NTNU – Trondheim
Norwegian University of
Science and Technology

TPG 4135 Production Technology

Field Processing and Systems

Postdoc Mariana Díaz
03 /25/2019

Plan

Week Nr.	Week starts	Topic	Lecturer
2	07.jan.19	Course introduction. Overview of field processing. Product specs.	MS
3	14.jan.19	Oil-Gas sep (VLE), Rachford Rice, EOS calculations.	MS
4	21.jan.19	Oil-Gas Separation . Introduction to process simulation (Hysys). Oil-Gas Separation. Bubble and droplet dynamics.	MD
5	28.jan.19	Separation capacity. Oil-water separation	MD
6	04.feb.19	Mechanical Design . Subsea and no standard separators	MD
7	11.feb.19	Water content in Natural gas. Gas dehydration (TEG)	MS
8	18.feb.19	Gas dehydration (TEG)	MS
9	25.feb.19	Pressure calculations in pipe (single and two-phase)	HA
10	04.mar.19	Pressure calculations in pipe (single and two-phase)	HA
11	11.mar.19	Heat transfer, pipe calculations, heat exchangers	HA
12	18.mar.19	Heat transfer, pipe calculations, heat exchangers	HA
13	25.mar.19	Pumping	MD
14	02.apr.19	Compression	HA
15	08.apr.19	Compression	HA
16	15.apr.19	Påskeferie	-
17	23.apr.19	Compression (probably one lecture only)	HA
18	29.apr.19	Spørretime	All

Monday: 12:15-14:00 (P12 PTS)
Tuesday: 14:15-16:00 (VG13 NHL)
Exercise: 16:15-18:00

