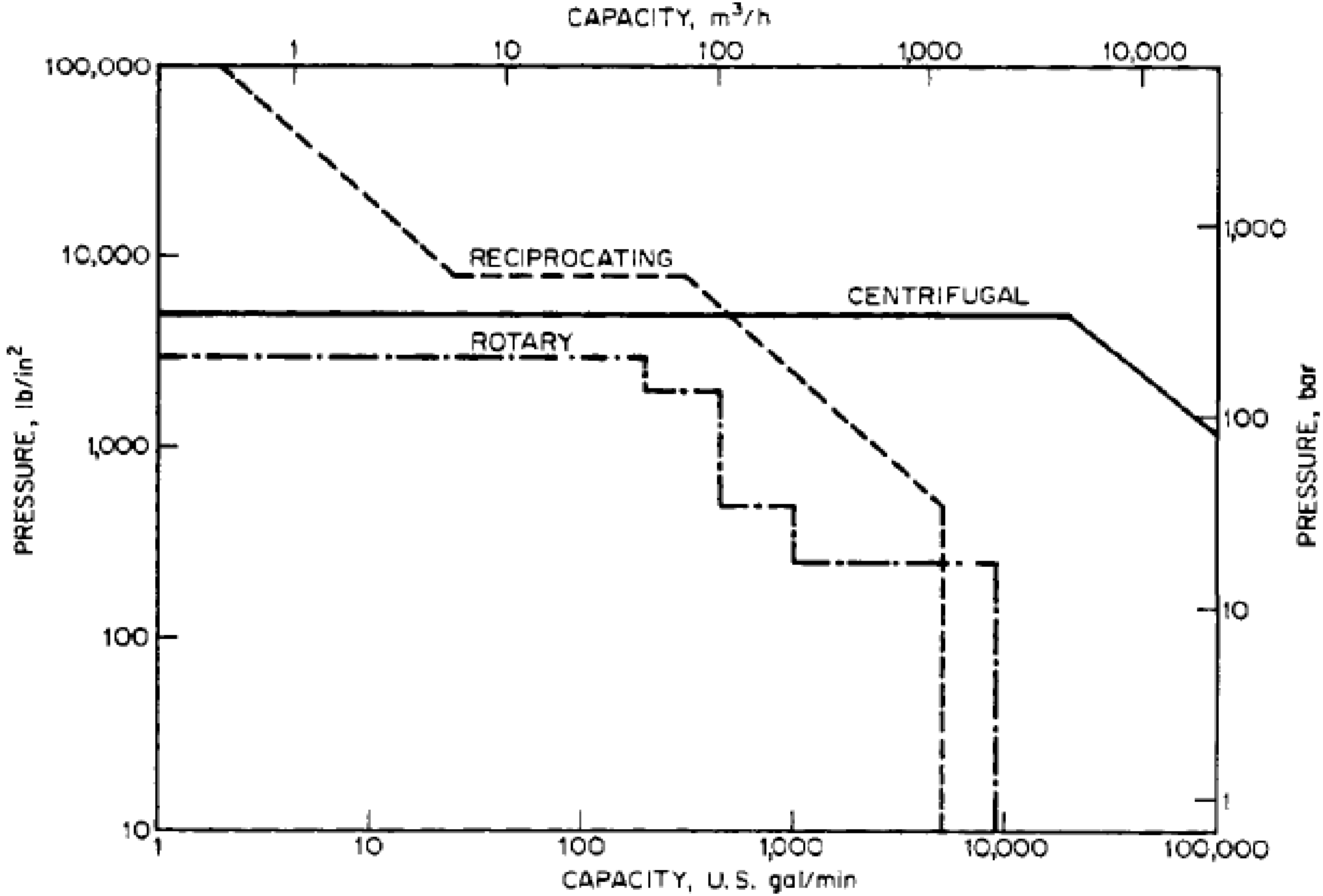


FIGURE 4 Approximate upper limit of pressure and capacity by pump class

Pump Specific speed

- It’s used to characterize operation of pump at its optimum condition **(** i.e**.** BEP with the maximum diameter impeller**)** and at a given rotative speed. Hence useful for ***preliminary pump selection and design***
- Specific speed is used for classifying the relative discharge of an impeller as radial, mixed or axial

Pump Specific speed EQUATION.

$$N_S = (C_Q)^{0.5} / (C_H)^{0.75}$$

C_H is head coefficient

C_Q Is Capacity Coefficient

N_S Is Pump Specific Speed

Open impeller | Semi-open impeller | Enclosed impeller

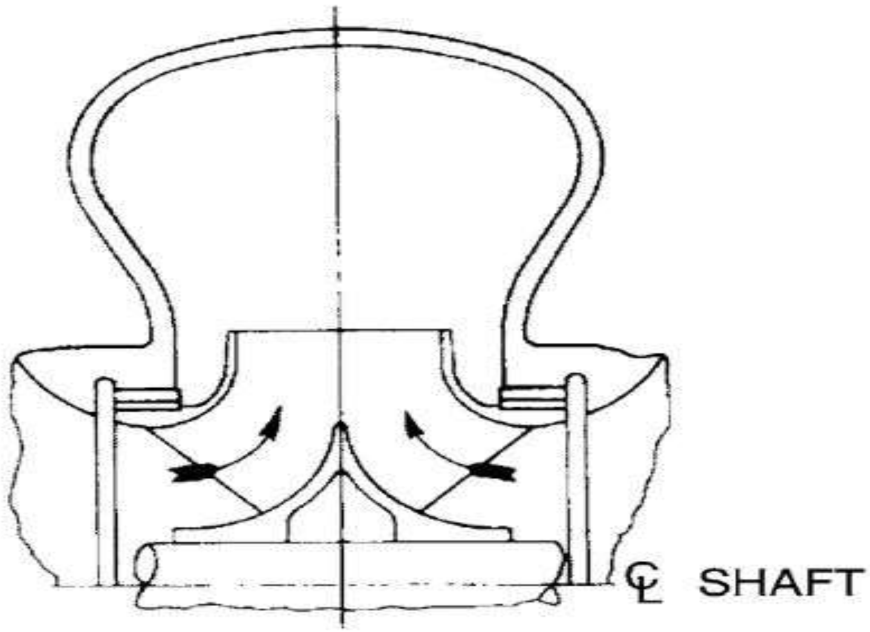


Figure 1.1.4.2 — Double suction radial flow impeller

Radial flow

Single inlet impellers usually have a specific speed below approximately 90 (4500) and, with double suction impellers, a specific speed below approximately 135 (7000)

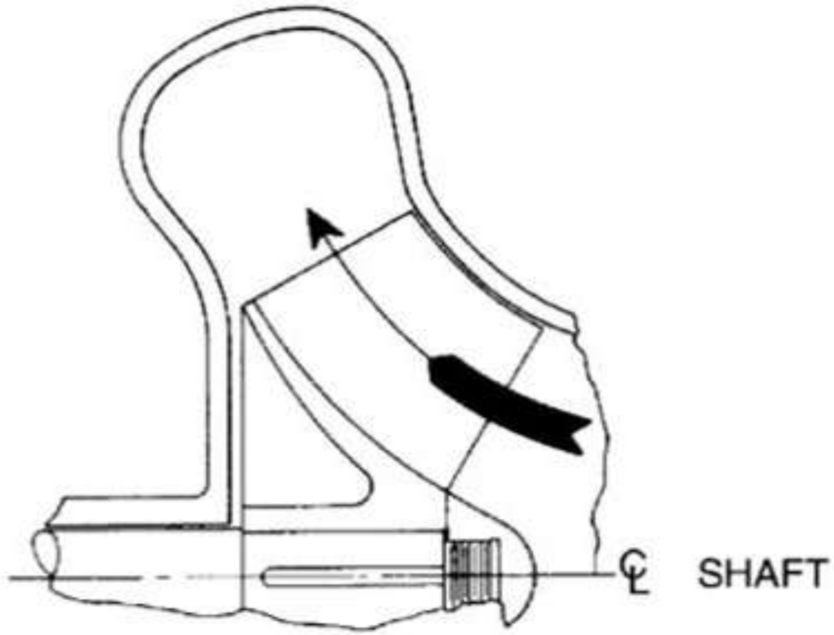


Figure 1.1.4.3 — Mixed flow impeller

Mixed flow -

Single inlet impeller where the flow enters axially and discharges in a mixed axial and radial direction. Pumps of this type usually have a specific speed from approximately 90 (4500) to 200 (10,000).

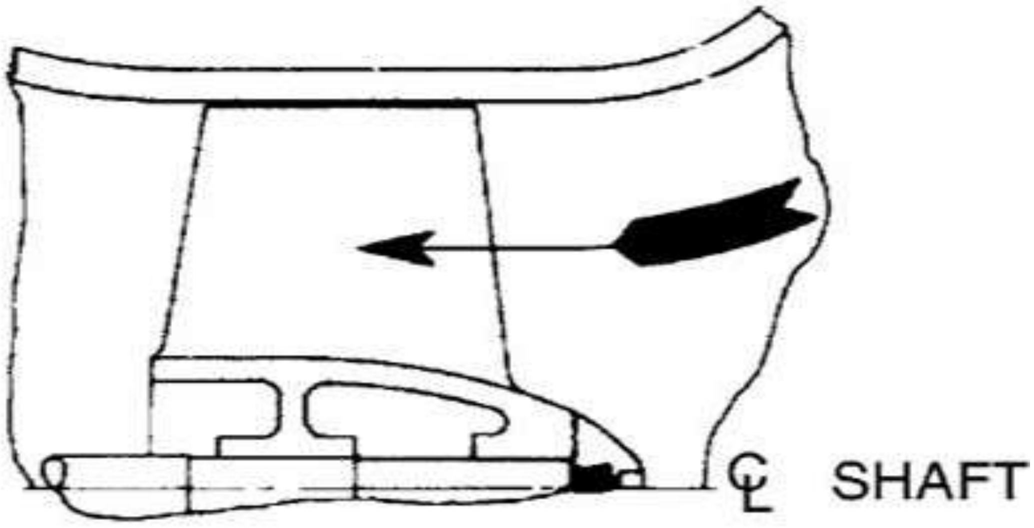


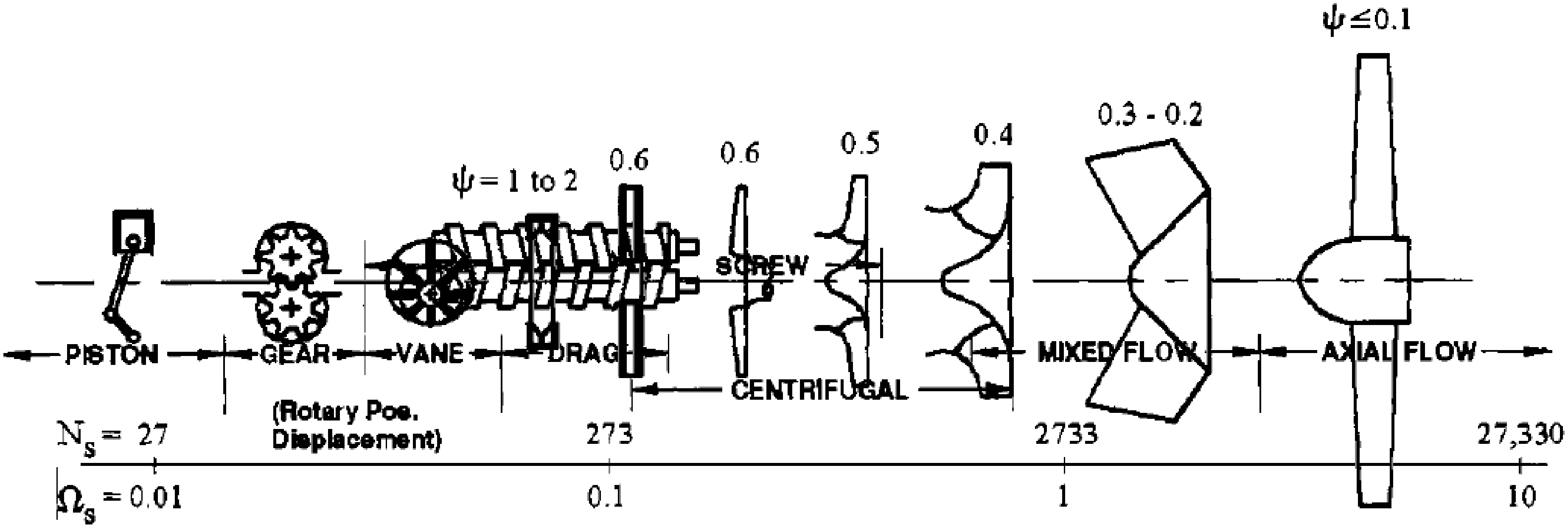
Figure 1.1.4.4 — Axial flow impeller

Axial flow

- sometimes called a *propeller pump*, has a single inlet impeller with the flow entering axially and discharging nearly axially. Pumps of this type usually have a specific speed above approximately 200 (10,000)

OPTIMUM GEOMETRY VERSUS SPECIFIC SPEED

- For low viscosity, SPECIFIC SPEED emerges as the major influence on rotor geometry



Optimum geometry as a function of BEP **specific speed**

Ψ is head coefficient i.e. C_H

Ω Is Pump Specific Speed

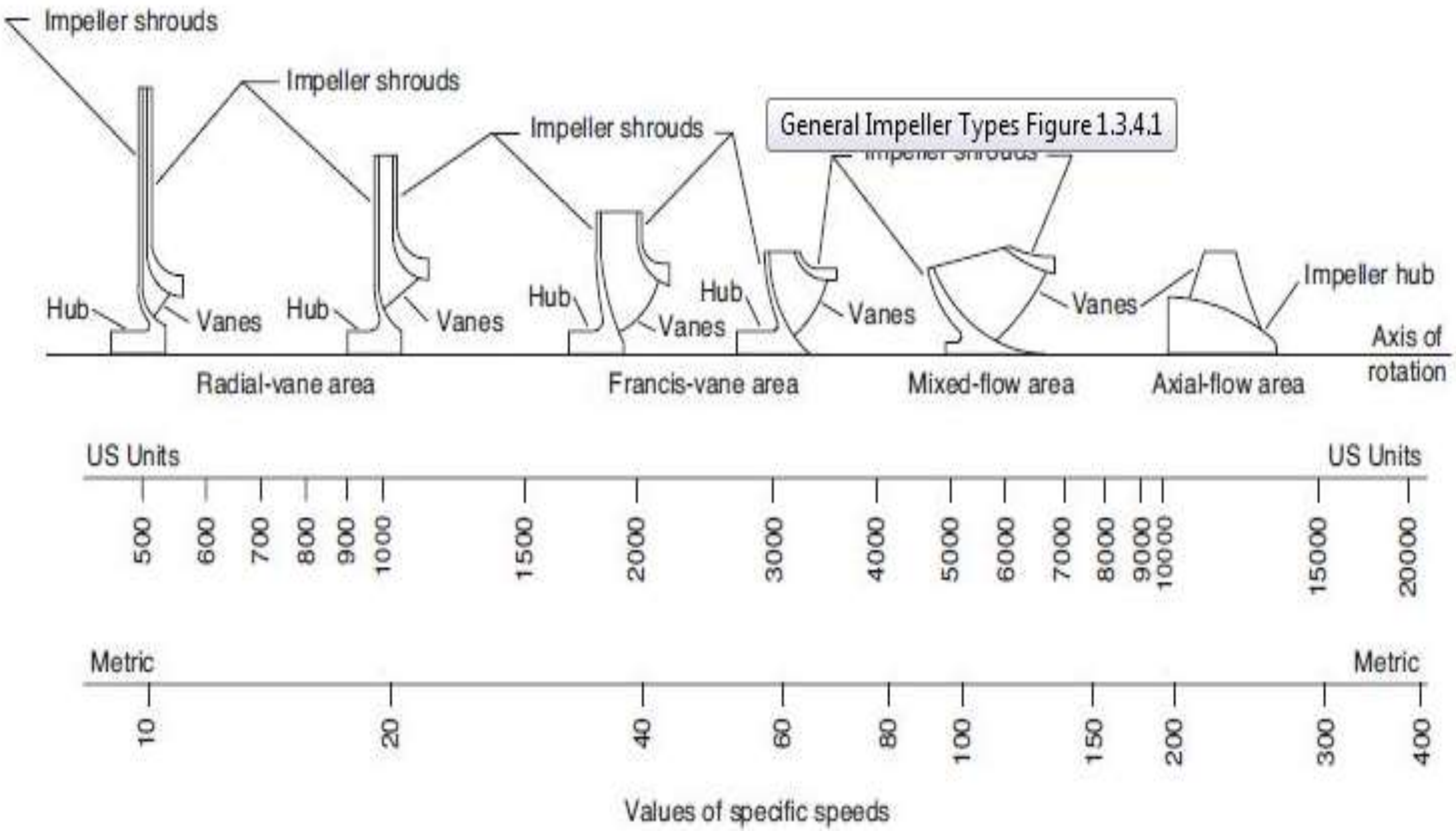
1. Rotary PDP - lower values of N_{sp}

2. *Lowest Ns-values reciprocating PDP*

3. Higher values *CFP*

pump	N_{sp}
Rotary PDP	N_{sp} Near About 0.01
Reciprocating PDP	$0.01 < N_{sp} < 0.1$
CFP(radial)	$0.1 < N_{sp} < 1.5$
CFP (Mixed Flow)	$1.5 < N_{sp} < 3.5$
CFP (Axial flow)	$N_{sp} > 3.5$

General Impeller Types



Pump Selection **BY** Nature of Pumpage

Type	Max System Pressure (kPa)	Approx. Capacity m3/s	Efficiency	Comments
Centrifugal (radial)	48000	10	40-80	Inexpensive , low maint., μ < 0.1 PaS , priming, cavitation
Centrifugal (Axial)	35000	10	50-85	Mod. Cost ,low maint, μ < 0.1 PaS ,priming, cavit, high speed low H
Regenerative (Turbine)	**5000**	**<1.0**	**20-40**	μ < 0.1 PaS Can handle **40% gas in suction** - for **volatile liq**.
Positive Disp. (Gear)	35000	0.1	40-85	**μ <400 PaS** ,Low noise, P .protection needed
Positive Disp.(Lobe)	35000	0.1	40-85	**μ <0.1 PaS** ,Low noise, P .protection needed, LOW MAINTA.

Positive Disp.(PISTON)	35000	0.004	40-85	μ <400 PaS Low noise, P .protection needed
Positive Disp.(Screw)	20000	0.1	40-70	**High cost, mod. Noise** , P protection needed **μ < 1000 PaS,**
Positive Disp.(sliding vane)	35000	0.1	40-85	No abrasive liq. **μ <400 PaS**
Resciprocating Piston	100000	0.03	50-90	High cost, High Main. Cost, Pulsating Flow, leakage, noisy , Very high H , **μ <400 PaS**
Diphragm	35000	0.006	20-50	High cost, Pulsating Flow, leakage, Mod Main. Cost, low viscosities.
Momentum Transfer Jet	35000	1.0	5-20	Can handle Corrosive Fluids , Inexpensive , low maint, contamination of fluids, low Q, e & H

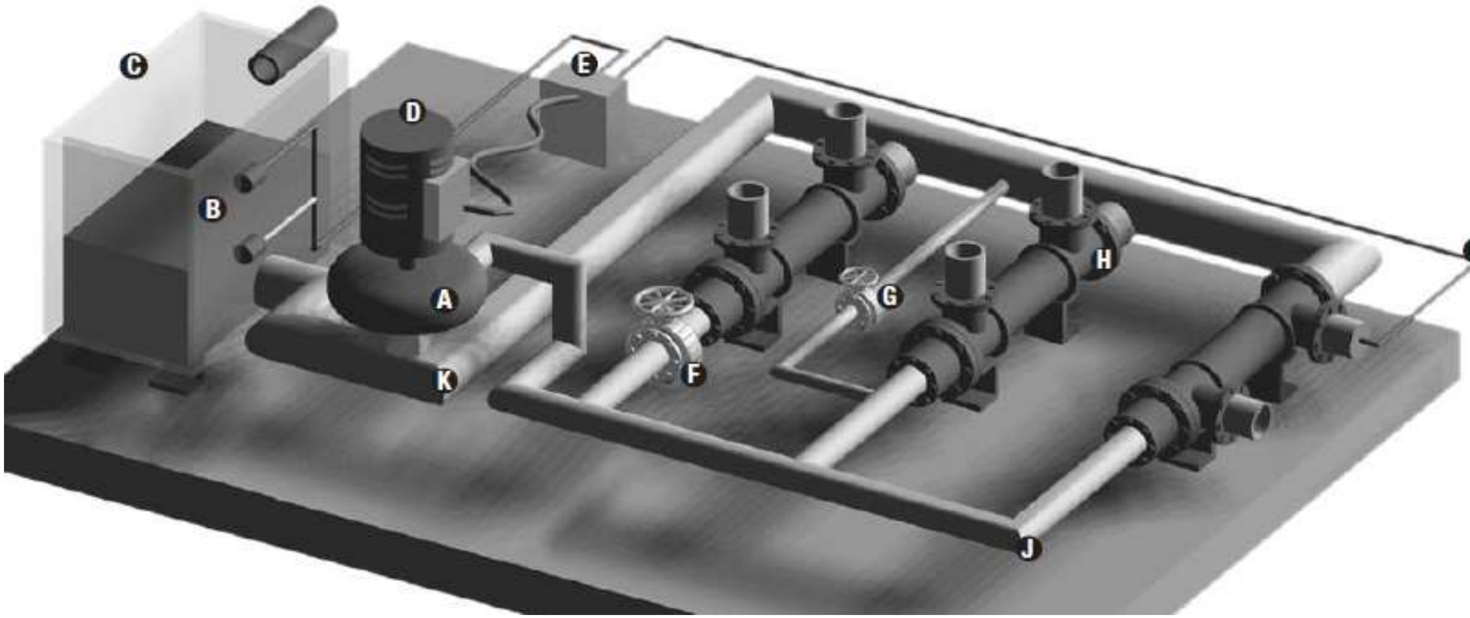
SELECTING THE IDEAL PUMP FOR TYPICAL CONDITIONS

Application	Standard Centrifugal	Diaphragm	Trash	Submersible
Clear Water	X			X
Slimy Water	X	X	X	X
Muck Water	X	X	X	X
Mud Water	X	X	X	
Silt Water	X	X	X	
Abrasive Water	X	X	X	
High Solid Content Water		X	X	
Slow Seepage Ditch Water		X		X
Septic Tank		X	X	
Man Holes	X		X	X

Matching Pump for Given System

1. Head Requirements: Finding Duty Point from Pump Characteristics Curve

2. NPSHR



Typical Pumping System Components

Key

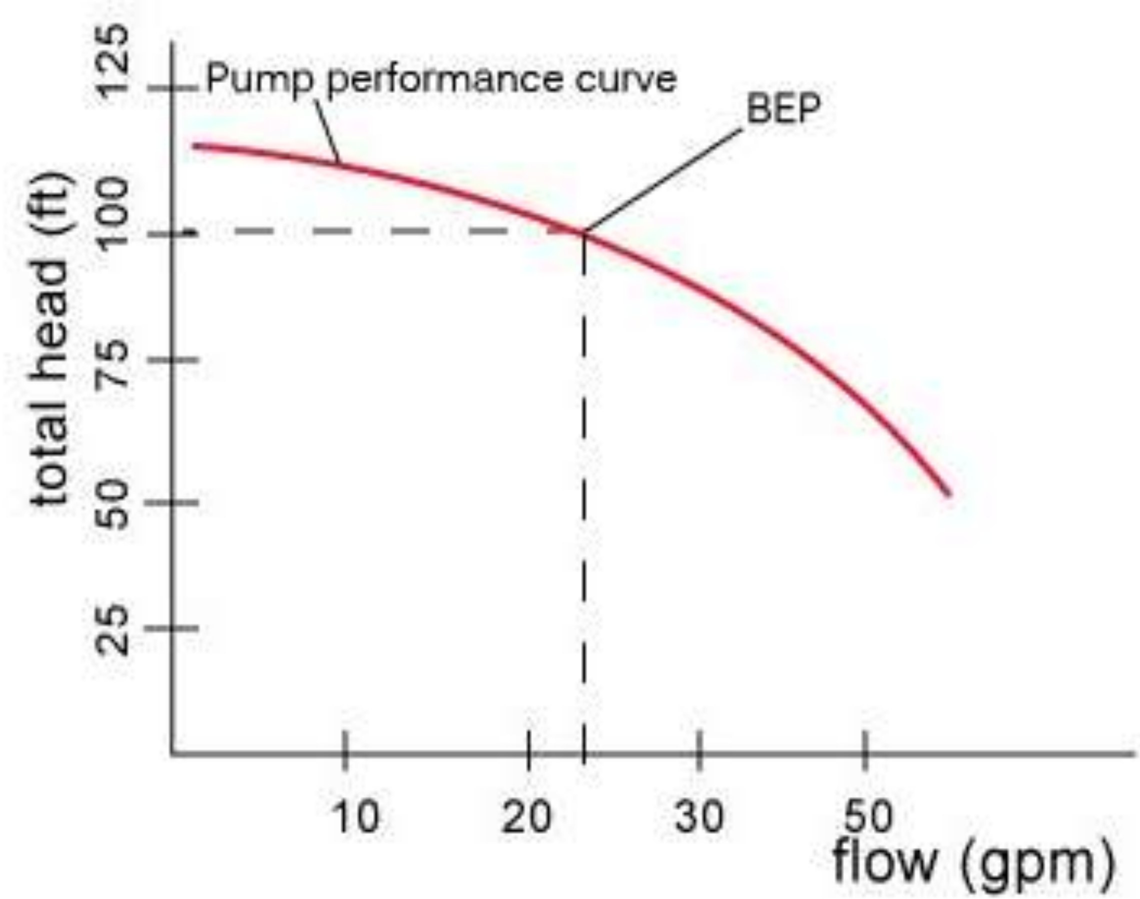
A. Pump **B**. Level Indicators **C**. Tank, Liquid Supply **D**. Pump Motor **E**. Motor Controller
F. Throttle Valve **G**. Bypass Valve **H** . Heat Exchangers) **I** . Instrumentation Line
J. Pump Discharge Piping **K**. Pump Suction Piping

- **Pump performance curves: How Pump performs**

1.BEP

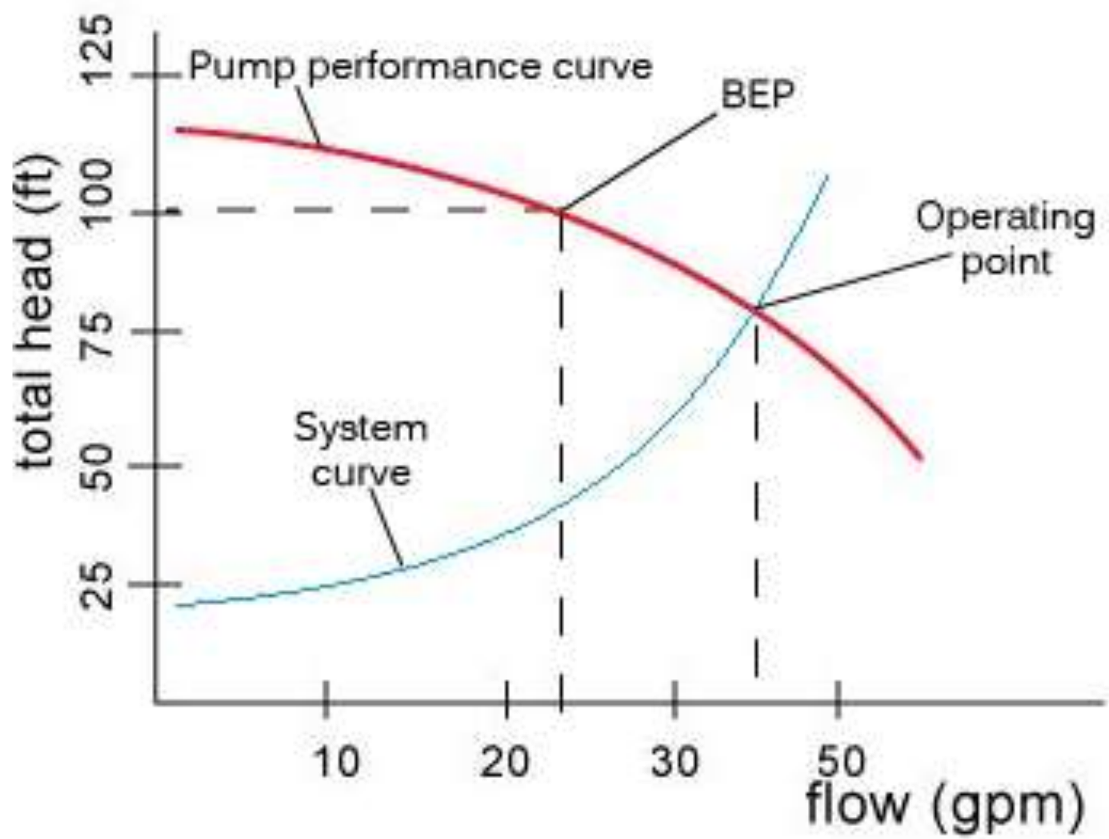
2.Duty Point

3.Failure Point



System Curve : System Requirements like H, Q

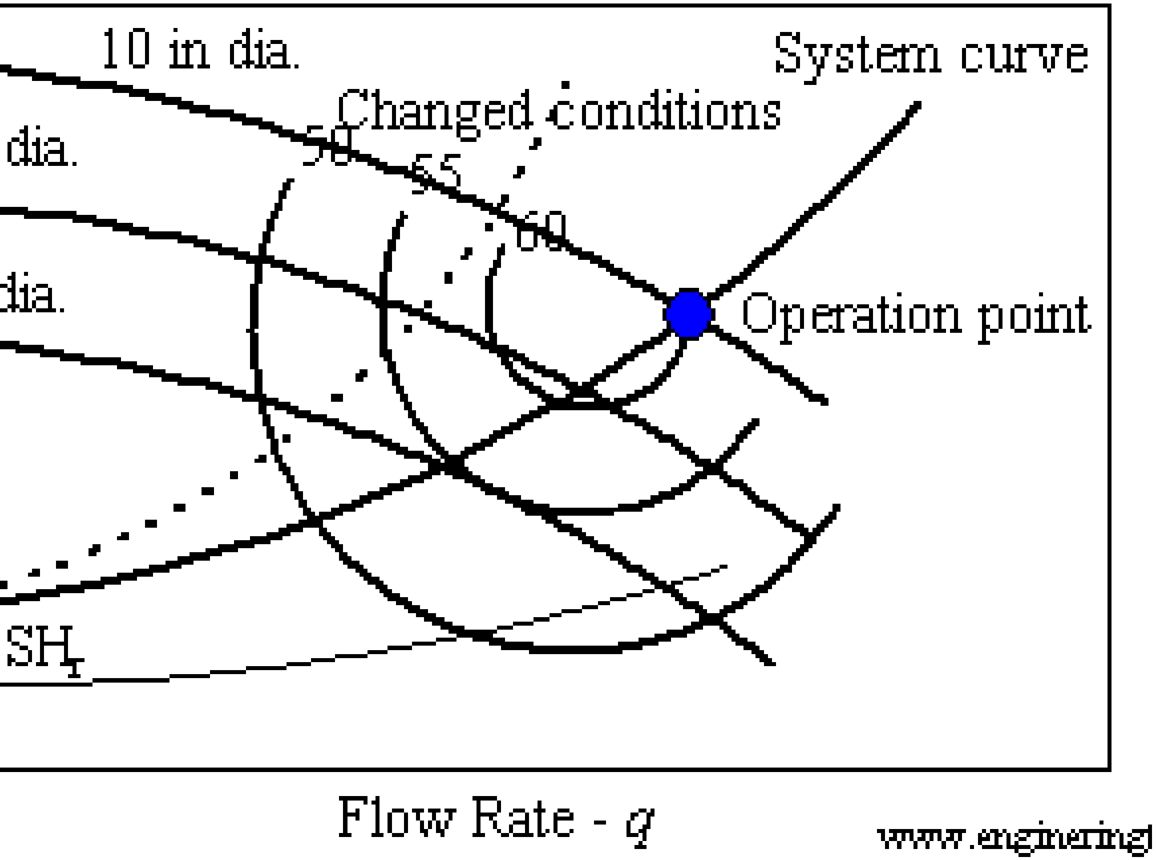
- The best pump choice for a system is one in which the required operating point intersects at the pump's BEP.



IMPELLER DIAMETER SELECTION:

1. Avoid Head wastage

2. Effiency *BHP should be high



PUMP STANDARDS

API 610 (centrifugal pumps)&
API 676 (rotary gear pumps) for heavy duty refinery pumps.

Fire pump service, NFPA

ISO 13709 is refinery utilities, chemical and pharma applications.

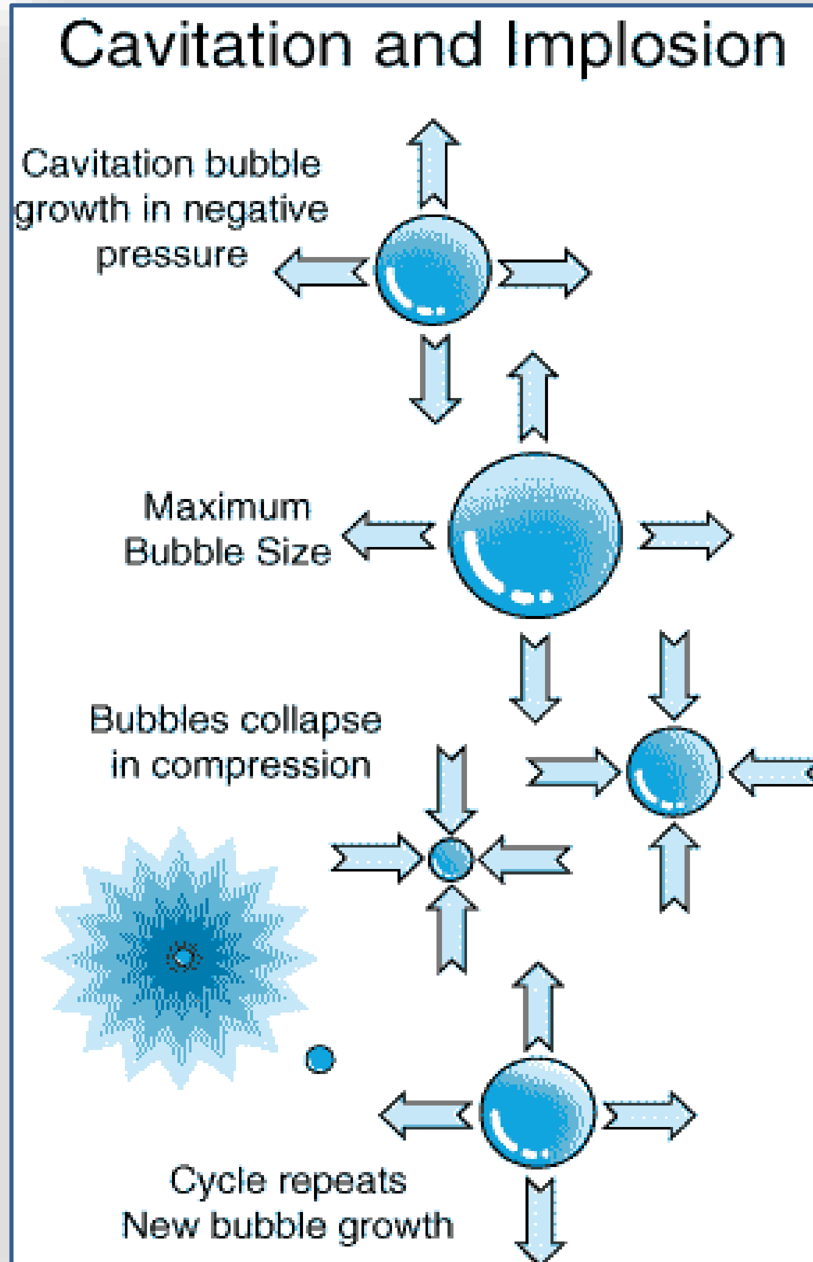
PROBLEMS IN PUMP OPERATION

Cavitation

The formation of and Immediate Implosion of Vapor Bubbles within a liquid

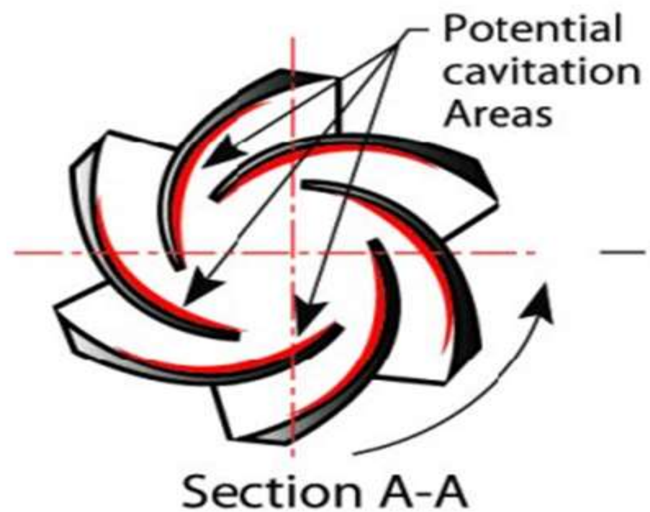
Two types of cavitation

1. Suction
2. Recirculation

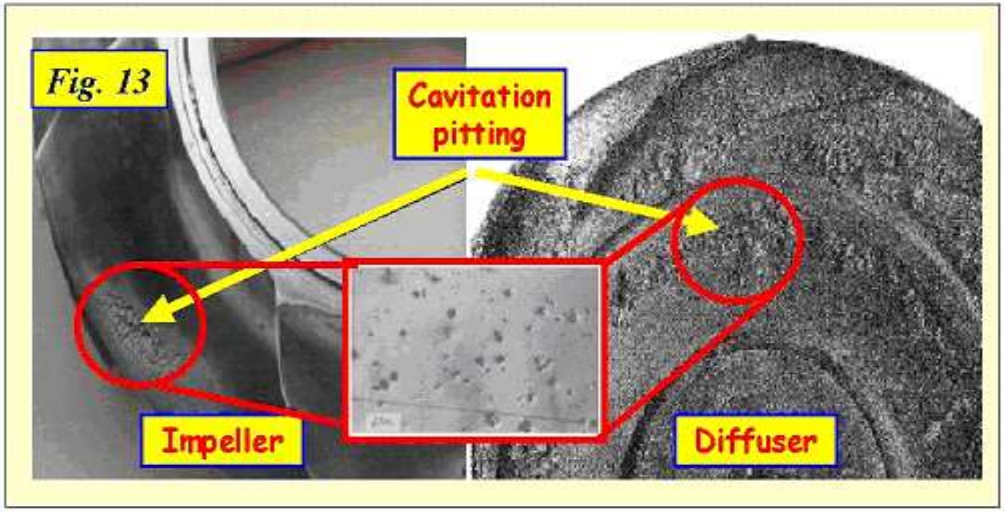


Suction Cavitation - caused by inadequate suction p.

Pump Suction

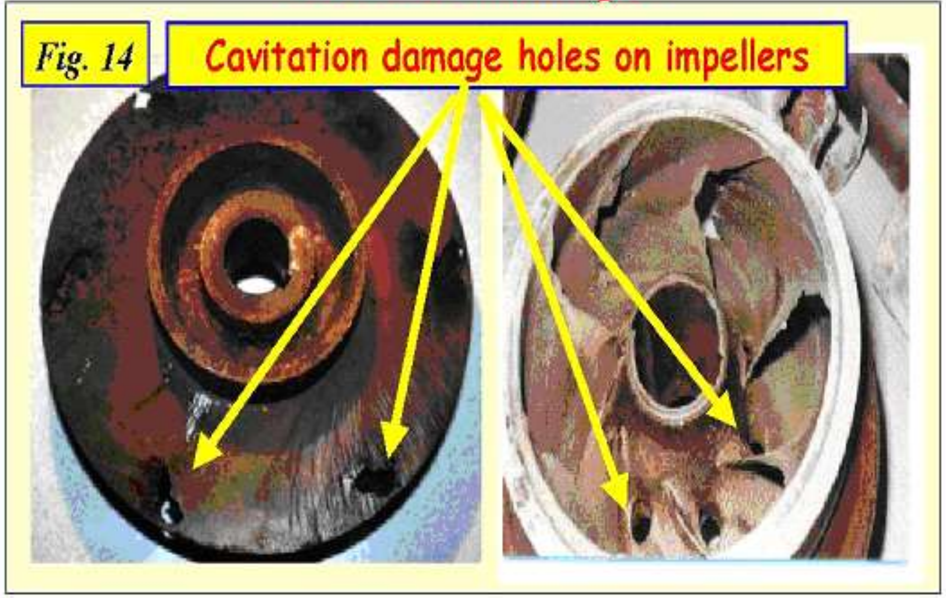


Cavitation pitting



www.cheresources.com

Cavitation damages



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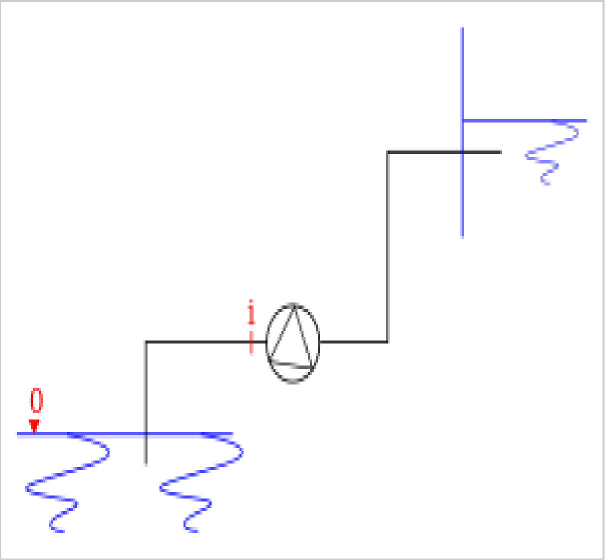
To Avoid Suction Cavitation

NPSH

NPSH$_{AV}$ or *NPSH$_{A}$* **:Actual pressure of the fluid in suction eye of the pump**

$$NPSH_A = \left(\frac{p_i}{\rho g} + \frac{V_i^2}{2g}\right) - \frac{p_v}{\rho g}$$



A simple hydraulic pumping circuit. Point 0 is the free suction surface, and point i is the inlet of the impeller.