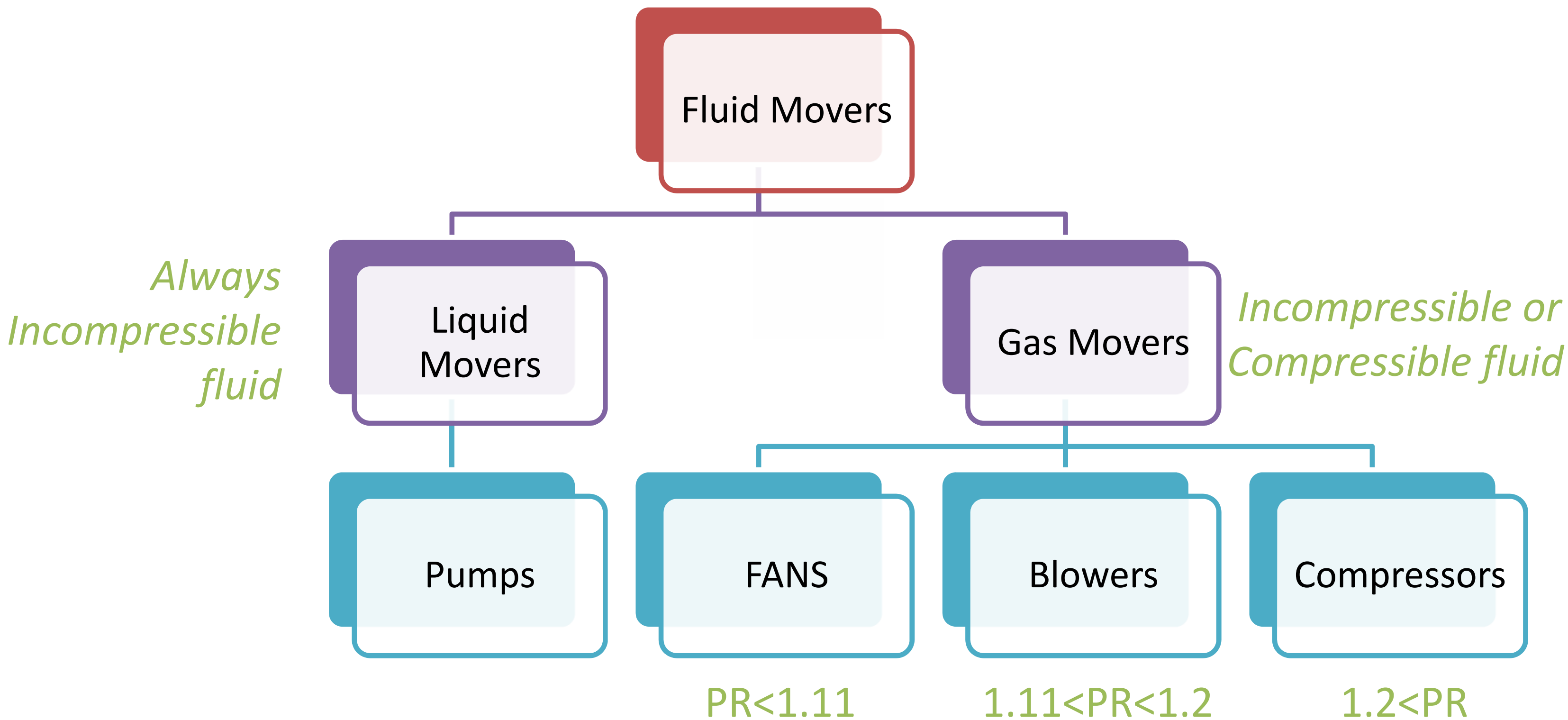
Exam: 29.05, 15:00-19:00

PUMPING

Introduction and basic theory

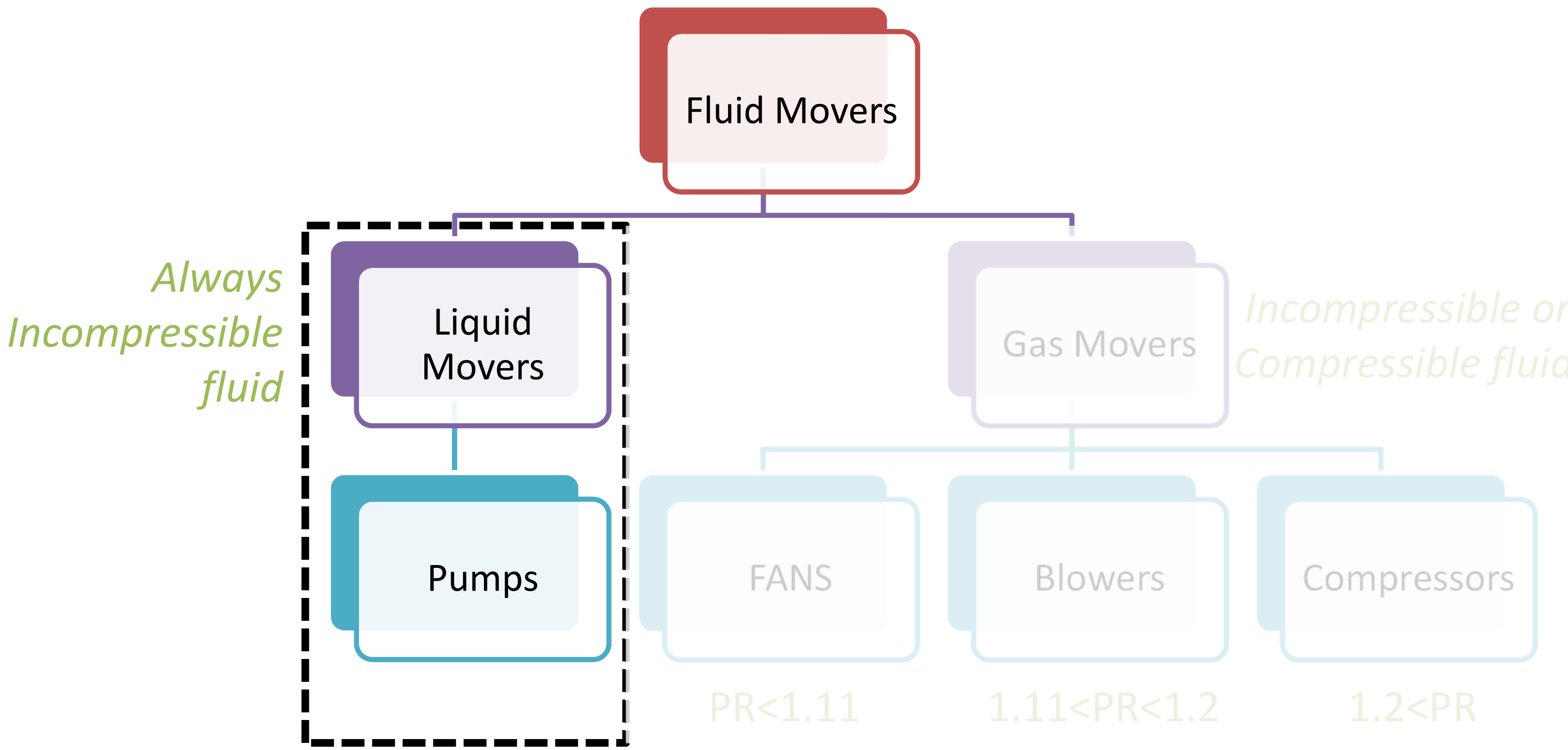
- Moving fluids from one place to another
- Fluids: gas or liquid
- Fluid movers: two main categories: liquid movers (PUMPS) and gas movers (FANS,BLOWERS,COMPRESSORS)
- *Fluid movers are used to increase the total energy content of a fluid. This energy increase may be in the form of* ***pressure increase***, ***velocity increase***, *or* ***the combined effect of both*** (Badr and Ahmed, 2014)
- *Flow in* ***liquid movers is always incompressible***. ***Gas movers may be incompressible*** *(FANS) or* ***compressible*** *(COMPRESSORS)*