USING B. E ELIMINATE VELOCITY TERM

$$NPSH_A = \frac{p_0}{\rho g} - \frac{p_v}{\rho g} - (z_i - z_0) - h_f$$

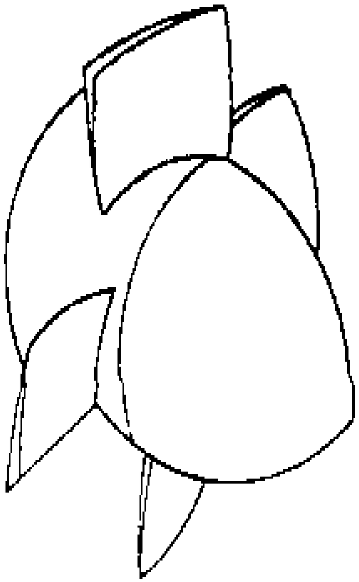
$NPSH_{req}$: **Minimum pressure** needed in the suction eye of the pump in order **to prevent cavitation** (presented by Manufacturer on Pump Data Sheet)

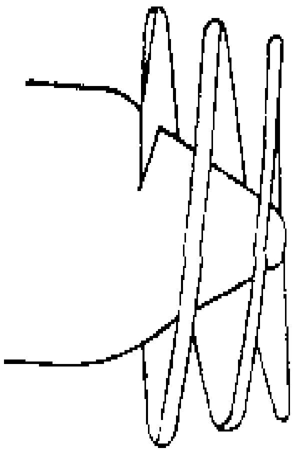
Pumping cold water through the pump while reducing the suction head until the pump showed a reduction in discharge head of three percent (3%), due to the low suction head and any formation of bubbles within the pump

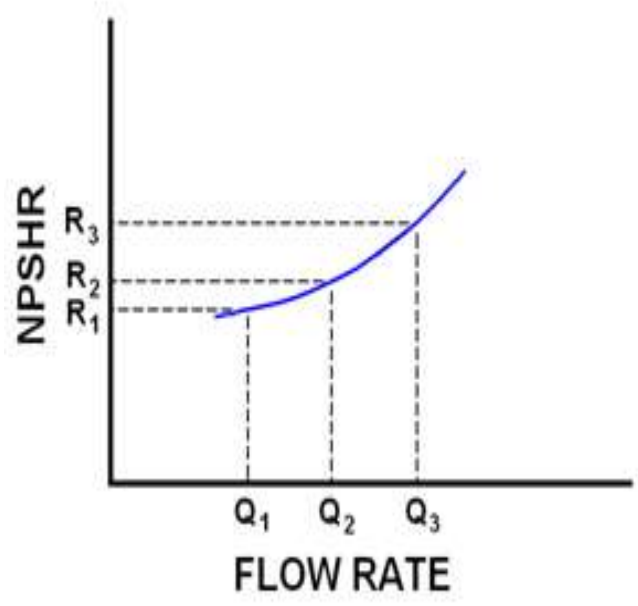
According to British Petroleum NPSHA should be at least 1.5 more than NPSH

Target 1: To reduce the $NPSH_{req}$

1.pump with ***less circular velocity*** / **FLOW**
*2.**more pumps*** or using a ***double-suction eyed pump***
3.specially designed suction-eye propeller (only specific volumetric flow rates)



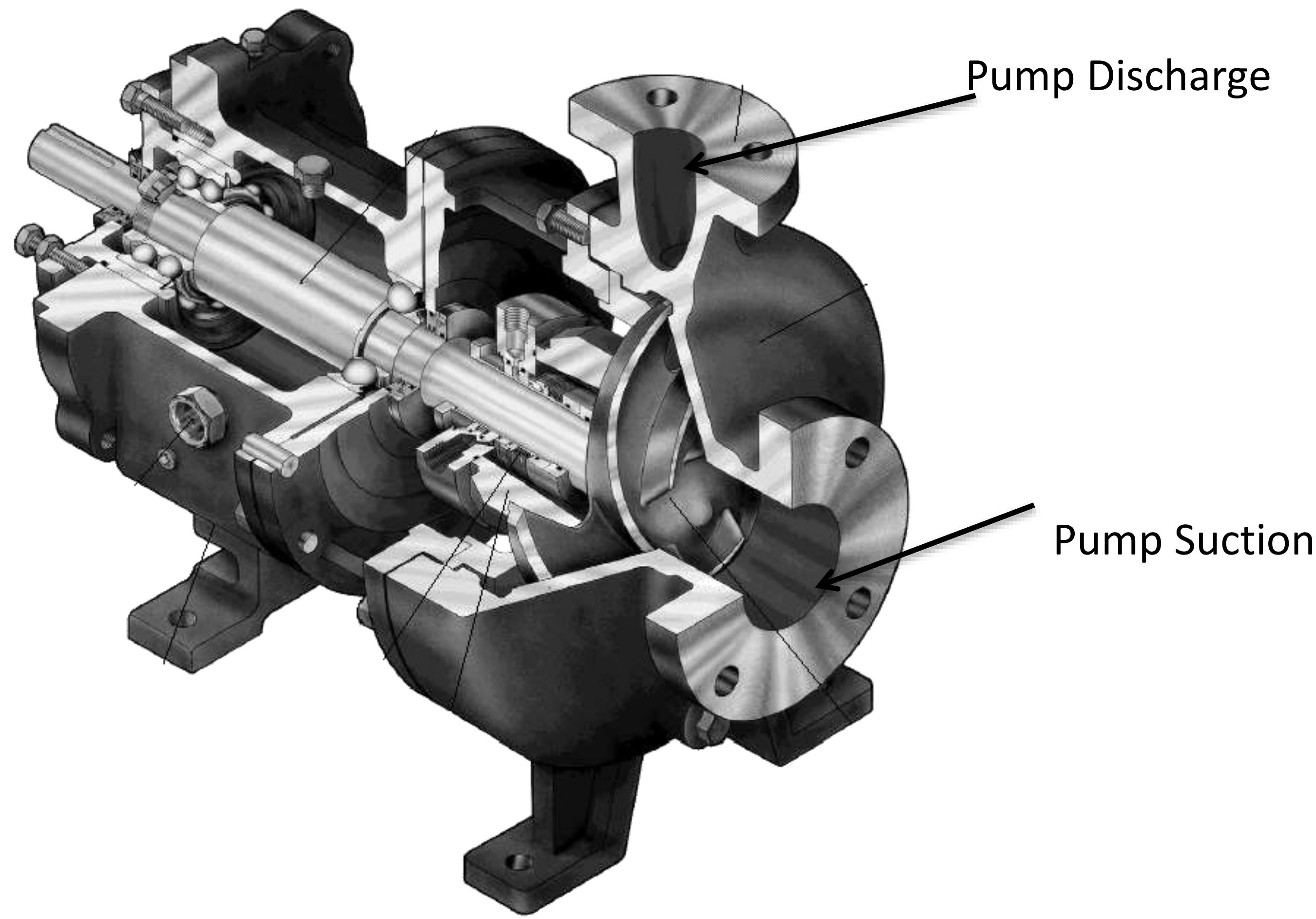




Target 2: To increase the $NPSH_A$

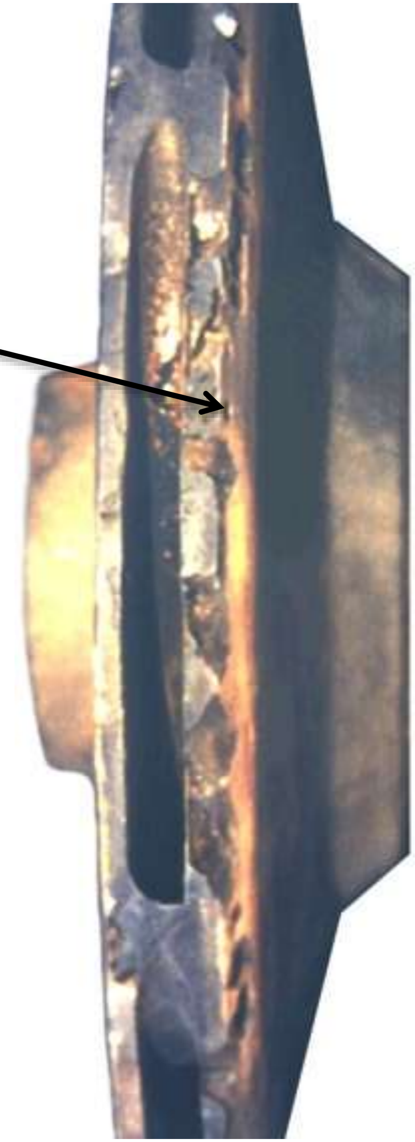
1. To increase pump suction pressure
2. Lower fluid Temperature
3. Low fluid velocity
4. Reducing the losses in suction pipe

Recirculation Cavitation - is caused by low flow through the pump this occurs at suction or discharge of the pump.



Damage Caused by Recirculation Cavitation

Damage to the outside of the impeller, on the outer periphery.



Minimum flow to CFP To Avoid Recirculation Cavitation

The pump shall be protected from minimum flow (30% of rated flow)
1. Thermal consideration which has effect to the pump efficiency (The efficiency will decrease significantly at low flow)

2. Internal recirculation will be occurred

3. Increase load impeller (both axial and radial)

4. liquid containing a large amount of abrasive particles must flow continuously through the pump. at low flow, the particles can circulate inside the pump and erode the

Three types of pump recycle systems

1. Continuous recycle system --> **use Orifice**
2. Control loop system and --> **use Control Valve**
3. Automatic recycle system. --> **use ARC**

1. ORIFICE

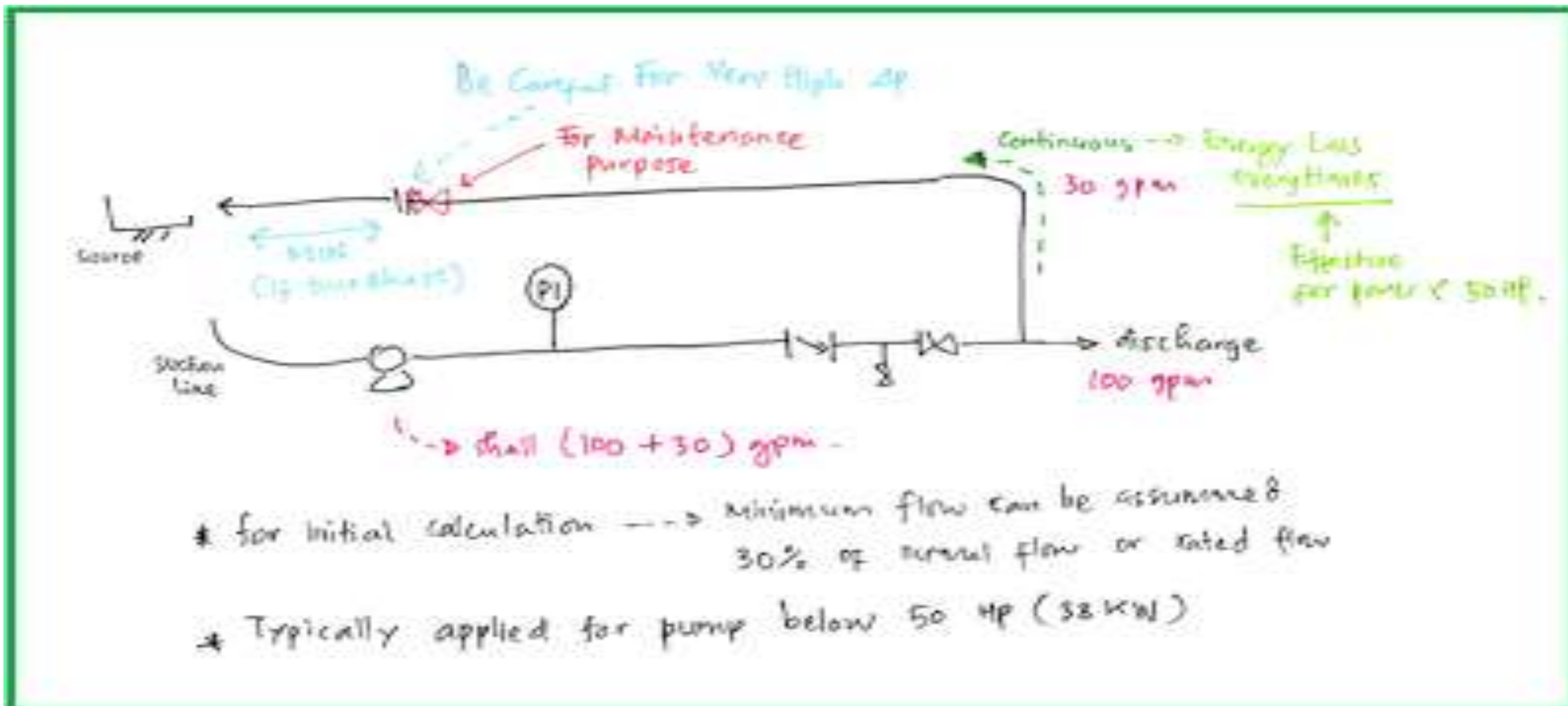
This system will provide continuous recycle flow whenever pump is running, regardless of the process demand.

Typically applied for pump below 50 hp (38kW), or small capacity.

Don't forget, you must consider the additional capacity of the pump (**the capacity is included recycle flow**)

For initial estimation, 30% of rated flow can be used as recycle flow basis.

Take care for high pressure drop condition, is there any flashing? Two phase? Or vibration? If two phases is occurred, the orifice should be located at the end of the recycle line.

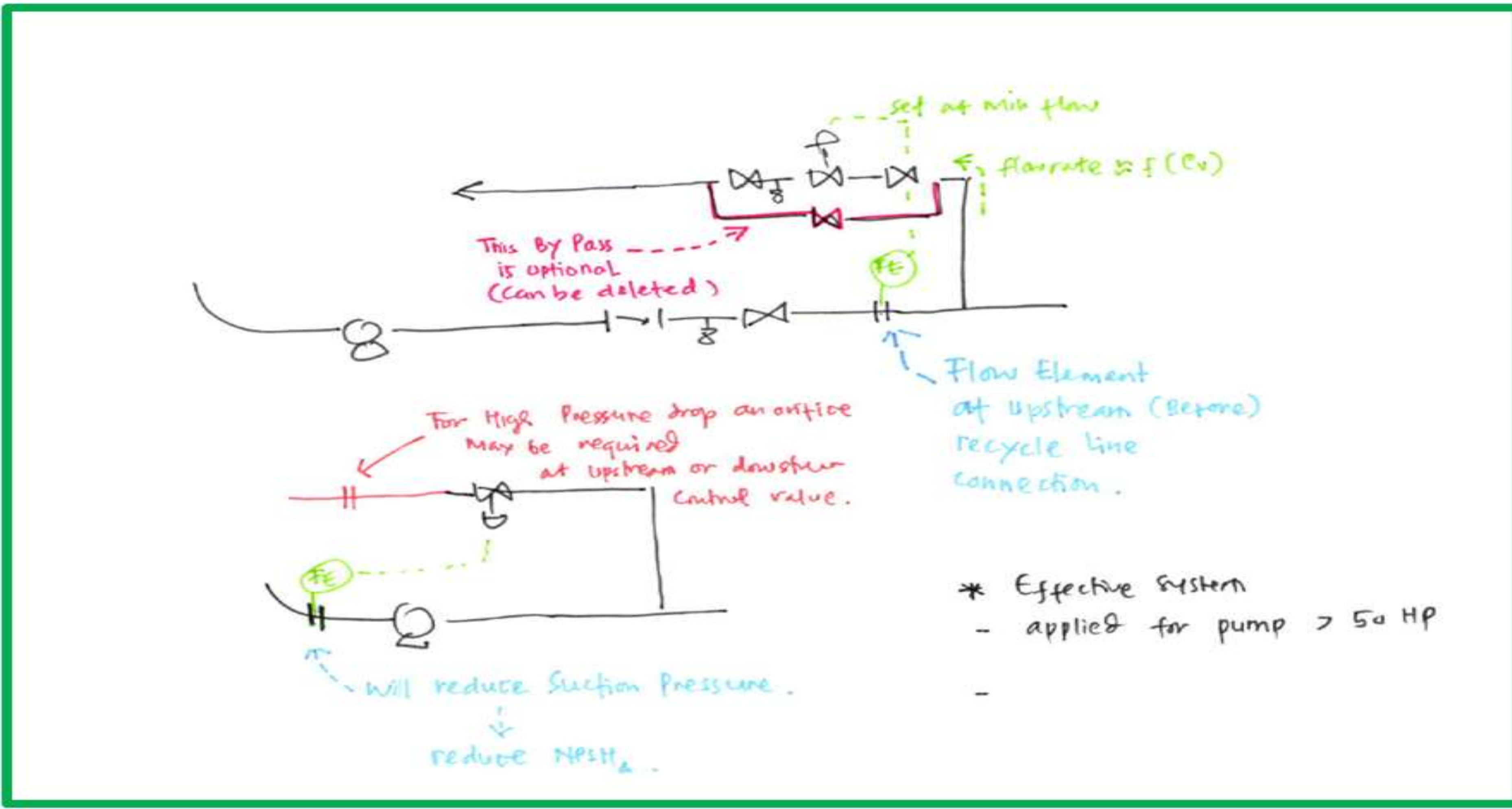


2. CONTROL VALVE

When the minimum flow is reached, the valve start to open. The flowmeter shall be located at pump discharge side (installing at suction side will decrease the suction pressure, decrease NPSHa)

The flow meter should be located before(upstream the) recycle line connection.

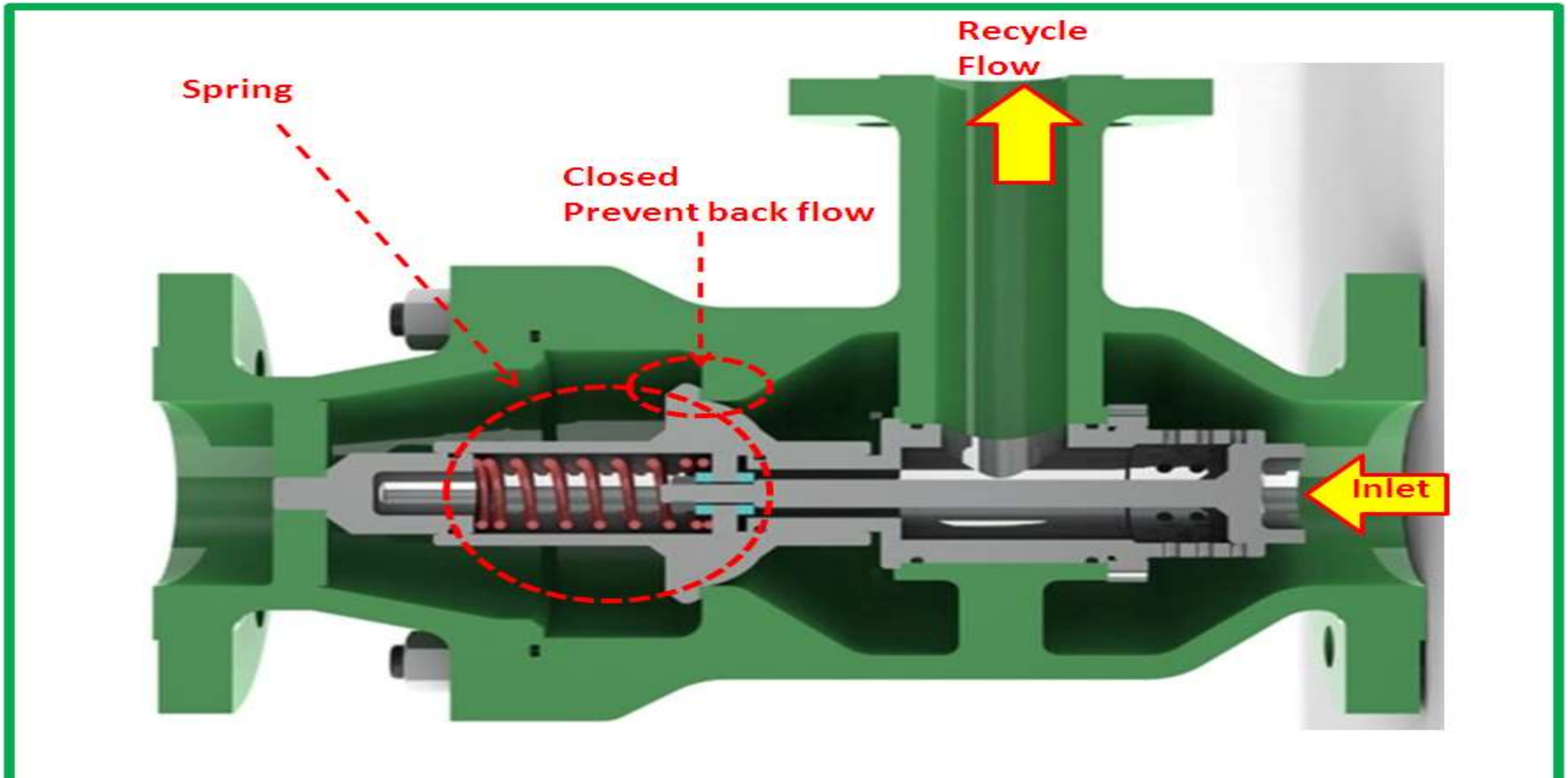
Be careful with high pressure drop, control valve may be noise and vibration (an orifice in series with the control valve may be required)p



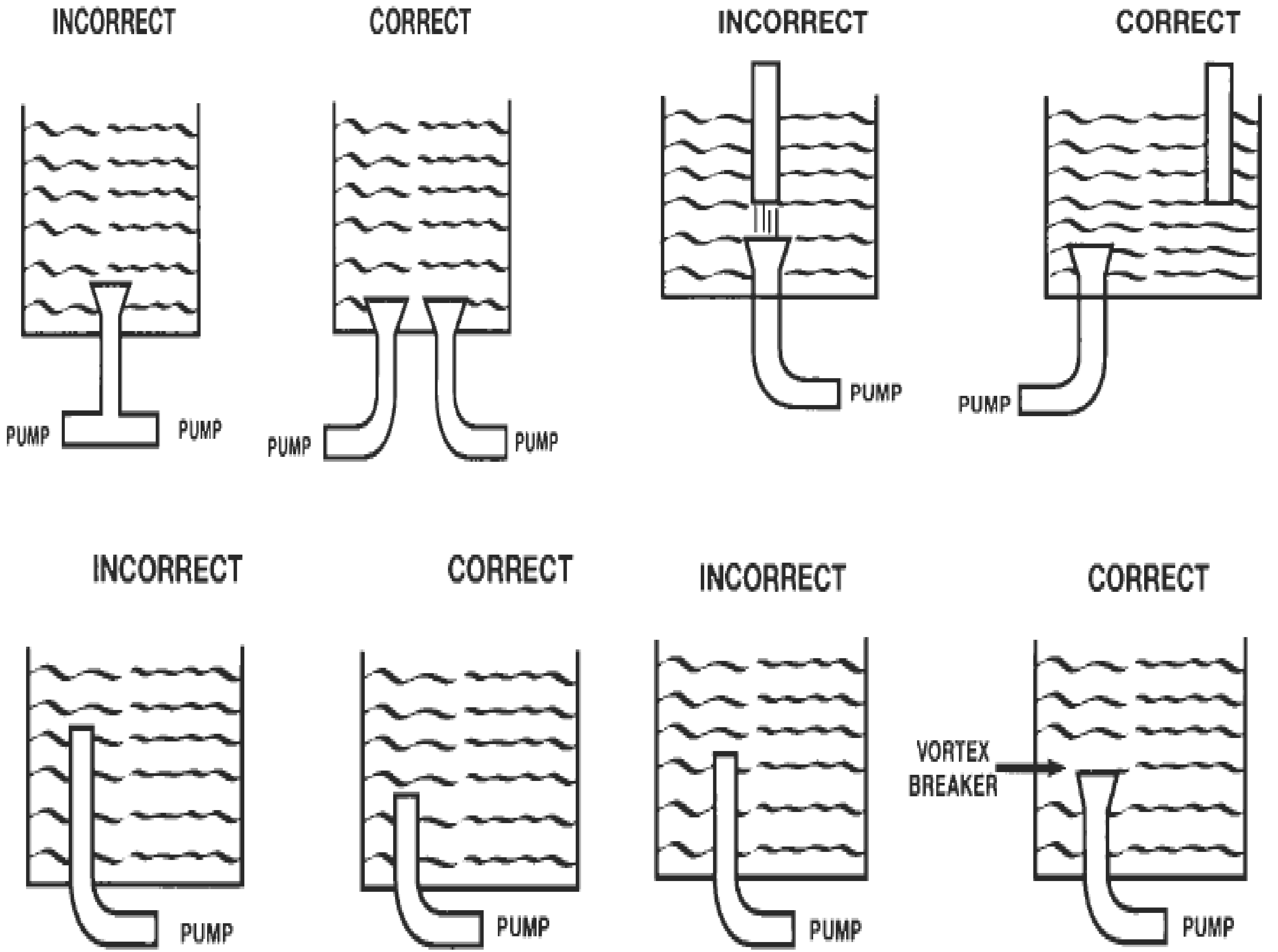
AUTOMATIC RECIRCULATION

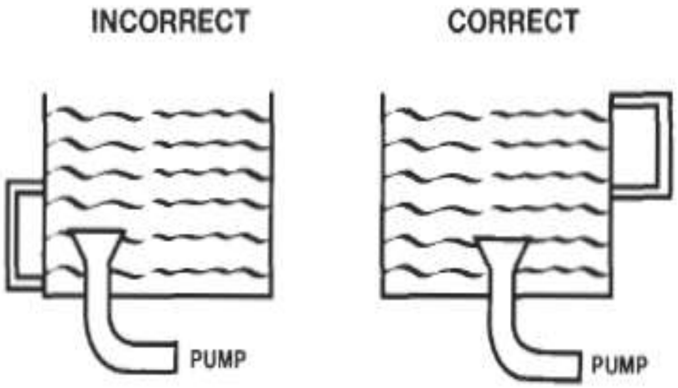
This type is the spring loaded, combined recycle and check valve

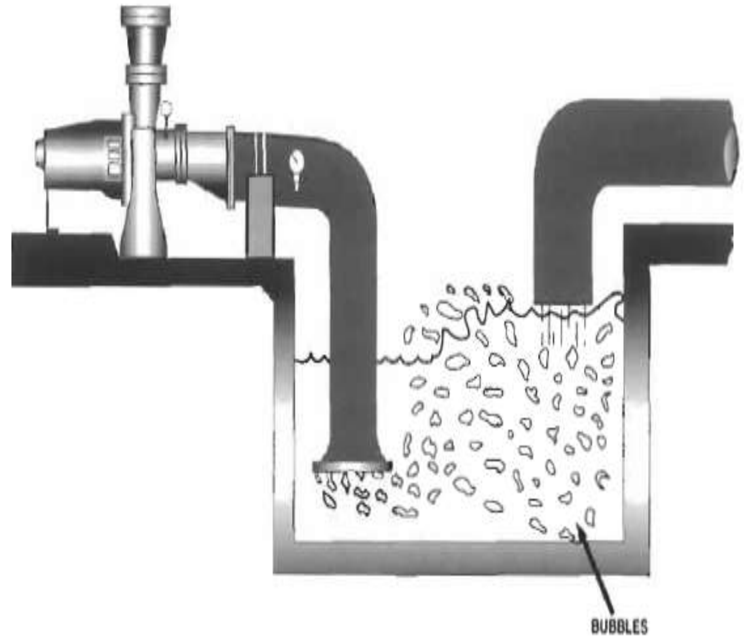
The spring loaded is set at a pressure correspond to minimum flow (based on pump curve) where the recycle starts to open.



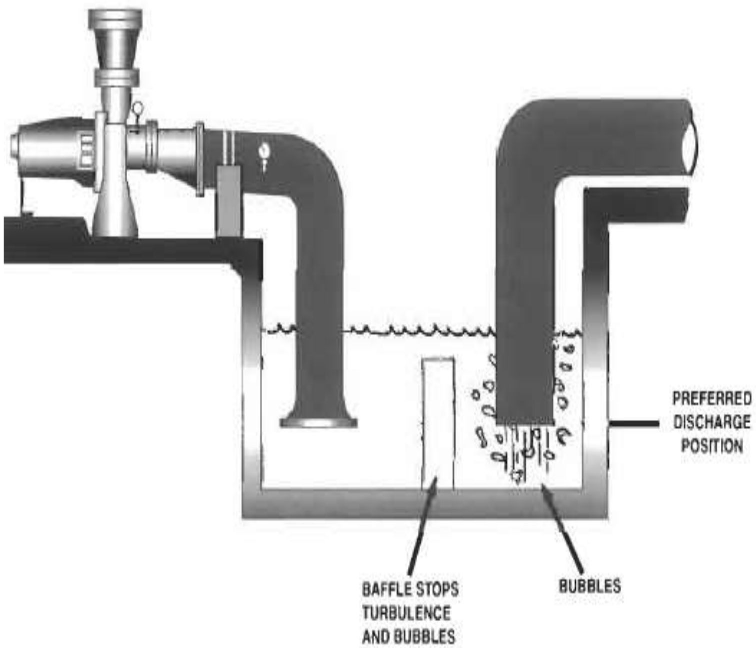
Pump Piping Corrections



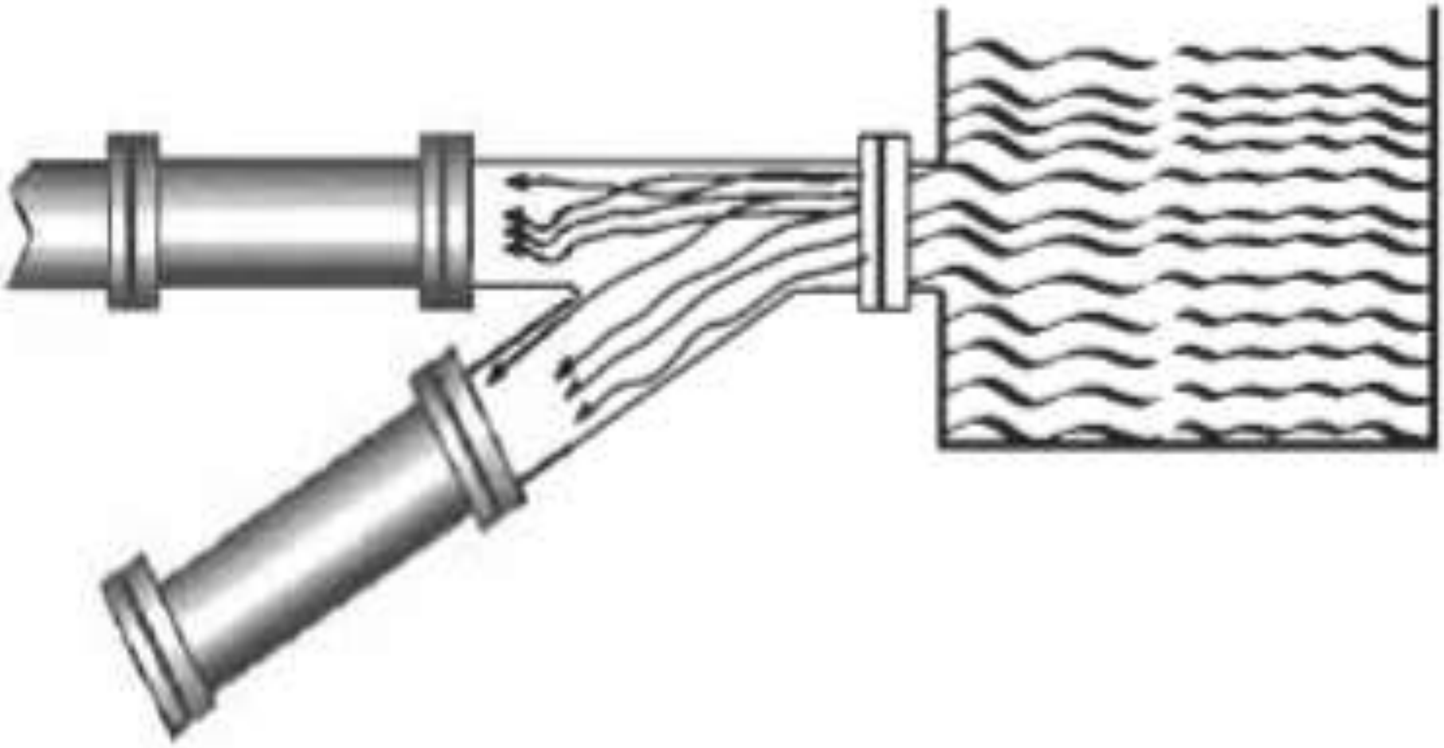




Inadequate design ,
bubbles entrained



Prefer Y branch rather than T to reduce turbulent



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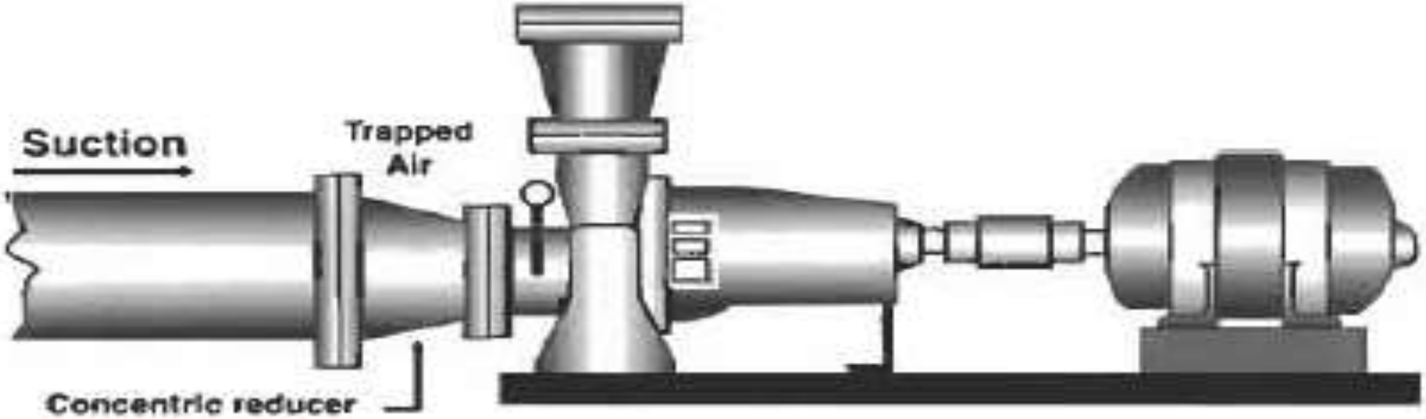

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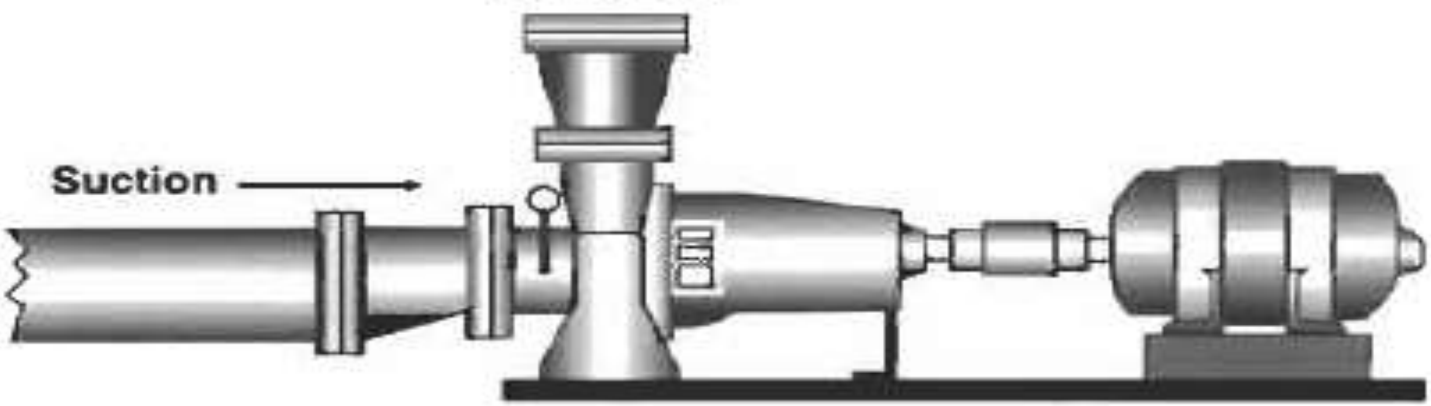


Main pump components

- **Pumps**
- **Prime movers: electric motors, diesel engines, air system**
- **Piping to carry fluid**
- **Valves to control flow in system**
- **Other fittings, control, instrumentation**

End-use equipment

- **Heat exchangers, tanks, hydraulic machines**

Energy Efficiency in pump systems

Energy Efficiency Opportunities

1. Selecting the right pump
2. Controlling the flow rate by speed variation
3. Pumps in parallel to meet varying demand
4. Eliminating flow control valve
5. Eliminating by-pass control
6. Start/stop control of pump
7. Impeller trimming

1. Selecting the Right Pump

- **Oversized pump**
  - **Requires flow control (throttle valve or by-pass line)**
  - **Provides additional head**
  - **System curve shifts to left**
  - **Pump efficiency is reduced**
- **Solutions if pump already purchased**
  - **VSDs or two-speed drives**
  - **Lower RPM**
  - **Smaller or trimmed impeller**

2. Controlling Flow: speed variation

Explaining the effect of speed

- **Affinity laws: relation speed N and**
  - **Flow rate Q α N**
  - **Head H α N^2**
  - **Power P α N^3**
- **Small speed reduction (e.g. ½) = large power reduction (e.g. 1/8)**

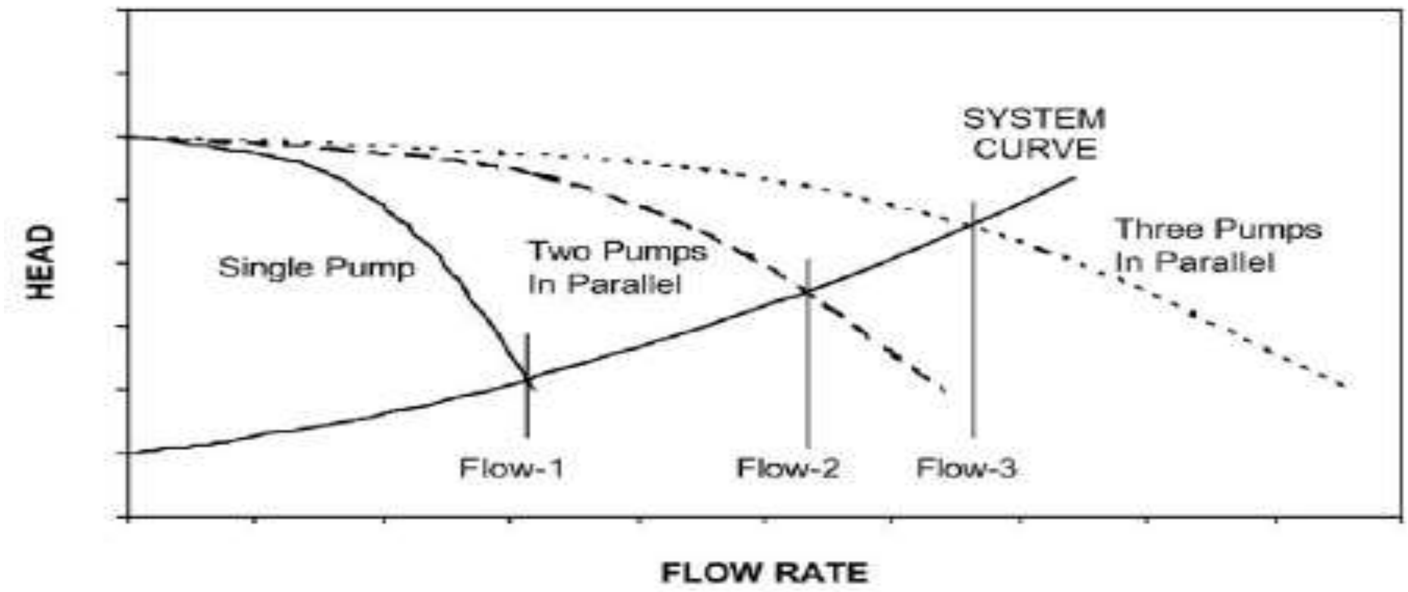
2. Controlling Flow : speed variation

Benefits of VSDs

- **Energy savings *(not just reduced flow!)***
- **Improved process control**
- **Improved system reliability**
- **Reduced capital and maintenance costs**
- **Soft starter capability**

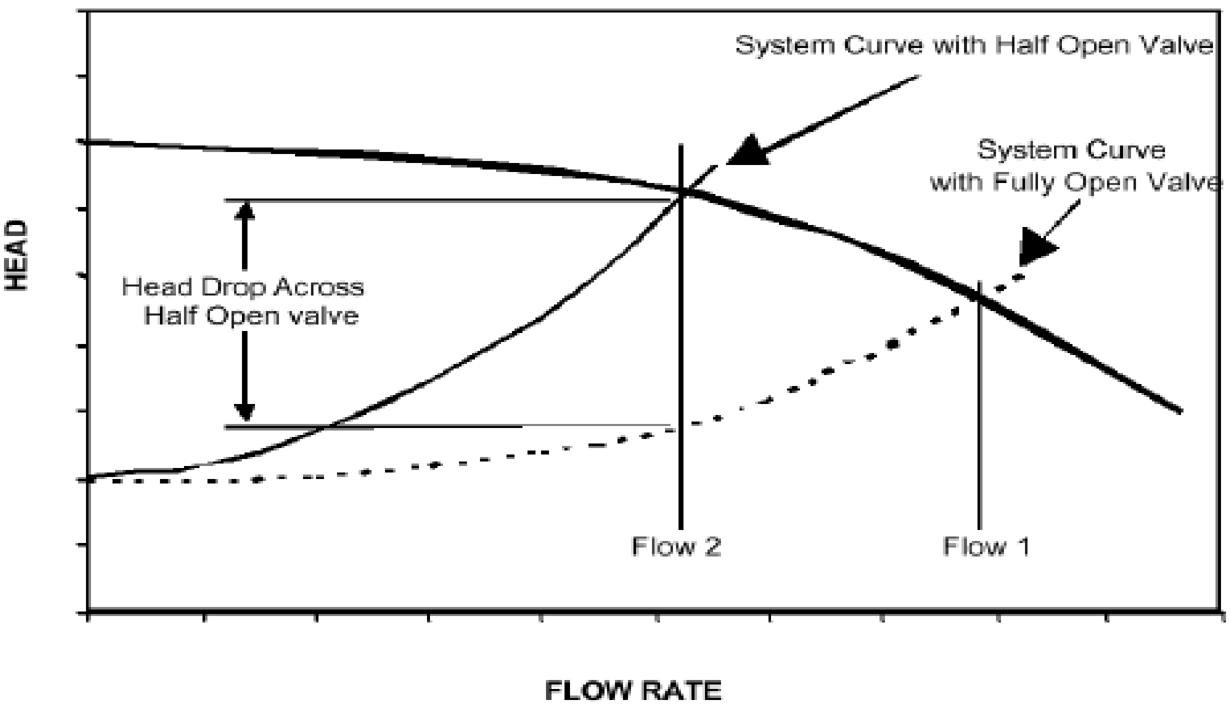
3. Parallel Pumps for Varying Demand

- Multiple pumps: some turned off during low demand
- Used when static head is >50% of total head
- System curve does not change
- Flow rate lower than sum of individual flow rates