Introduction and basic theory



PR: pressure ratio between discharge pressure and suction pressure

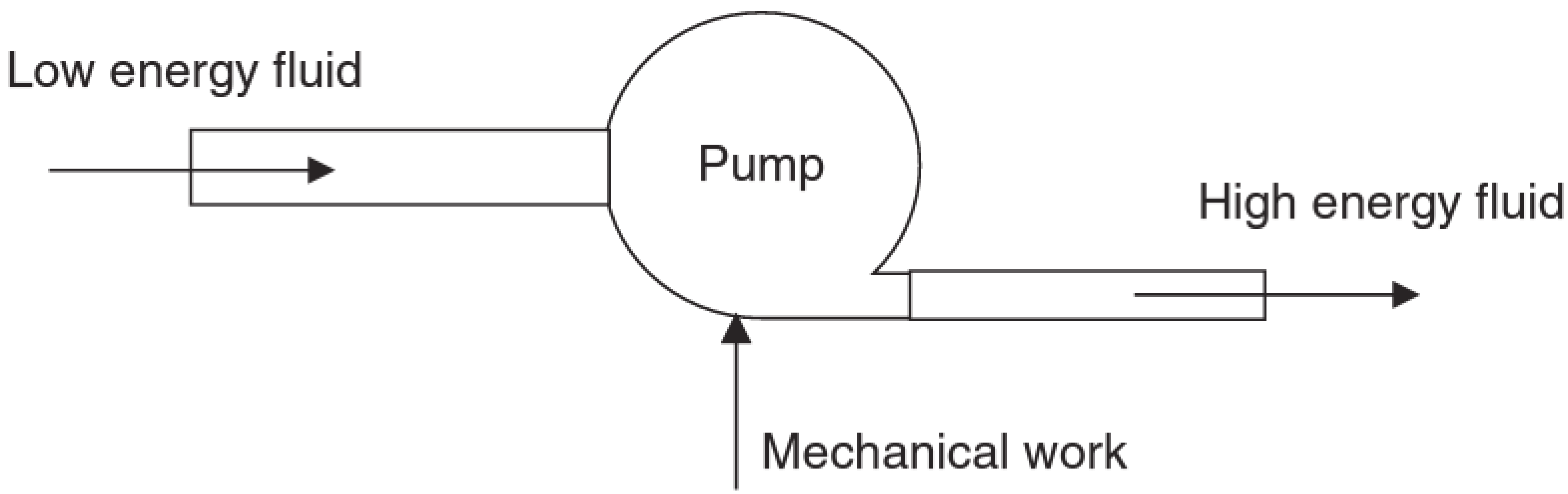
Introduction and basic theory



PR: pressure ratio between discharge pressure and suction pressure

Introduction and basic theory

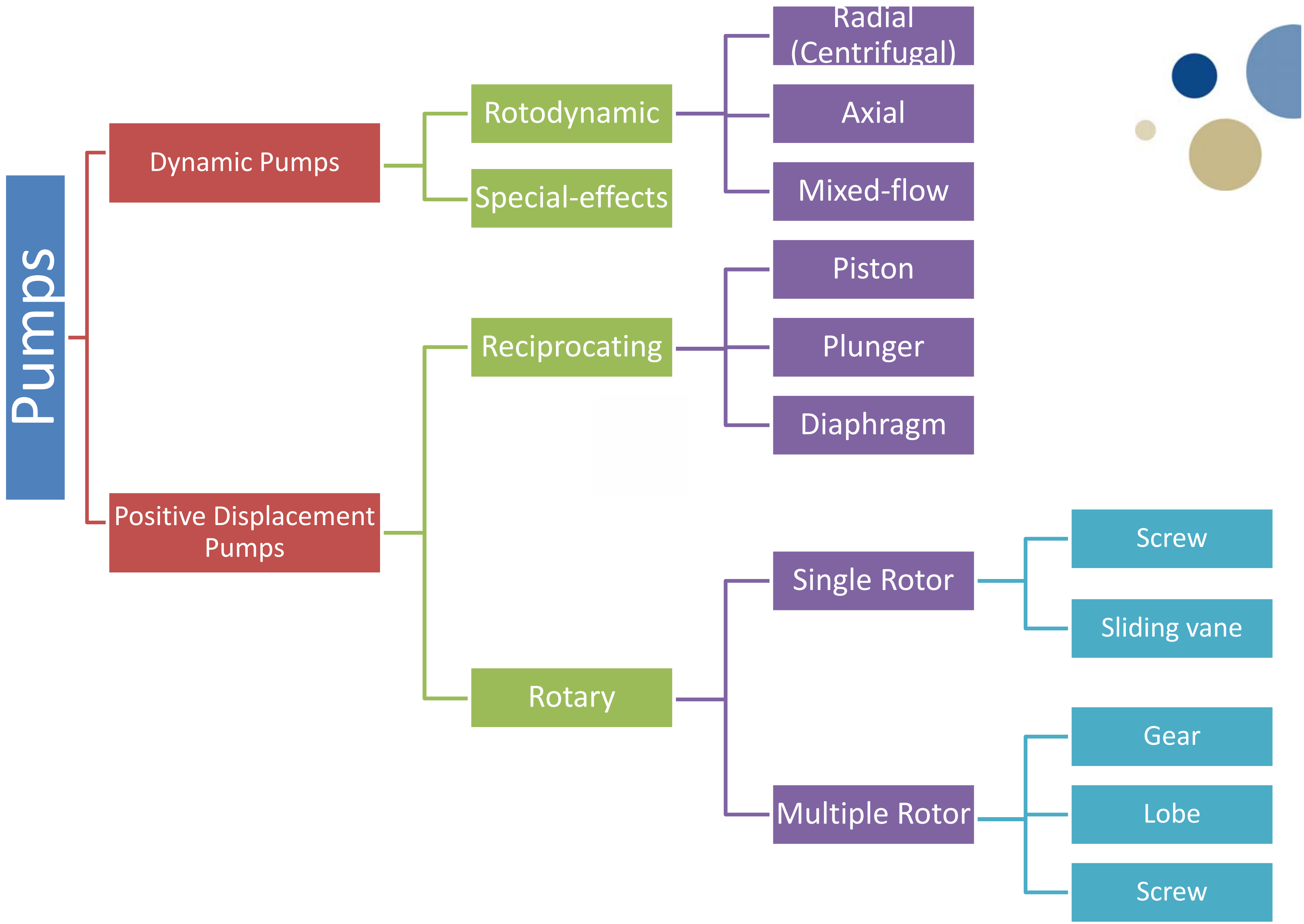
A **pump** is a liquid mover that utilizes **mechanical work** to **increase the total energy content of a fluid**