4. Eliminating Flow Control Valve

- **Closing/opening discharge valve ("throttling") to reduce flow**
- **Head increases: does not reduce power use**
- **Vibration and corrosion: high maintenance costs and reduced pump lifetime**



5. Eliminating By-pass Control

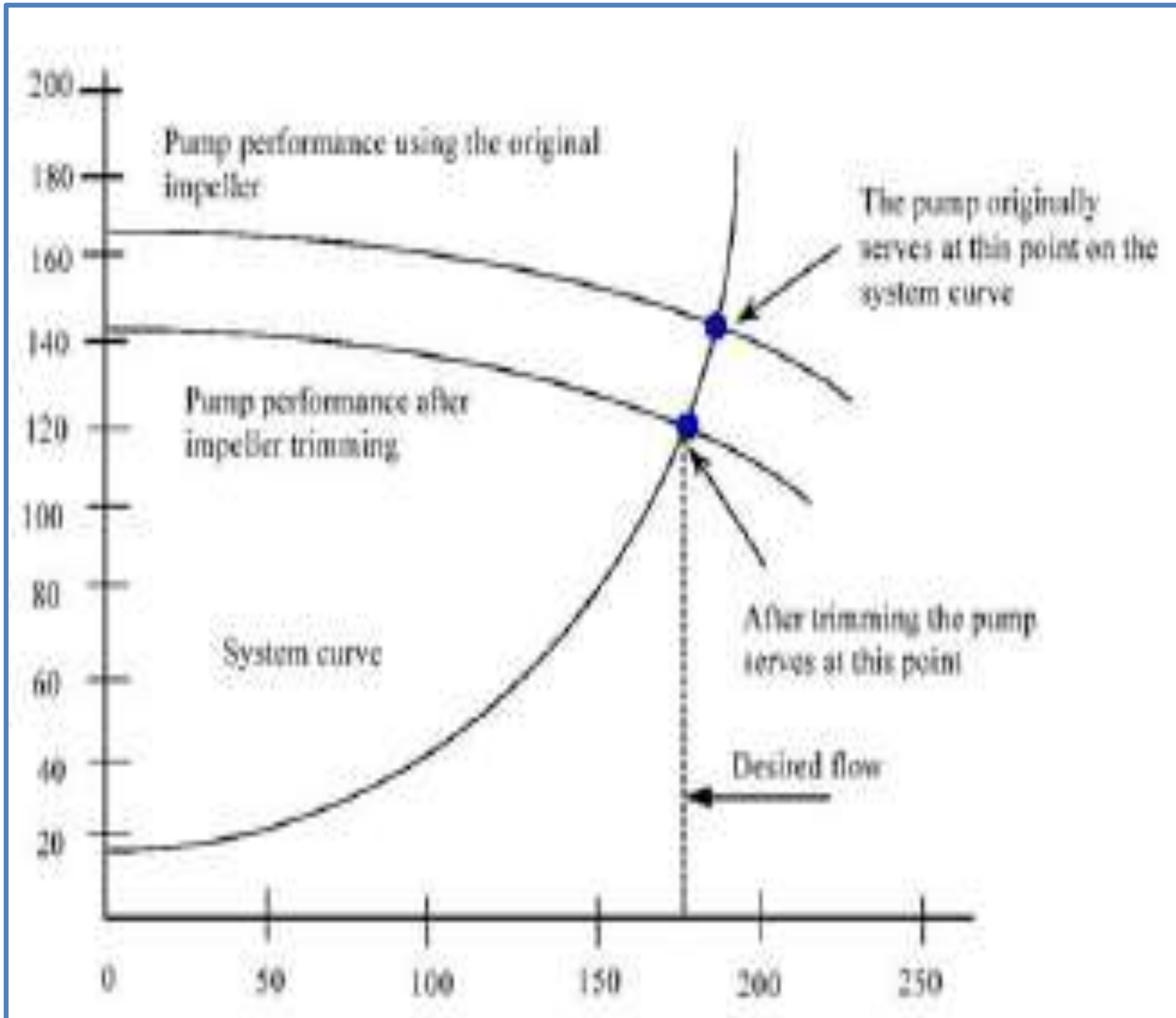
- Pump discharge divided into two flows
  - One pipeline delivers fluid to destination
  - Second pipeline returns fluid to the source
- Energy wastage because part of fluid pumped around for no reason

6. Start / Stop Control of Pump

- **Stop the pump when not needed**
- **Example:**
  - **Filling of storage tank**
  - **Controllers in tank to start/stop**
- **Suitable if not done too frequently**
- **Method to lower the maximum demand (pumping at non-peak hours**

7. Impeller Trimming

- **Changing diameter: change in velocity**
- **Considerations**
  - **Cannot be used with varying flows**
  - **No trimming >25% of impeller size**
  - **Impeller trimming same on all sides**
  - **Changing impeller is better option but more expensive and not always possible**



200
180
160
140
120
100
80
60
40
20
0
50
100
150
200
250
Pump performance using the original impeller
Pump performance after impeller trimming
System curve
The pump originally serves at this point on the system curve
After trimming the pump serves at this point
Desired flow

Comparing Energy Efficiency Options

Parameter	Change control valve	Trim impeller	VFD
Impeller diameter	430 mm	375 mm	430 mm
Pump head	71.7 m	42 m	34.5 m
Pump efficiency	75.1%	72.1%	77%
Rate of flow	80 m^3/hr	80 m^3/hr	80 m^3/hr
Power consumed	23.1 kW	14 kW	11.6 kW

PUMP SCALE UP

1.Geometric Similarity : If 2 PUMPS are geometrically similar

2.Dynamic Similarity : if independent parameters are equal i.e. C_Q, Re, (Ea/D)

$$\frac{Q_1}{Q_2} = \frac{n_1}{n_2} \qquad \frac{H_1}{H_2} = \frac{n_1^{\ 2}}{n_2^{\ 2}} \qquad \frac{P_1}{P_2} = \frac{n_1^{\ 3}}{n_2^{\ 3}}$$

$$\frac{Q_1}{Q_2} = \frac{D_1^{\ 3}}{D_2^{\ 3}} \qquad \frac{H_1}{H_2} = \frac{n_1^{\ 2}}{n_2^{\ 2}} \qquad \frac{P_1}{P_2} = \frac{n_1^{\ 3}}{n_2^{\ 3}}$$

But efficiency of scaled up pump is always higher than small one given by

Moody efficiency correction equation for pumps:

$$\boxed{\eta_{\text{pump, prototype}} \cong 1 - (1 - \eta_{\text{pump, model}})\left(\frac{D_{\text{model}}}{D_{\text{prototype}}}\right)^{1/5}}$$

Positive Displacement Pumps

For

- Low capacity and High pressure, low pumpage velocities those mostly **beyond the capabilities of centrifugal pumps.**

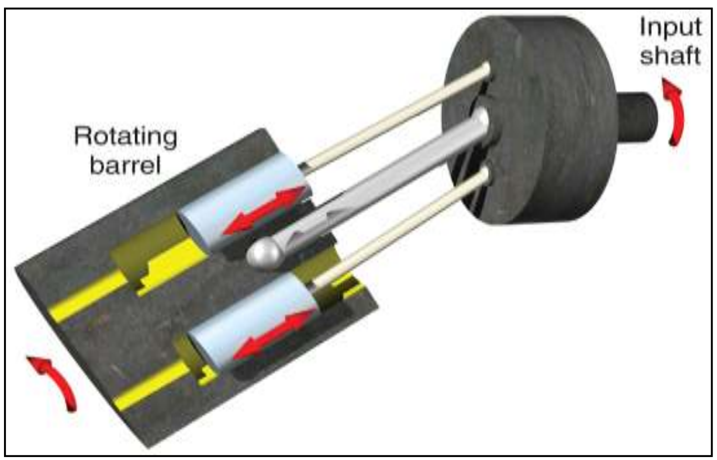
- Well-suited for abrasive-slurry and high-viscosity services.

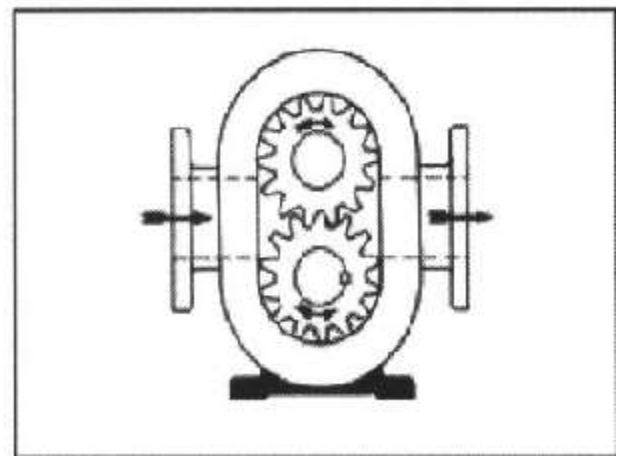
Positive Displacement Pumps

2 major classes PDP

Rotary

Reciprocating





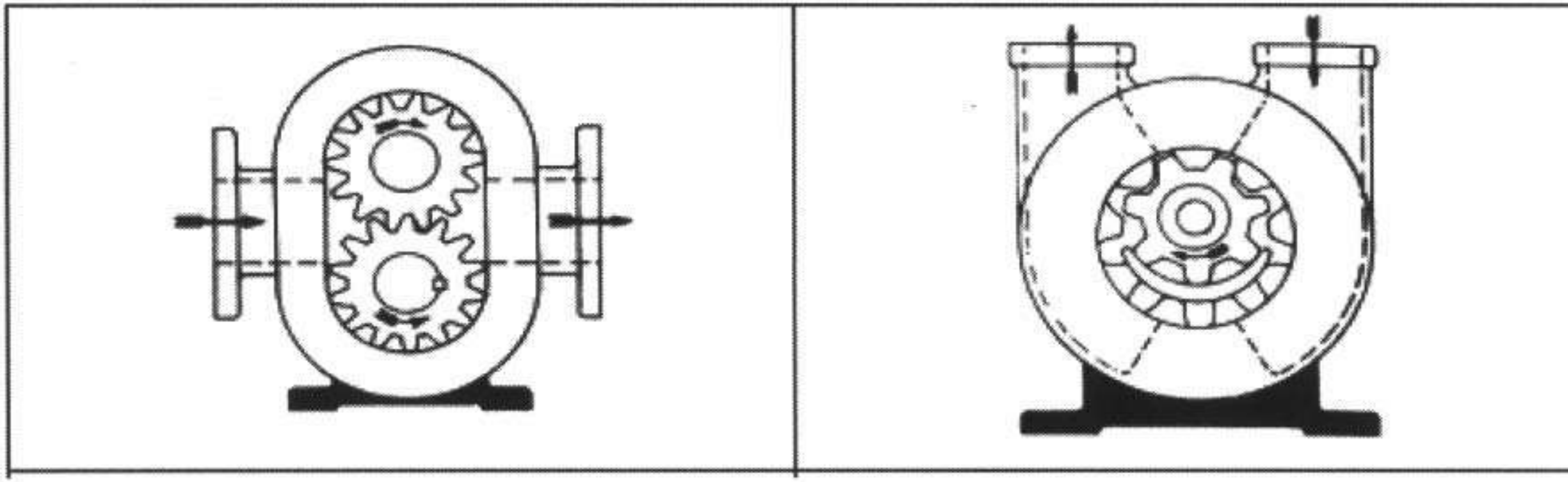
Reciprocating

Rotary

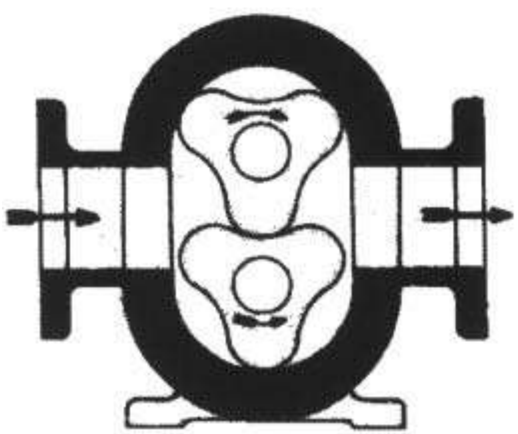
Parameter	Reciprocating Pumps	Rotary Pumps
Capacity	Low	Low/Medium
Pressure (Head)	High	Low/Medium
Maximum Flow Rate	10,000+ GPM	10,000+ GPM
Maximum Pressure	100,000+ PSI	4,000 PSI
Requires Relief Valve	Yes	Yes
Flow Type	Constant	Constant
Flow Characteristic	Pulsating	Smooth
Space Considerations	Requires More Space	Requires Less Space
Initial Costs	Higher	Lower
Maintenance Costs	Higher	Lower
Energy Costs	Lower	Lower
Liquids Recommended	Viscous liquids, dirty chemicals, tacky glue and adhesives, oil, and lubricating fluids. Specialty fitted pumps can handle abrasives.	Optimum for viscous fluids. Requires clean, clear, non-abrasive fluid due to close tolerances.

Pump Type	Advantages	Disadvantages	Media
Gear	Few moving parts; simple construction	Can't handle solids-filled media	Clean, viscous fluids
Lobe	Sanitary options; gentle pumping action	Reduced lift with thin liquids	Viscous, shear sensitive fluids. Fluids containing fragile solids
Peristaltic	Seal-less; no leakage; no contamination; low maintenance	Can't handle abrasives	Corrosive, viscous, solids-containing, shear sensitive fluids
Screw	High-flow rates; low fluid velocity/turbidity	High cost; large size required for high pressure	Viscous, two-phase (liquid + gas) fluids
Vane	Good vacuum; peak performance even with non-lubricating media	Complex housing and many parts; can't handle abrasives; not suitable for high pressures	Thin liquids. Gases, solvents, aqueous solutions, alcohols, aerosol and propellants

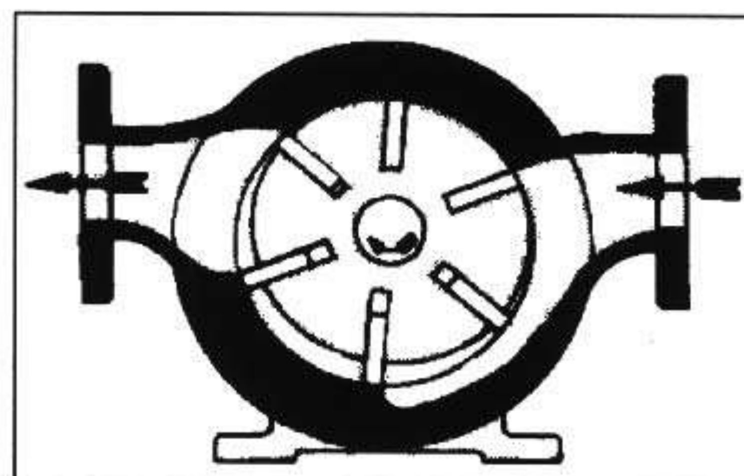
External gear pump (left) and Internal gear pump (right)



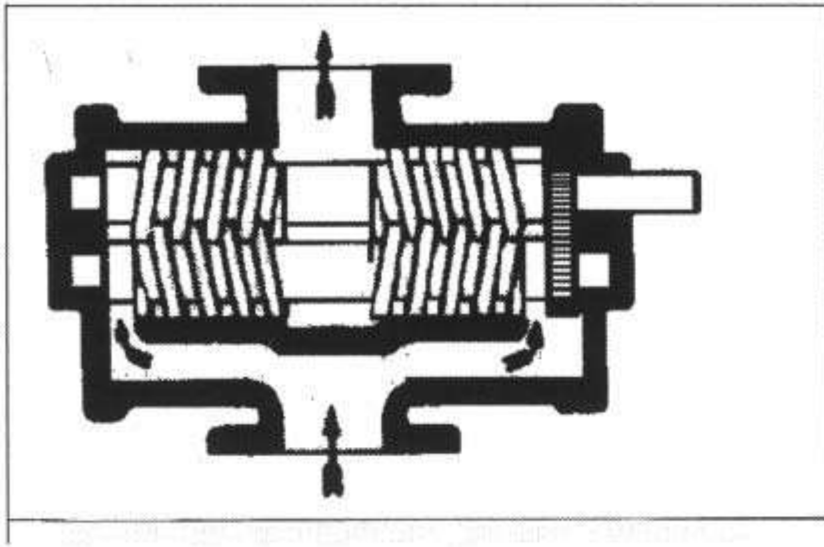
Lobe Pump

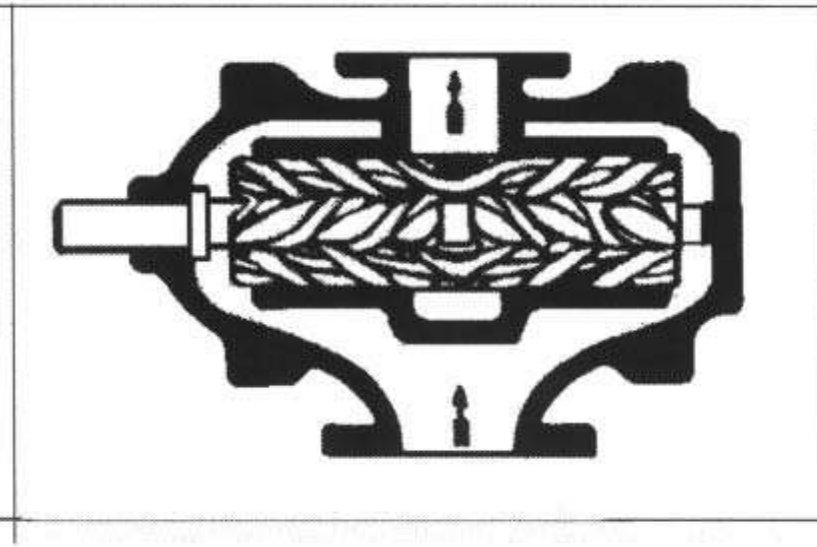


Vane Pumps

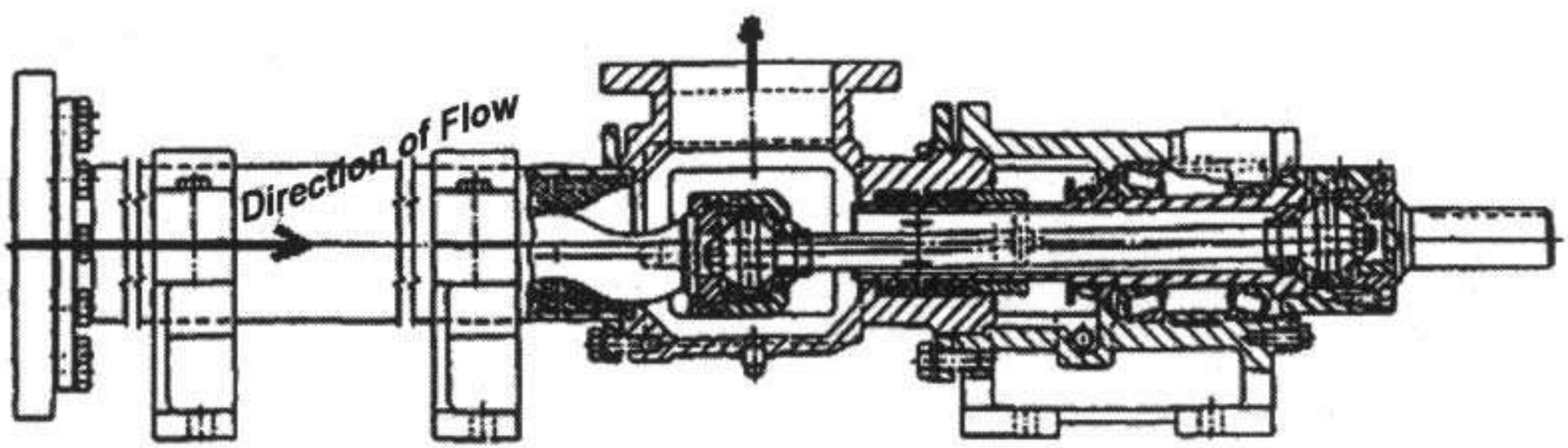


Two-screw pump (left) and Three-screw pump (right)