(Badr and Ahmed, 2014)

Performance characteristics depend on:

- Fluid properties
- Shape and size of the machine
- Speed of rotation



Pumps
Dynamic Pumps
Positive Displacement Pumps
Rotodynamic
Special-effects
Reciprocating
Rotary
Radial (Centrifugal)
Axial
Mixed-flow
Piston
Plunger
Diaphragm
Single Rotor
Multiple Rotor
Screw
Sliding vane
Gear
Lobe
Screw

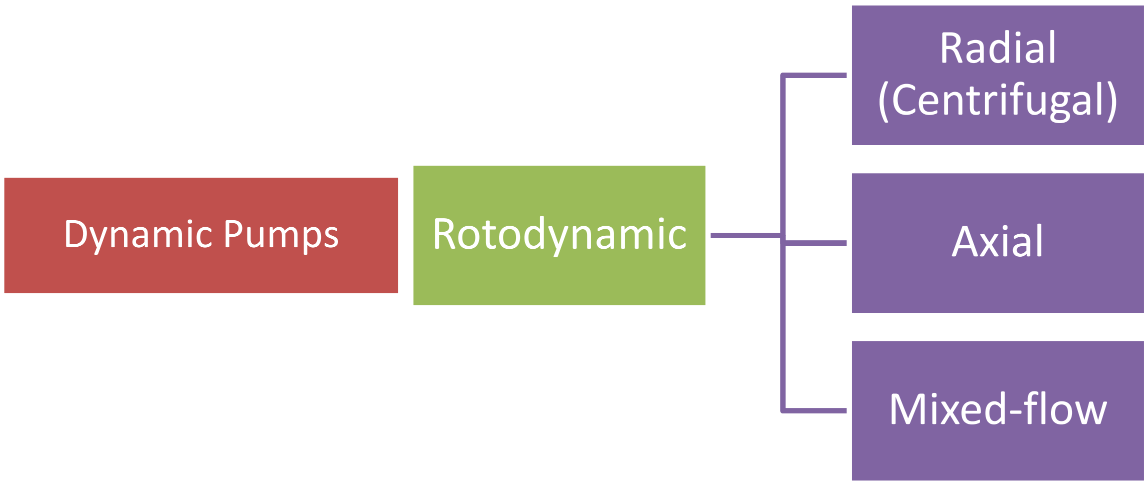
Dynamic Pumps

*The **fluid velocity is increased inside the pump** to values higher than the discharge velocity. **Velocity reductions within or after the pump create higher pressure*** (Badr and Ahmed, 2014)

Positive Displacement Pumps

*Energy is added to the fluid by **the direct application of a force that moves the fluid from the low pressure side to the high pressure side.*** (Badr and Ahmed, 2014)