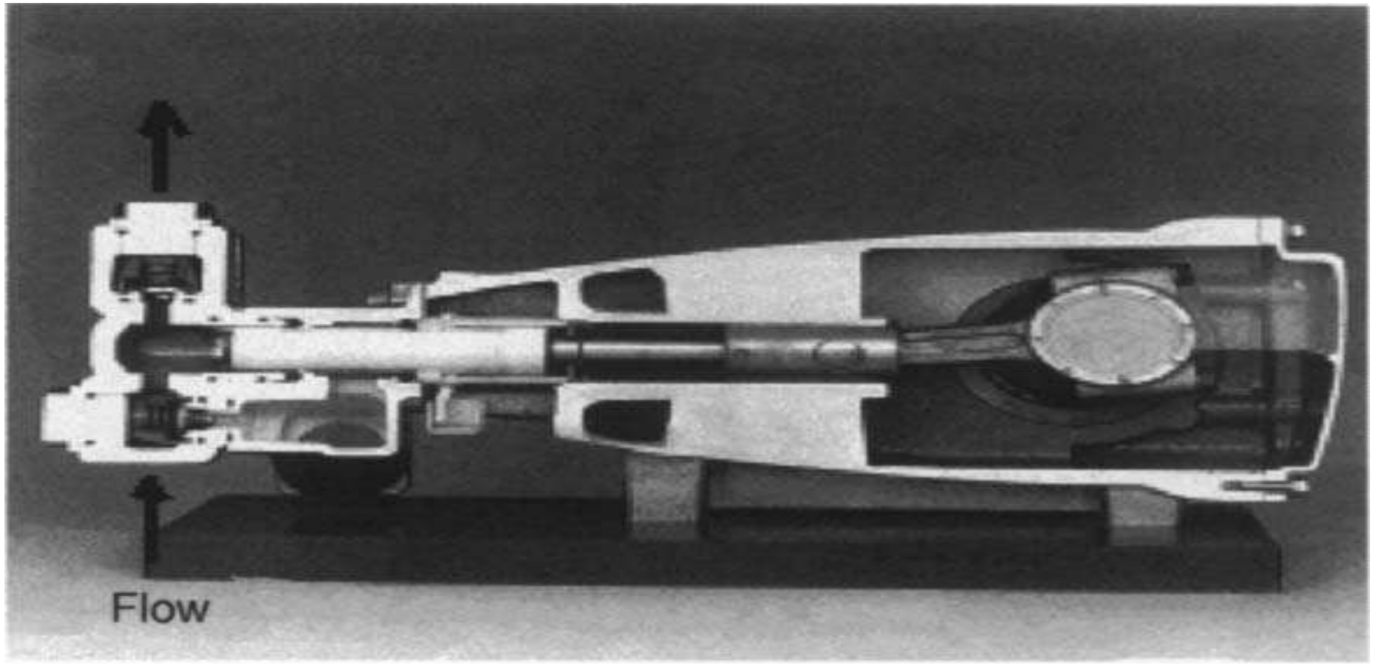




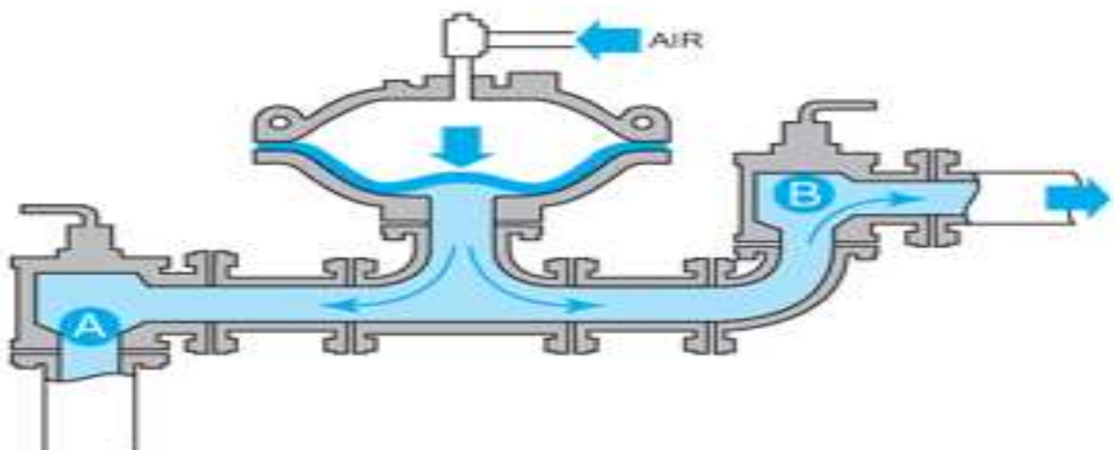
Progressive Cavity pump



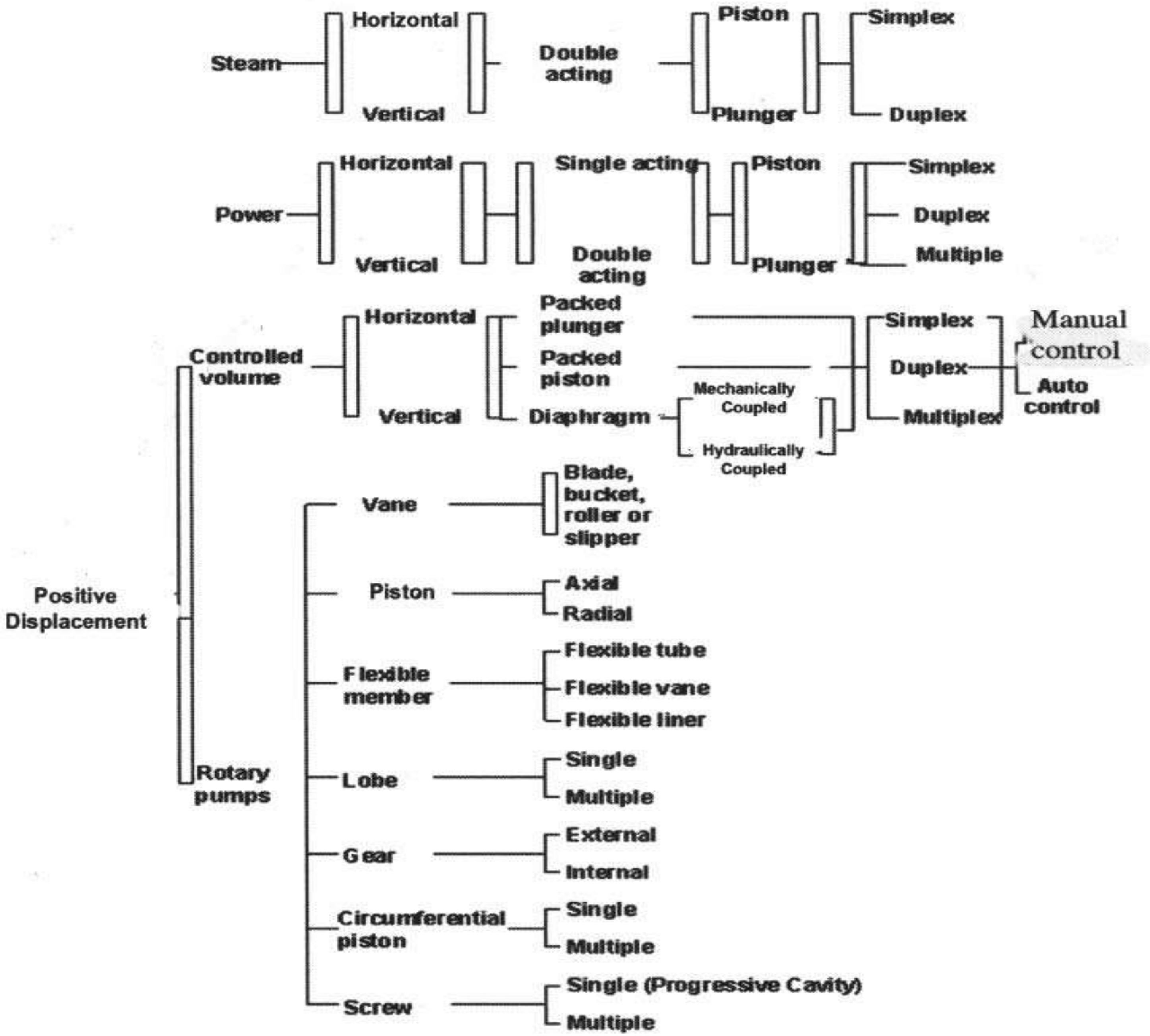
Piston/Plunger Pumps



diaphragm pump



All Types of PDP



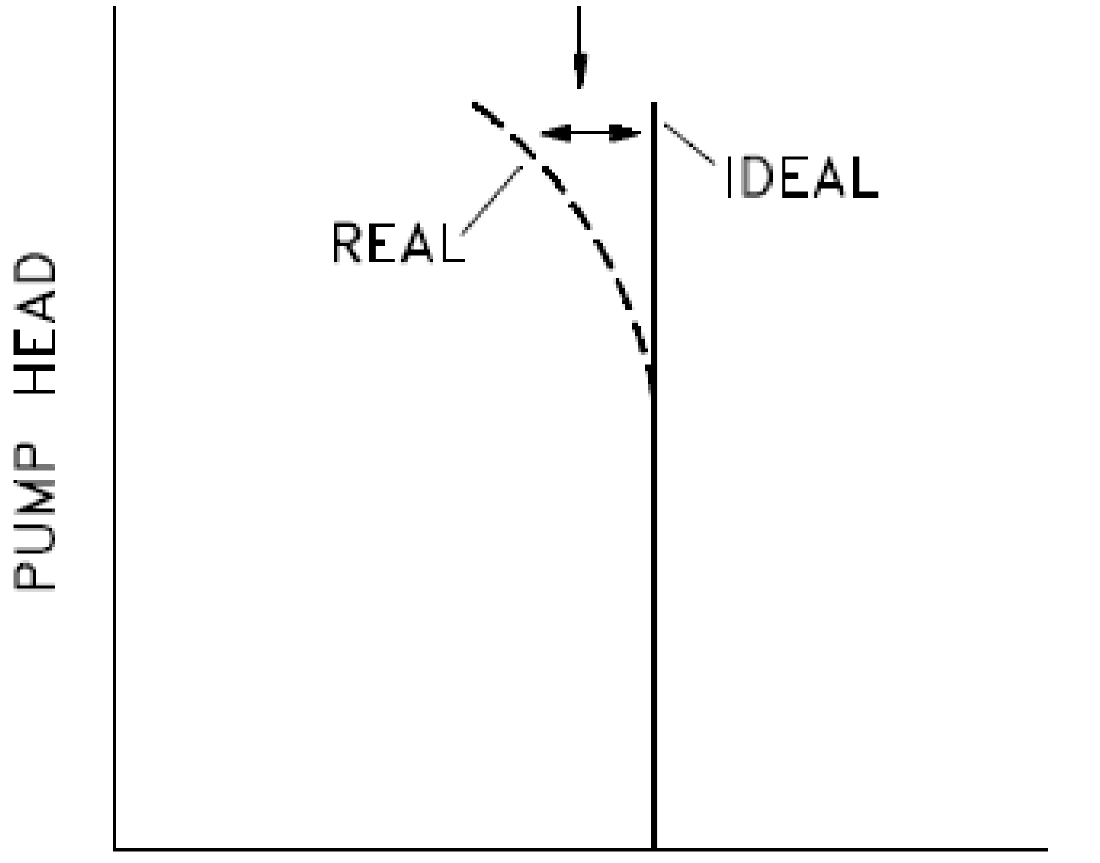
ADVANTAGE OF POSITIVE DISPLACEMENT PUMP

1. The working fluid is highly viscous
2. The system requires high-pressure, low-flow pump performance
3. The pump must be self-priming
4. The working fluid must not experience high shear forces
5. The flow must be metered or precisely controlled
6. Pump efficiency is highly valued

DISADVANTAGE OF POSITIVE DISPLACEMENT PUMP

- Require more system safeguards, such as relief valves, Rupture disc etc
- Higher costs of power and maintenance

Slippage problem



Positive displacement pumps do not utilize fluid momentum, meaning that flow rate is relatively independent of pump head.

Slippage high discharge pressures causing some liquid to leak back to the pump suction, reducing capacity.

Net Positive Inlet Pressure (NPIP)

Minimum required pressure (or equivalent NPIPR) as such where 5% of the flow reduction occurs due to cavitations.

NPIP is analogous to that of NPSH (defined in pressure terms)

NPIP = (pump inlet pressure) –(fluid vapor pressures)

Velocity head portion (dynamic head) ignored since PD pumps typically operate in systems with low inlet velocities

Efficiency

Overall pump efficiency assessment has not been as widely used with PDP as with CFP

Volumetric efficiency has been a much more common method of comparison between different designs and applications

$$\eta_{vol} = \frac{Q_o - Q_{slip}}{Q_o}$$

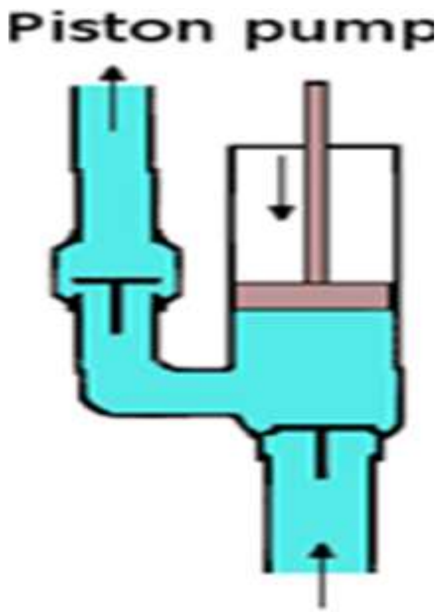
$Q_a = Q_o - Q_{slip}$

Q_a -Pump net flow, gpm

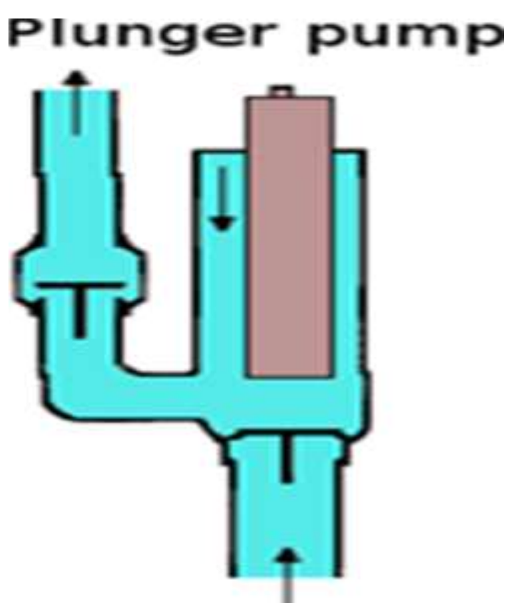
Q_o -Pump theoretical flow, gpm (disregarding slip)

Q_{slip} -Pump slip (gpm)

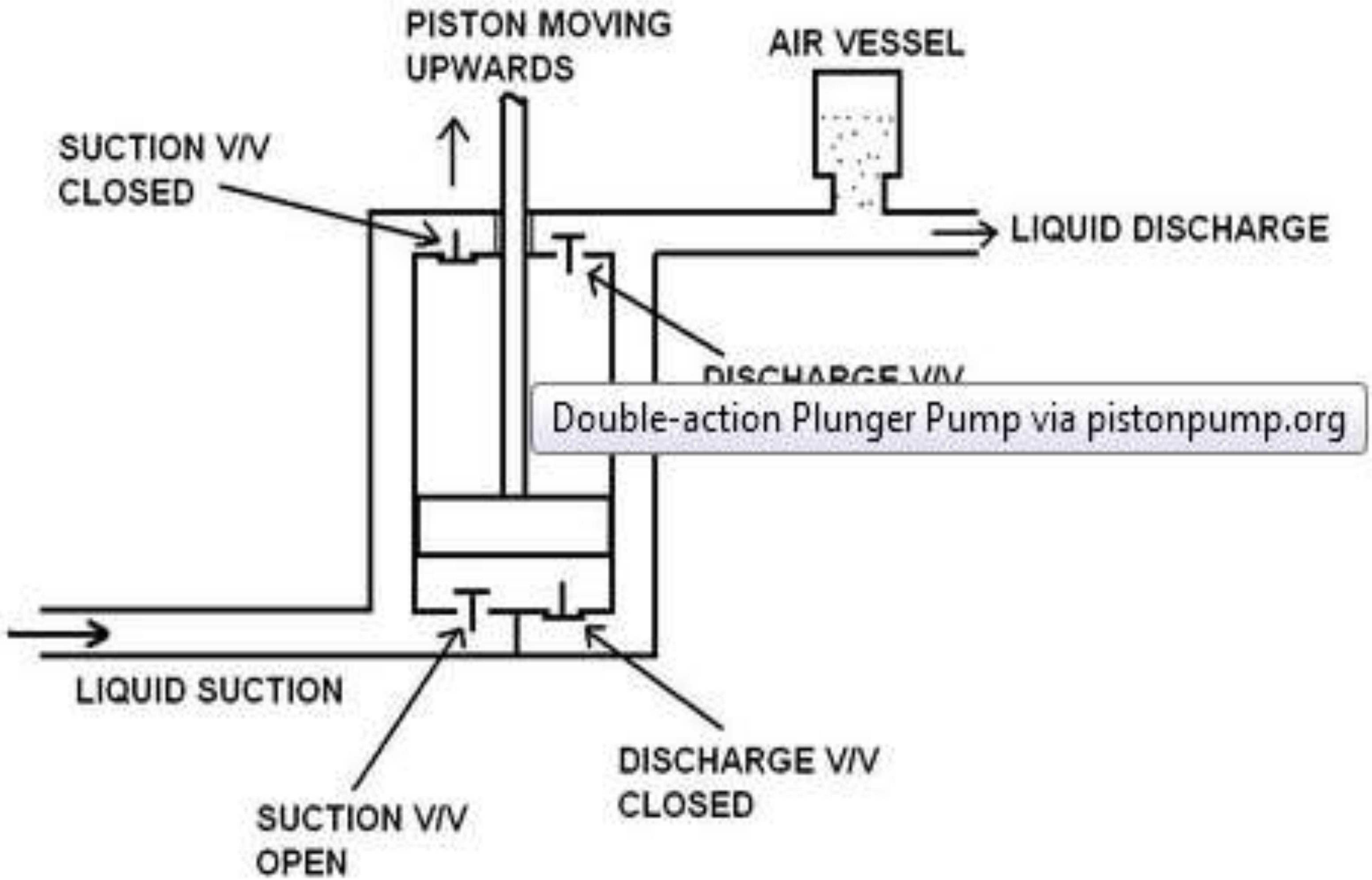
Piston & Plunger Pumps - contracting and expanding cavities to move fluids. Specifically, they are reciprocating pumps



Piston pumps are capable of drawing their own liquid. The inlet pressure range ***of a piston pump is -8.5 psig to 40 psig for proper operation***. Piston pumps work in an output ***pressure range from 100-1200 psi***



Plunger Pump can handle a slightly higher inlet pressure than a piston pump (60-70 psi), but ***requires a flooded inlet*** or pressure supply from a booster pump. Select a plunger pump for high pressure applications. Plunger pumps operate in an ***output pressure range from 100-10,000 psi***.



Double-action plunger pump. *Image Credit: pistonpump.org*

Axial piston pumps

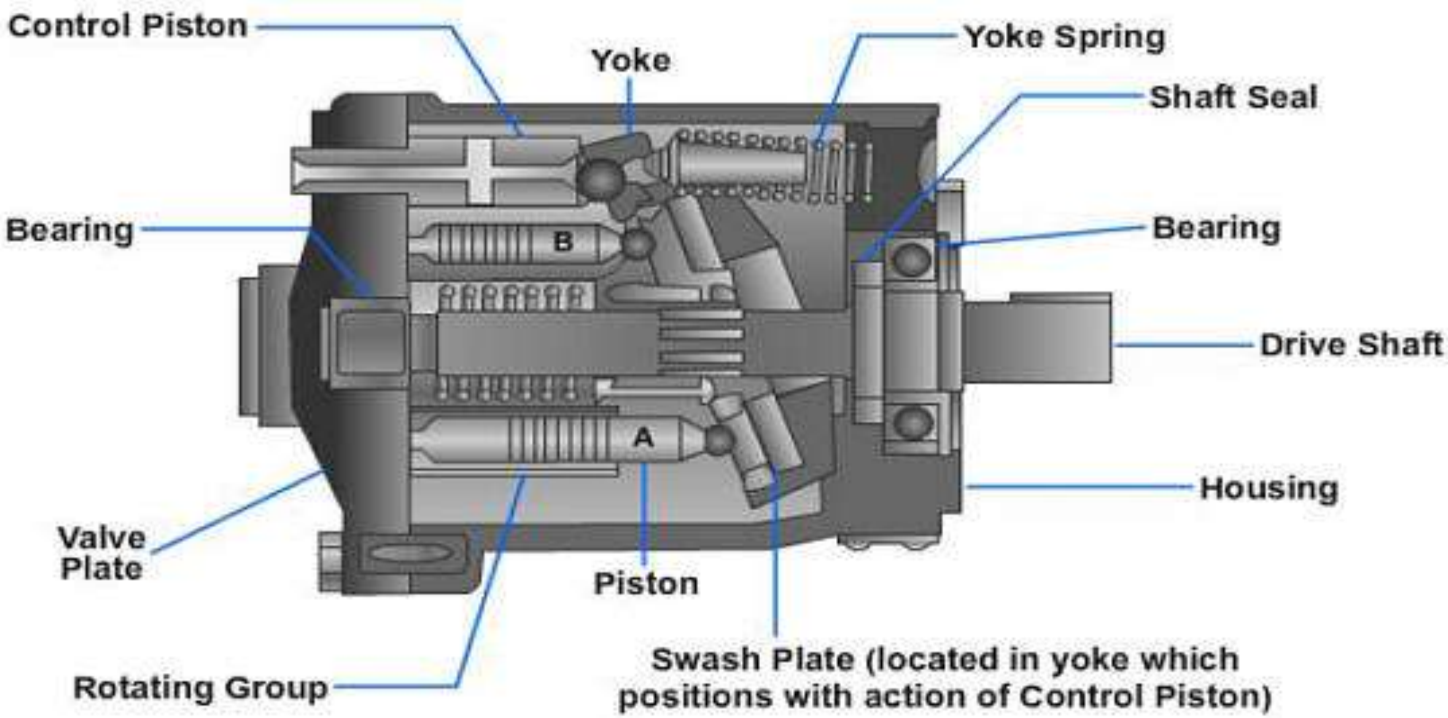


Image courtesy - IEEE GlobalSpec

Radial piston pumps

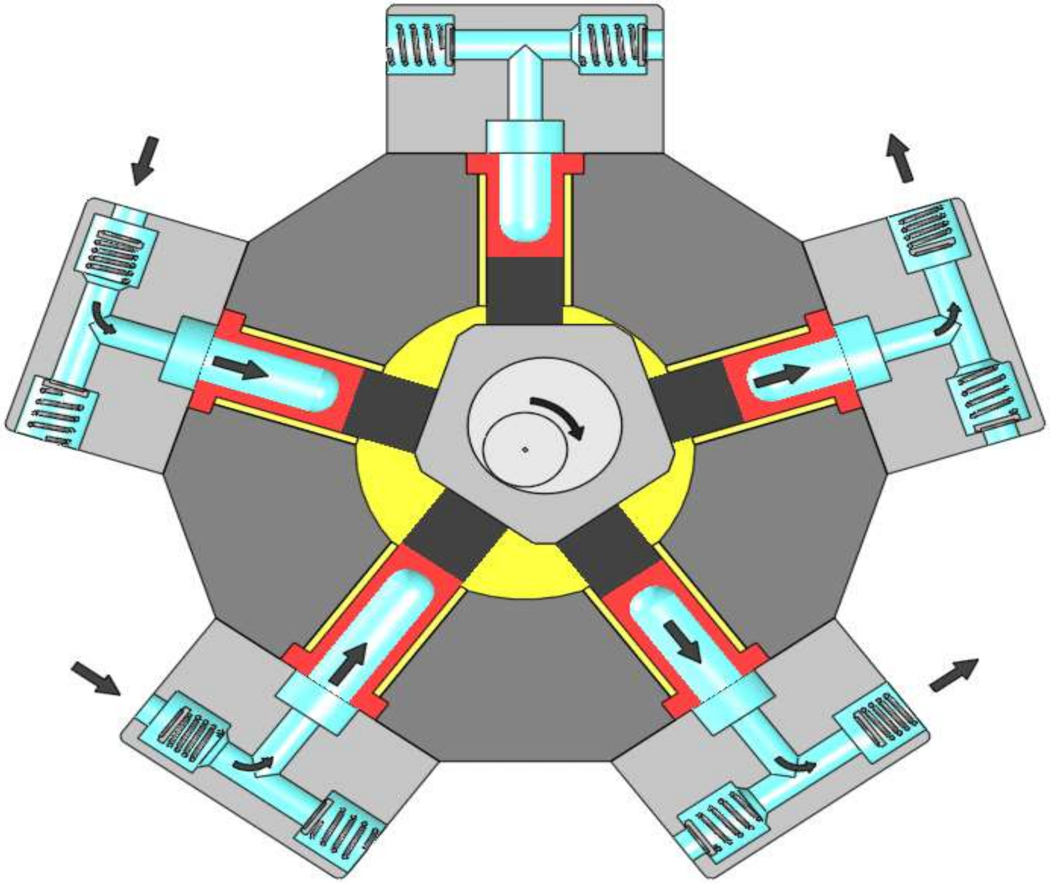


Image courtesy - IEEE GlobalSpec

Piston & Plunger

Advantages	Disadvantages
• Wide pressure range - can achieve very high pressures	• High operating and maintenance costs.
• Pressure can be controlled without affecting flow rate.	• Typically heavy and bulky
• Pressure and flow rate changes have little effect on performance.	• Typically only handles lower flow rates
• Capable of moving viscous fluids, slurries, and abrasives with proper valve design.	• Pulsating flow

Number of Cylinders
The number of pump cylinders is the number of pumping cylinders in the pump. Increasing the number of pump cylinders increases the capacity of the pump.

Simplex pumps have one cylinder.
Duplex pumps have two cylinders.
Multiplex pumps have more than two cylinders

Damage cause by abrasion can be identified by examining the high pressure seal and/or ceramic plunger for scoring as illustrated above.

MOC for Piston & Plunger Pump

based on type of application. The base (casing) and housing (cylinder) materials should be of adequate strength and also be ***able to hold up against the conditions of its operating environment***. Materials in contact with the pumped media (the plunger, discharge valves, and suction valves) need to be resistant to any corrosion induced by the fluid. Some materials used are listed below.

Cast iron provides high tensile strength, durability, and abrasion resistance corresponding to high pressure ratings.

Plastics are inexpensive and provide extensive resistance to corrosion and chemical attack

Steel and stainless steel alloys provide protection against chemical and rust corrosion and have higher tensile strengths than plastics, corresponding to higher pressure ratings.

Other materials used in pump construction include: Aluminium, Brass, Bronze, Ceramics Nickel-alloy
(ref - For more information on materials and other pump features, visit IEEE GlobalSpec's Pump Features page)

According to a report by McIlvaine Company world market for industrial pumps in 2006 was $29 billion. The world market for industrial has pumps **reached $40 bil** in 2015

McIlvaine (market research company) has ranked the pump companies by sales revenues as follows(2015) :

Ranking	Company
1	ITT
2	Flowserve
3	KSB
4	Sulzer
5	Grundfos
6	Ebara
7	Weir
8	Baker Hughes
9	Schlumberger
10	Clyde Union

Resiprocating PUMP MANUFACTURERS & suppliers

Alfa Laval Inc. (Mfg.)

EXEL North America, Inc. (Mfg., Svc.)

Federal Equipment Company (Svc.)

Gardner Denver Thomas (Mfg.)

General Pump (Mfg., Svc.)

GRI Pumps (A Gorman-Rupp Company) (Mfg.)

Haskel International LLC (Mfg.)

IDEX Health & Science (Mfg., Svc.)

New Pig Corporation (Mfg., Dist.)

Oil-Rite Corp. (Mfg.)

Radwell International, Inc. (Dist., Svc.)

SC Hydraulic Engineering Corporation (Mfg.)

Wanner Engineering, Inc. (Mfg.)

Cannon Water Technology Inc. (Dist.)

KNF Neuberger, Inc. (Mfg.)

OMEGA Engineering, Inc. (Mfg., Dist.)

Valcor Engineering Corporation (Mfg.)

A & F Machine Products Co. (Mfg.)

A&S Hydraulic Co., Ltd. (Mfg.)

A-L-L Equipment, Inc. (Dist.)

A1 Hydraulics Limited (Dist.)

Advanced Pump Company, Inc. (Dist.)

AESPUMP (Dist., Svc.)

AFI America LLC (Dist.)

AG Enterprise Supply, Inc. (Dist.)

AGALLDOS Eichler GmbH (Mfg.)

AGI Industries, Inc. (Dist.)

Agilent Technologies, Inc. (Mfg.)

Air Pumping Engineering Services, Ltd. (Mfg.)

Airlessco (Mfg.)

Airline Hydraulics Corp. (Dist.)

Airmo, Inc. (Mfg.)

ALA Industries - Yuken Hydraulics (Dist.)

Alan Dale Pumps, Ltd. (Mfg.)

Albin Pump AB (Mfg.)

ALEDco, Inc. (Dist.)

Alfa Laval Ltd. (Mfg.)

Alitea AB (Mfg.)

Alkota Cleaning Systems Inc. (Mfg.)

All Best Industry Co., Ltd. (Mfg.)

All Jetting Technologies, Inc. (Mfg., Dist.)

All Power, Inc. (API) (Mfg., Dist.)

Syringe Pumps : used to deliver precise amounts of fluid at specific time intervals

Sizes : 0.5 µl to 140 ml

Flow rate : 1.260 pl/min to 88.320 ml/min

Fig: KD Scientific Dual Syringe Pump, Infusion, Programmable, 220V CE

Fig: KD Scientific Dual Syringe, Programmable Touch Screen, Continuous Flow, Push-Pull Pump

Main types

1) Infusion pump : infuse high, but controlled pressures
2) Withdrawal pumps :to remove fluid samples automatically

Power Sources

1) Pneumatic
2) Electrically-powered syringe pumps(DC /AC)

Certifications :syringe pumps may bear the UL Mark and/or the CSA Mark. Underwriters Laboratories (UL) is a non-profit organization that tests components, systems, and materials according to its published standards for safety. Products that bear a CSA Mark have been tested by the Canadian Standards Association (CSA) and meet applicable standards for safety and/or performance.

Extensive Applications

1) Chemical Development
2) Pilot Plant Reactor Dosing
3) Continuous Flow
4) Dye Dilution
5) Pharmaceutical Development
6) Reactor Injections
7) Flow Chemistry
8) Cell Manipulation

Applications and Features :*General-purpose products are not designed* for a specific industry. Specialized pumps are rated **for agricultural, cryogenic, dairy, food and beverage processing, maritime, medical, pharmaceutical, or semiconductor manufacturing applications**

SYRINGE PUMP MANUFACTURERS & SUPPLIERS

Hamilton Co. (Mfg.)

Iwaki America and Walchem, IWAKI America Inc (Mfg.)

IDEX Health & Science (Mfg., Svc.)

Adelab Scientific (Dist.)

Agilent Technologies, Inc. (Mfg.)

Analytical Scientific Instruments (Mfg.)

Angel Canada Enterprises Ltd. (Mfg.)

Aurora Instruments (Mfg.)

Axel Semrau GmbH & Co. KG (Dist., Svc.)

Brandel (Mfg.)

Carl Stuart Co. (Dist.)

cetoni GmbH (Mfg.)

Chemyx Inc. (Mfg.)

Classic Controls, Inc. (Svc.)

Cole-Parmer (Dist.)

Cole-Parmer Canada Inc. (Dist.)

Cole-Parmer India (Dist.)

Cole-Parmer Instrument Co., Ltd. (Dist.)

Eldex Laboratories, Inc. (Mfg.)

FIAlab Instruments, Inc. (Mfg.)

Fisher Scientific UK Ltd (Mfg.)

Fluid Metering, Inc. (Mfg.)

Fluitron, Inc. (Mfg., Svc.)

GENEQ, inc. (Dist.)

GeSiM (Mfg.)

Gilson, Inc. (Mfg.)

Harvard Apparatus, Inc. (Mfg.)

Harvard Bioscience, Inc. (Mfg.)

Hi-Pro Pressure Products Ltd (Mfg.)

ibidi GmbH (Mfg.)

ILS Innovative Labor Systeme GmbH (Mfg.)

Instech Laboratories, Inc. (Mfg.)

J-KEM Scientific, Inc. (Mfg.)

JL White LLC (Svc.)

KD Scientific, Inc. (Mfg.)

Kruss USA (Mfg.)

LAMBDA Laboratory Instruments (Mfg.)

Leica Biosystems (Mfg.)

Med-E-Quip Locators, Inc. (Dist.)

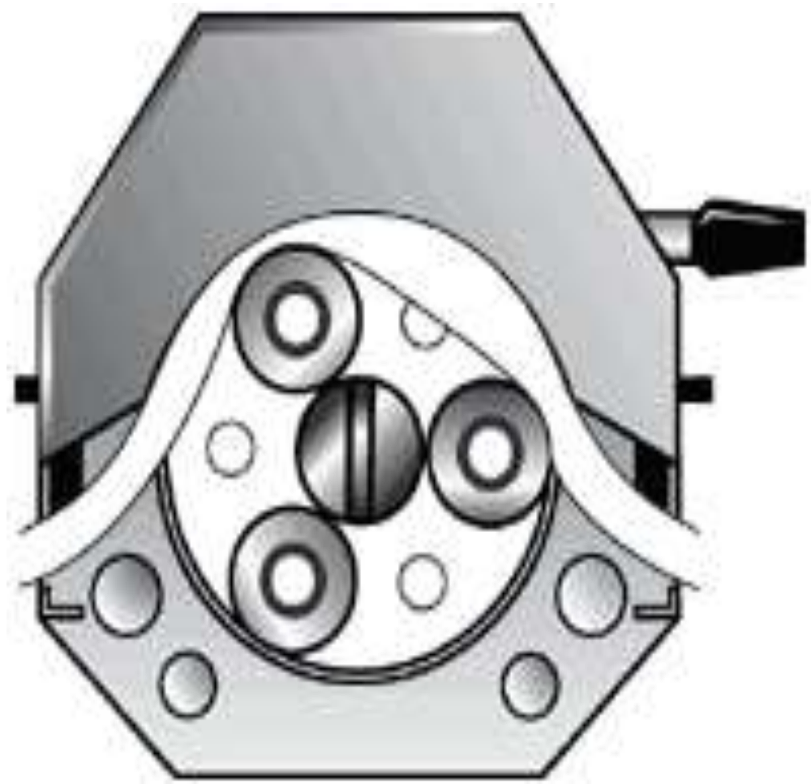
Microfluidica, LLC (Mfg., Svc.)

New Era Pump Systems, Inc. (Mfg.)

Next Advance, Inc. (Mfg.)

Nichiryo America, Inc . (Mfg.)

Peristaltic Pumps : rotating rollers pressed against special flexible tubing to create a pressurized flow



Low pressure : Low pressure pumping applications
e.g. IVs (medical fluids) and chemical metering.

High pressure (**up to 16 bar**): reinforced tubes . The *casings in these pumps are lined with lubricants* to avoid damage from abrasion and friction, as well as to dissipate heat build up.
e.g. Industrial grade pumps designed for ***pumping of aggressive sewage and slurries***

Design Specifications

A number of design parameters should be considered when selecting peristaltic pumps.

1) **Tubing size** - diameter and wall thickness [inches (in) or millimeters (mm)]. It affects the discharge and the size of tubing needed for replacement. Pumps may be designed to allow multiple sizes of tubing.

2) **Number of rollers** - the number of rollers or shoes used in the drive mechanism. *More rollers reduce pulsation and provide a smoother flow*.

3) **Number of channels** - the number of separate tubes in the pump which operate simultaneously.

Peristaltic Pump Tubing

Peristaltic pump is increasing in popularity because of its contamination free fluid transfer . Each application requires its own type of tube material. So when designing, tube material selection, is an important factor. The factors are

- Chemical compatibility
- Pressure build-up in pump tubing
- Temperature of pump medium and environment
- Viscosity of the liquid
- Permeability of the pump tubing
- Tubing dimensions and demanded delivery rate
- Life expectancy
- Transparency
- Cost

Use Chemical compatibility Chart : When a chart is not sufficient, immersion tests may be used to determine its compatibility or resistance to corrosion

Immersion tests: a small piece of tubing is **weighed**, and **its diameter and length** are **measured.** The tubing then is immersed in a closed vessel with the chemical in question for a minimum of **48 hours**. Afterward, the test piece of tubing is rinsed, dried, weighed and measured, and any c**hanges are recorded**

Even trace levels of some acids or solvents can be enough to destroy pump tubing .

- Once a promising material or group of materials has been identified, a pump test should be performed. A sample of each potential tubing in a pump should be run under a plant's actual process conditions and the results carefully monitored. If the tubing survives the test without discoloration, swelling, cracking, loss of flow or other signs of deterioration, then it is compatible with the fluid.
- chemical resistance decreases as temperature increases
- Chemical compatibility varies widely between different materials and solutions, but some materials have excellent overall chemical resistance. Viton tubing, for example, is resistant to many inorganic chemicals and even to some organic solvents
- (PTFE) is compatible with nearly all substances. However, because PTFE is a rigid tubing, it requires a special pump head when used with peristaltic pumps. A tubing material with broad chemical resistance might be the best choice, especially if the pump will be used with more than one aggressive chemical.

"Amy Ebelhack "Chemical Processing magazine, October 2001 Peristaltic Pumps —Matching the Tubing to the Fluid.

Pressure

- Working pressure ratings ranging from about 10 (psi) to 40 psi, with softer materials such as silicone at the low end of the range and firmer materials such as Norprene® toward the high end
- Recent material advances have yielded high-pressure materials, expanding the working pressure range for tubing materials such as high-pressure PharMed® up to 125 psi.
- **Backpressure** can be generated When selecting a tubing material for use in a peristaltic pump, end-users always should ensure the pressure in the system does not exceed the recommended working pressure of the tubing
- **PSV** can be installed to prevent excessive pressure buildup.

Temperature

- End-users should identify both **the minimum and maximum temperatures possible in the system**, and then ensure the tubing can operate safely within that range.
- **silicone have a relatively broad temperature range** and are well-suited to both high- and low-temperature processes
- A process will be operating at elevated temperatures, end-users should consider the effect of temperature on both chemical resistance and pressure capabilities. As temperature increases, the working pressure for a given tube decreases.

`Amy Ebelhack ` Chemical Processing magazine, October 2001 Peristaltic Pumps —Matching the Tubing to the Fluid.

Dimensions (Tube's inside diameter and wall thickness.):
➢Inside diameter determines the amount of fluid delivered with each turn of the rotor.
➢ The wall thickness affects the tubing's ability to spring back to its original shape after each compression,
➢**Even small variations** can cause **unacceptable** deviations in flow rates and the amount of fluid dispensed. Although some manufacturers provide "look-alike" tubing for use in peristaltic pumps with dimensions close to the pump manufacturer's recommended sizes, "close enough" often is not adequate. For optimal performance and accuracy, end-users always should use the exact tubing size recommended for the pump.

Tubing Life Expectancy : A pump tubing with a long life reduces the total cost of pump ownership.
Transparency: sensitivity to light
No - transparent material such as Tygon or silicone is a good choice
Yes -opaque tubing material is a better option.

Regulatory Approval: United States Pharmacopoeia (USP), European Pharmacopoeia (EP), U.S. Department of Agriculture (USDA) and National Sanitation Foundation (NSF).

Cost:

e.g. a tubing material that costs $2.00 per foot and needs to be replaced every 500 hours is more cost-effective than a formulation that costs $1.00 per foot but requires replacement every 100 hours.

Poor-quality tubing that suddenly ruptures can waste valuable fluids being pumped or cause extensive damage to the pump, requiring costly downtime and resulting in extensive repairs or even complete pump replacement.

least expensive tubing is not always the most economical choice

Silicone - A translucent medical/food grade tubing which is odorless, non-toxic, and has FDA and USP Class VI approvals. It is autoclavable and has a temperature range up to 220°C. Used in most general applications.

Autoprene - This is an opaque thermo-plastic rubber with unmatched wear resistance when long tube life is required. This material has FDA food grade approval, and has been further enhanced to meet the requirements and approval standards of USP Class VI criteria for medical bio-compatibility.

Viton - A black, shiny, synthetic rubber with resistance to concentrated acids, solvents, ozone, radiation and temperatures up to 200o C. Viton is expensive, and while it has excellent chemical compatibility, Viton is not renowned for durability and will have a limited service life.

Tygon - This tube has excellent chemical resistance, handles virtually any inorganic chemical, and is one of the family of non-toxic tubes. Tygon has a clear finish and is available in a limited size range.

Prothane II - A transparent blue polyester polyurethane tubing which is resistant to ozone, diesel fuel, kerosene, motor oil, mild solvents, aromatic hydrocarbons, petrol and concentrated acid and alkaline solutions.

Vinyl - The least expensive of any pump tubing type, but is not widely chemically compatible and has a below average service life. It cannot be autoclaved and cannot handle temperatures above 80°C.

Fluoropolymer - The most chemically inert tubing material, but with an extremely short service life. It is autoclavable.

Advantages	Disadvantages
• Tube/hose eliminates contamination potential	• Tubing wear decreases efficiency over time and can cause leaks
• Handles aggressive, corrosive, viscous, and abrasive media	• Low pressure
• Easy to install and inexpensive to maintain	• Hose typically requires routine cleaning and replacement
• Pump design prevents back-flow without the use of valves	• Intermittent/pulsed flow

Material	Rating
Aluminium	C
Bioprene	-
Buna N	C
Cast iron	-
EPDM	C
Epoxy	-
Fluorel	-
F-NBR	C
Gore style 400	-
Hypalon (CSM)	C
Marprene	-
Mild steel	C
Natural Rubber - Endurance	C
Neoprene	-
Nitrile	C
Petroproof	C
PFPE Lubricant	-
Polyethylene	A
Polypropylene	C
PTFE	A
Pumpsil and Pumpsil D	-
PureWeld	-
PVC	-
PVDF	-
ReNu Glycerol lubricant	A
ReNu Silicone lubricant	A
Santoprene	-
SEBS	-
SS316	C
STA-PURE PCS	-
STAPURE PFL	-
Viton	-

A	Little to minor effect. Tubing: 0-5% volume swell
B	Moderate effect. Tubing: 5% - 10% volume swell
C	Severe effect. Tubing: 10% or greater volume swell
-	No data available

Peristaltic PUMP MANUFACTURERS & suppliers

Cannon Water Technology Inc. (Dist.)

EXEL North America, Inc. (Mfg., Svc.)

Gardner Denver Thomas (Mfg.)