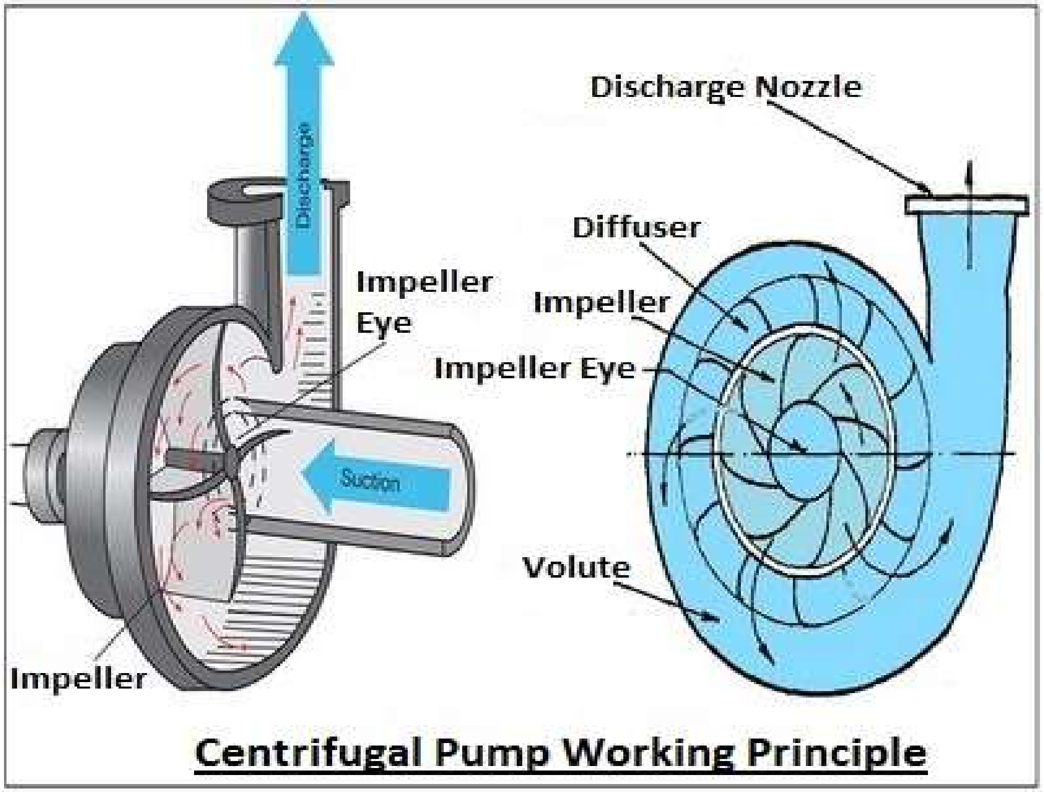
These pumps operate with enclosed liquid volumes which are forced forward in the direction of pumping (Nesbitt, 2006)



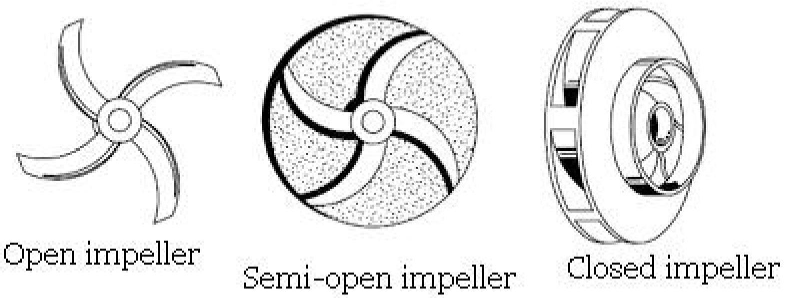
*It is characterized by one or more **impellers** equipped with **vanes** which rotate in a **pump casing***

Rotodynamic

Radial (Centrifugal)



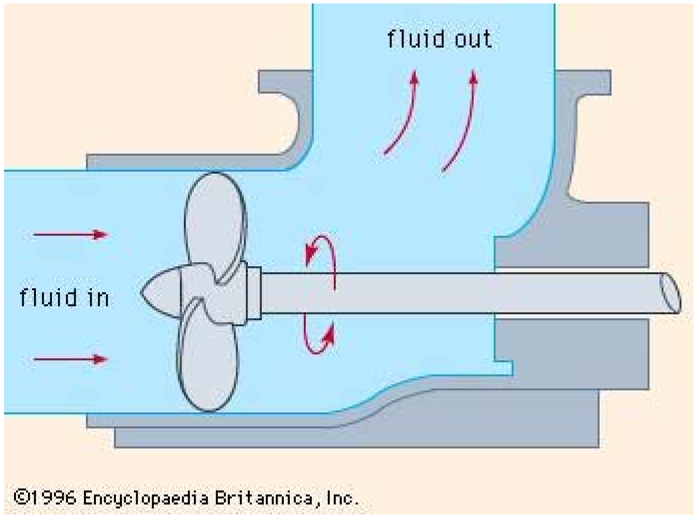
https://mechanicallyinfo.com/centrifugal-pump-working-principle/



https://chemicalada.blogspot.com/2016/09/centrifugal-pump.html

Rotodynamic

Axial



[1]

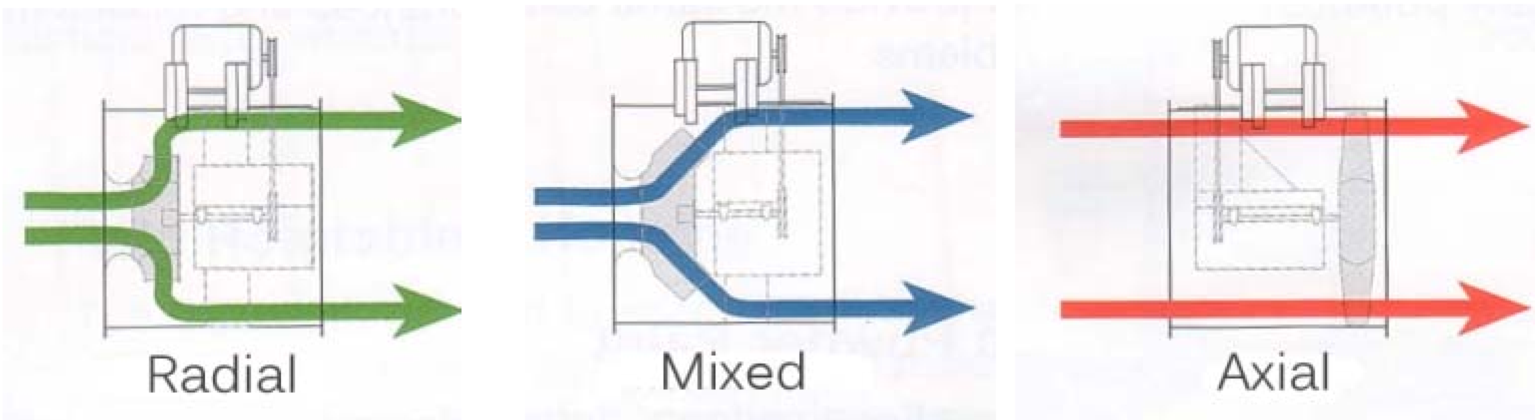
[2]

[3]

[1] http://www.writeopinions.com/axial-flow-pump

[2] https://www.globalspec.com/learnmore/flow_transfer_control/pumps/axial_flow_pumps

[3] https://www.indiamart.com/proddetail/axial-pump-impeller-10585051862.html



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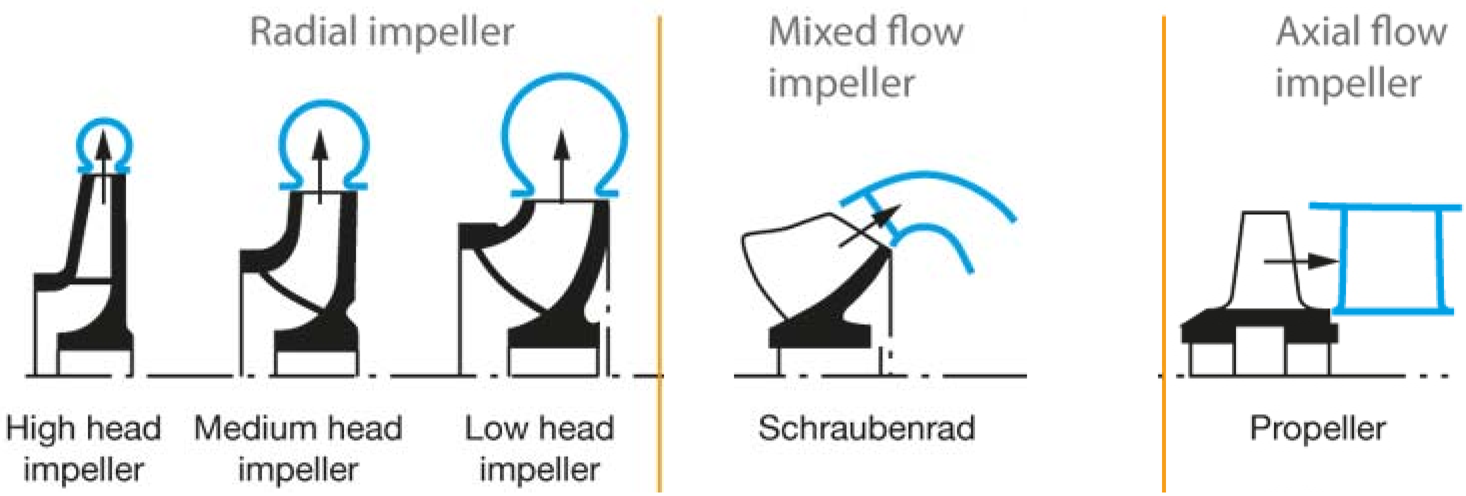
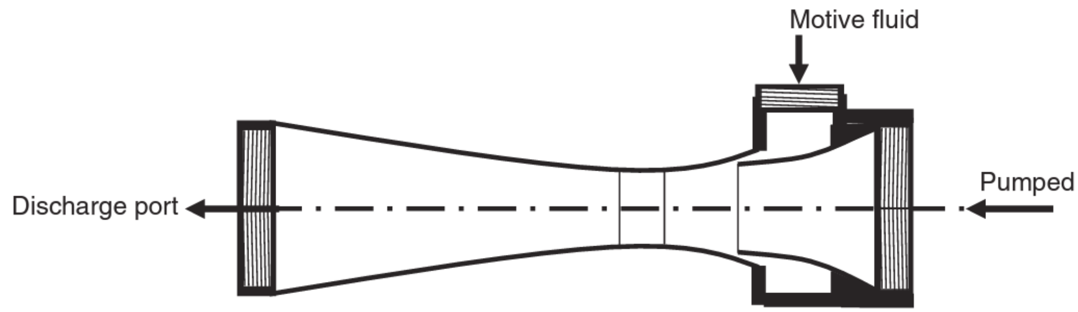