IDEX Health & Science (Mfg., Svc.)

OMEGA Engineering, Inc. (Mfg., Dist.)

RS Components, Ltd. (Mfg., Dist.)

Wanner Engineering, Inc. (Mfg.)

Watts (Mfg.)

GRI Pumps (A Gorman-Rupp Company) (Mfg.)

SEEPEX Inc. (Mfg., Svc.)

Aalborg Instruments (Mfg., Svc.)

AB Industrial Equipment Co. (Dist.)

Adelab Scientific (Dist.)

Advanced Integration Inc. (Svc.)

Advanced Supplies (Dist.)

Advantage Controls (Europe) Ltd. (Mfg.)

Anchor Sales (Dist.)

Anko Products, Inc. (Mfg.)

Apple Scientific Inc. (Dist.)

Apumas Group (Dist.)

AQUAFIN, Inc. (Mfg., Svc.)

Arobone and Company, Inc. (Svc.)

Aspen Pumps, Ltd. (Mfg.)

Associate Measurement Company (Dist., Svc.)

Aurora Instruments (Mfg.)

Automated Machine Technologies, Inc. (Mfg.)

AXEON Water Technologies (Mfg.)

Axis Engineering (Mfg., Dist., Svc.)

Baoding Signal Fluid Technology Co., Ltd. (Mfg.)

BASSI, L.L.C. (Mfg., Dist.)

Becker Equipment, Inc. (Dist.)

Bennett Scientific Ltd. (Dist.)

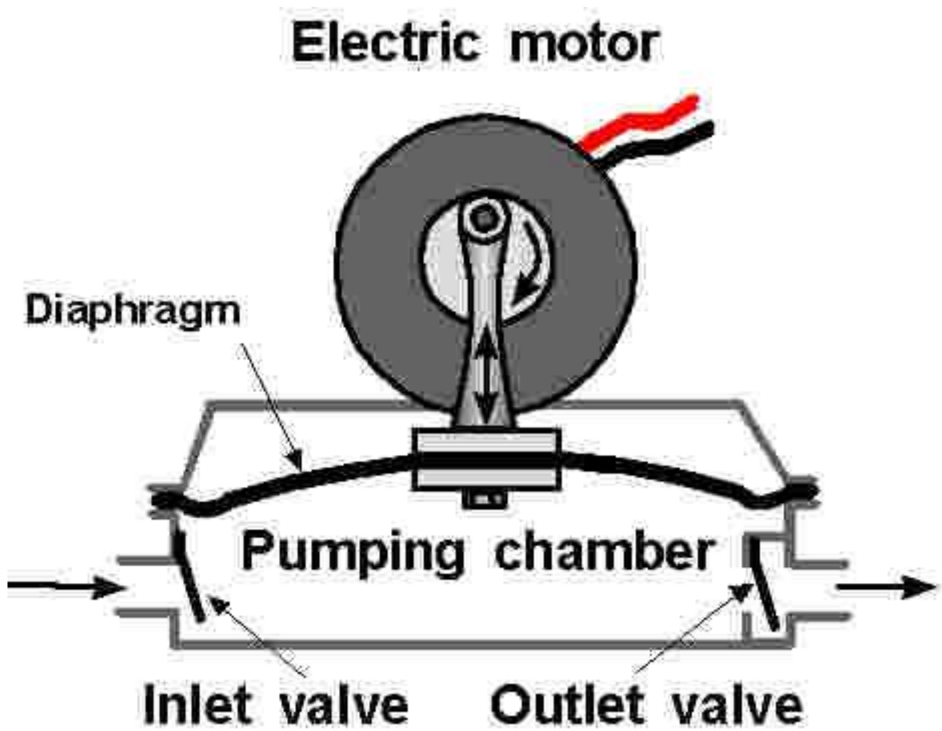
BestPump Ltd. (Dist.)

Beta Technology (Mfg.)

Bill Parker Sales & Engineering (Dist.)

Diaphragm Pumps positive displacement pump which move gases, liquids, or gas-liquid mixtures via a reciprocating diaphragm.

- They are highly reliable do not include internal parts that rub against each other.
- They also contain no sealing or lubricating oils within the pumping head, meaning there is no chance of oil vapor leakage or contamination of the handled media.



Types

The action of a diaphragm pump refers to how many diaphragms and sets of valves the pump incorporates.

- **Single acting** pumps incorporate one diaphragm and one set of valves, and are characteristic of mechanical drive pumps.
- **Double acting** pumps, also known as double diaphragm pumps, incorporate two diaphragms and two sets of valves. Air-operated diaphragm pumps are characteristically double-acting. For more information on specifically selecting double diaphragm pumps

Design

Pump Stroke

The pump stroke length defines a pump's capacity and pressure ratings. Higher offset (longer stroke) produces higher flow rates and greater pressure/suction per stroke.

Diaphragm

Three different characteristics define a diaphragm's design.

1)Durometer - Measures the stiffness of the diaphragm elastomer Higher durometer means a harder diaphragm which can generate higher pressures and flows Lower durometer diaphragms product are rated for lower pressures and require less energy to operate.

2)Shape - Determines the flow and pressure level of the pump.

Flat - Inexpensive and can provide adequate vacuum separation between chambers, but has a limited stroke/offset length and lower energy efficiency. It also has a lower lifespan since it tends to deform as it adjusts to the stroke.

Rolled/molded - Shaped to factor in the required stroke length, it provides a repeatable displacement with a constant effective pressure area. It has a longer life than the flat type and creates less resistance (higher efficiency) but is more expensive.

Structured- Patented diaphragm design that incorporates a ribbed underside to accommodate a specific load. Provides higher strength, good capacity, and higher efficiency than other types in a small size

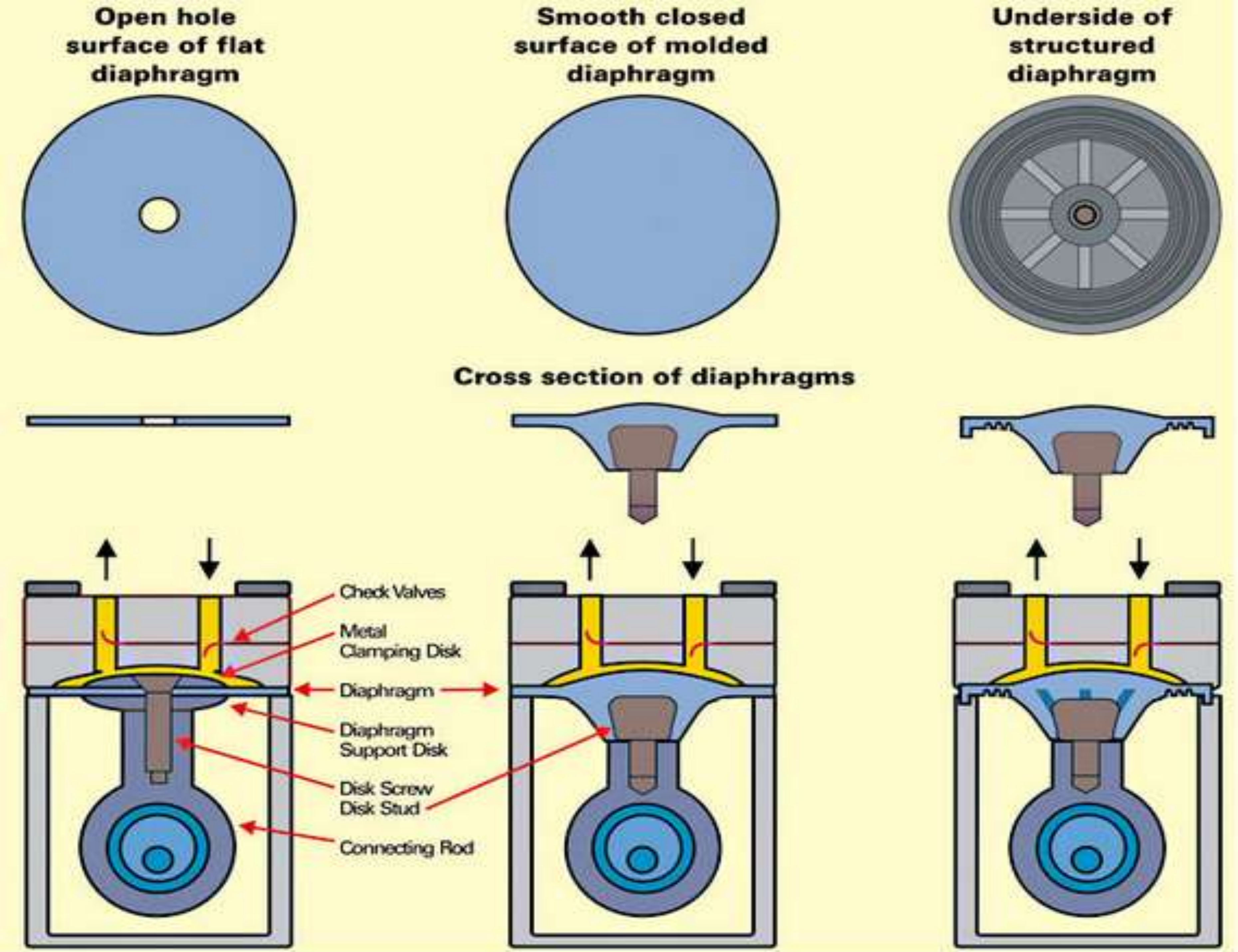
3)MOC of Diaphragm

The industry standard is EPDM rubber . Other materials include PTFE, rubber, and other plastics and elastomers. Material affects the diaphragms lifespan, stiffness (durometer) & resistance to corrosion.

- **Cast iron** provides high tensile strength, durability, and abrasion resistance corresponding to high pressure ratings.
-
- **Plastics** are inexpensive and provide extensive resistance to corrosion and chemical attack

- **Steel and stainless steel alloys** provide protection against chemical and rust corrosion and have higher tensile strengths than plastics, corresponding to higher pressure ratings

- **Other materials** used in pump construction include:
  Aluminium, Brass, Bronz, Ceramics, Nickel-alloy


Open hole surface of flat diaphragm
Smooth closed surface of molded diaphragm
Underside of structured diaphragm
Cross section of diaphragms
Check Valves
Metal Clamping Disk
Diaphragm
Diaphragm Support Disk
Disk Screw Disk Stud
Connecting Rod

Applications

Diaphragm pumps are commonly called **"mud hogs" and "mud suckers**" because of their use in **pumping slurries and wastewater in shallow depths**. They are capable of handling all sorts of aggressive media including gases and gas/liquid mixtures, and can achieve very high pressures. They should not be used to pump dangerous or toxic gases, since diaphragm pumps are not hermetically sealed.

Advantages	Disadvantages
• Seal-less and oil-free	• Low maximum speed
• Self-priming up to 6 meters	• Not very energy efficient
• Simple cleaning/maintenance	• Pulsed flow - requires dampener for reduction
• Versatile design and function (can handle most media types)	
• Can run dry for short periods	

DIPHRAGM PUMP MANUFACTURERS & SUPPLIERS

Cannon Water Technology Inc. (Dist.)

EXEL North America, Inc. (Mfg., Svc.)

Federal Equipment Company (Svc.)

Gardner Denver Thomas (Mfg.)

General Pump (Mfg., Svc.)

GRI Pumps (A Gorman-Rupp Company) (Mfg.)

Haskel International LLC (Mfg.)

Hayward Flow Control (Mfg.)

Iwaki America and Walchem, IWAKI America Inc (Mfg.)

KNF Neuberger, Inc. (Mfg.)

OMEGA Engineering, Inc. (Mfg., Dist.)

Radwell International, Inc. (Dist., Svc.)

RS Components, Ltd. (Mfg., Dist.)

Wanner Engineering, Inc. (Mfg.)

Alldoo Micropump Co., Ltd. (Mfg.)

ALLDOS Inc. (Mfg.)

ALMATEC Maschinenbau GmbH (Mfg.)

ALPHADYNAMIC Co. (Mfg.)

American-Marsh Pumps (Mfg.)

American Transit Supply, Inc. (Dist.)

AMI Pipe & Supply Company (Dist.)

AMT Pump (Mfg.)

Anchor Sales (Dist.)

Anderson Pump & Process (Dist.)

Angel Air Repair & Specialty Co., Inc. (Dist., Svc.)

Apollo Enterprises, Inc. (Mfg.)

Applied Products (Dist.)

APS Supply Co., Inc. (Mfg., Dist.)

Gear Pumps

positive displacement rotary pumps that transport liquids using rotating gears

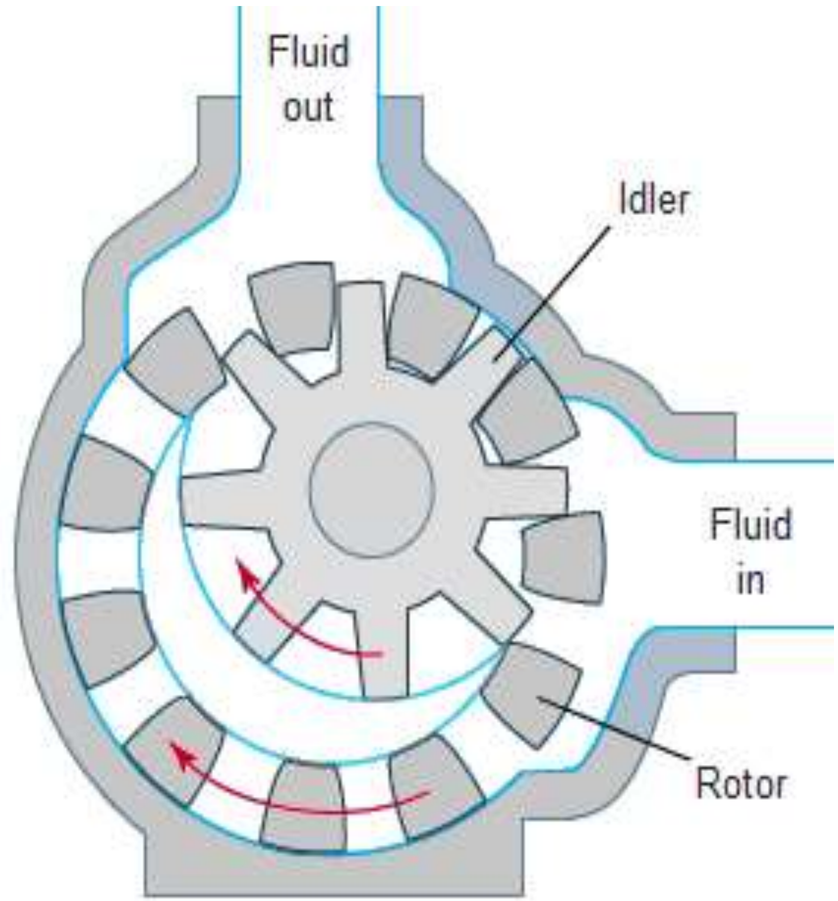
- ❖What if you need **5,000-psi discharge** pressure ?
- ❖temperature is **700-deg F**?
- ❖you have **viscosities** in the hundreds of **thousands** or even in the **millions cP**?

few pumps that may be able to handle one or two of these conditions

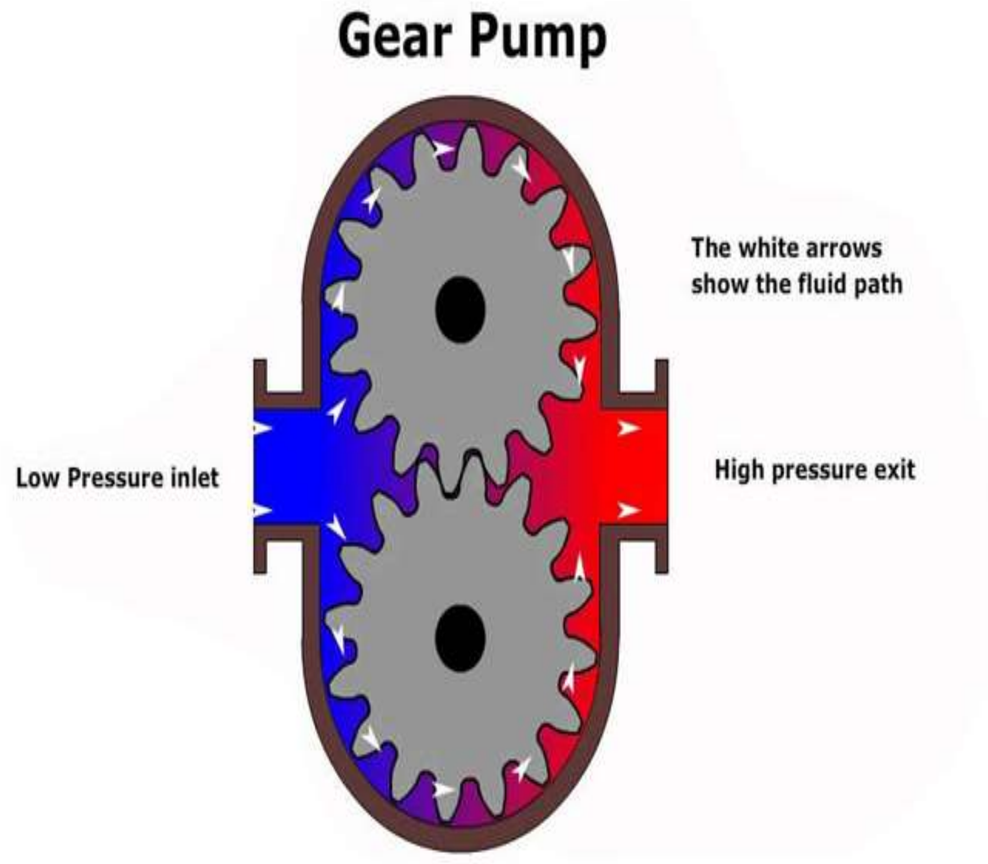
But what if your application has all three?

✓positive displacement rotary pumps capable of handling any or all of these conditions using optimized materials, clearances, and designs.

e.g oils, plastics, paint, adhesives, or soaps.



Internal Gear Pump



External Gear Pump

External Gear Pump	Internal Gear Pump
• A pair of external gears forms the rotor assembly.	• An internal gear & a external gear form the rotor assembly.
• There are four bearings supporting the rotor shafts.	• Rotor is supported on one or (at the most) two bearings.
• Pump design is compact.	• Pump design is bulky & even inefficient for higher-spec models.
• Larger outlet sizes and high capacities.	• Small outlet sizes and medium/low capacities.
• Possible gear designs include spur, helical or herringbone.	• All gears are spur design, further a wedge is required to separate the two gears.
• Medium/low temperature and high pressure pumping.	• High temperature, moderate pressure, low capacity pumping.

Gear Types

Gear pumps use one of two types of gears: spur gears or herringbone gears.

Spur gears provide excellent suction lift, are ideal for water or light oils, are bi-directional (reversible), and are the most economical.
Herringbone gears are ideal for viscous fluids, offer quiet operation in a non-clogging design, but are uni-directional. To learn more about herringbone gears,

MOC

Pumps are typically designed with a number of different materials. The base materials, which constitute the parts of the pump exposed to the pumped media and the outside environment, are the most important to consider. Fluid characteristics, pressure ratings, and operating environment factors should be considered when selecting these materials.

Cast iron provides high tensile strength, durability, and abrasion resistance corresponding to high pressure ratings.
Plastics are inexpensive and provide extensive resistance to corrosion and chemical attack.
Steel and stainless steel alloys provide protection against chemical and rust corrosion and have higher tensile strengths than plastics, corresponding to higher pressure ratings.

GEAR PUMP MANUFACTURERS & SUPPLIERS

EXEL North America, Inc. (Mfg., Svc.)

General Pump (Mfg., Svc.)

GRI Pumps (A Gorman-Rupp Company) (Mfg.)

IDEX Health & Science (Mfg., Svc.)

jbj Techniques Limited (Mfg., Dist., Svc.)

Magnatex Pumps, Inc. (Mfg.)

Mahr Federal Inc. (Mfg., Svc.)

MTC Industries & Research Carmiel Ltd. (Mfg., Svc.)

OMEGA Engineering, Inc. (Mfg., Dist.)

Pentair Engineered Solutions (Mfg.)

Radwell International, Inc. (Dist., Svc.)

RS Components, Ltd. (Mfg., Dist.)

Witte Pumps & Technology GmbH (Mfg.)

A & L Hydraulics, Inc. (Mfg., Dist.)

A&S Hydraulic Co., Ltd. (Mfg.)

Albany Pump Co. Ltd. (Mfg.)

Albert B. Crush Co., Inc. (Dist.)

ALEDco, Inc. (Dist.)

Algae-X (Mfg.)

ALLWEILER GmbH (Mfg., Svc.)

American-Marsh Pumps (Mfg.)

American Transit Supply, Inc. (Dist.)

AMT Pump (Mfg.)

Anchor Sales (Dist.)

Anderson Pump & Process (Dist.)

Anfield Industries, Inc. (Dist.)

Antech Hydraulics Ltd. (Mfg.)

Applied Energy Company, LLC (Dist., Svc.)

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2)Pump User’s Handbook Life Extension By *Heinz P.Bloch & Allan R.Budris*

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4) Johann Friedrich Gülich Centrifugal Pumps Second edition

5)Improving Pumping System Performance : A Sourcebook for Industry by Hydraulic Institute

6) Pump Handbook, Fourth Edition William *C.* Krutzsch Warren H. FraserIgor J Karassik

7)IEEE Global specifications

Thank U