[1] https://www.globalspec.com/learnmore/flow_control_flow_transfer/pumps/impellers

[2] https://www.ksb.com/centrifugal-pump-lexicon/specific-speed/191172/

Dynamic Pumps

Special-effects

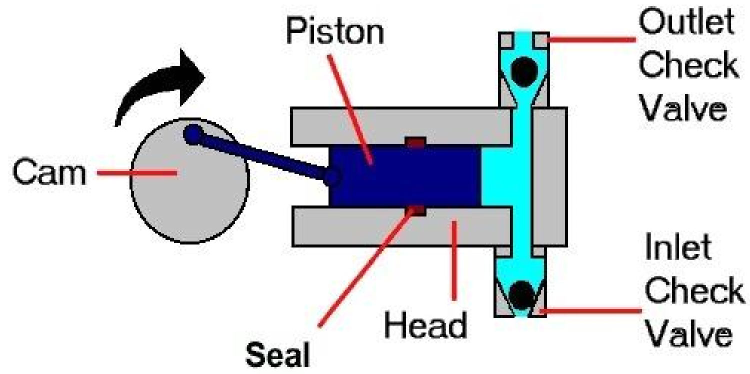


Jet Pump

(Badr and Ahmed, 2014)

Positive Displacement Pumps

Reciprocating



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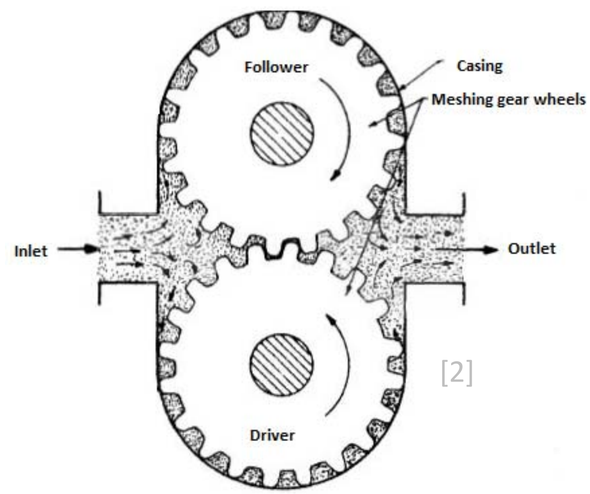
Rotary

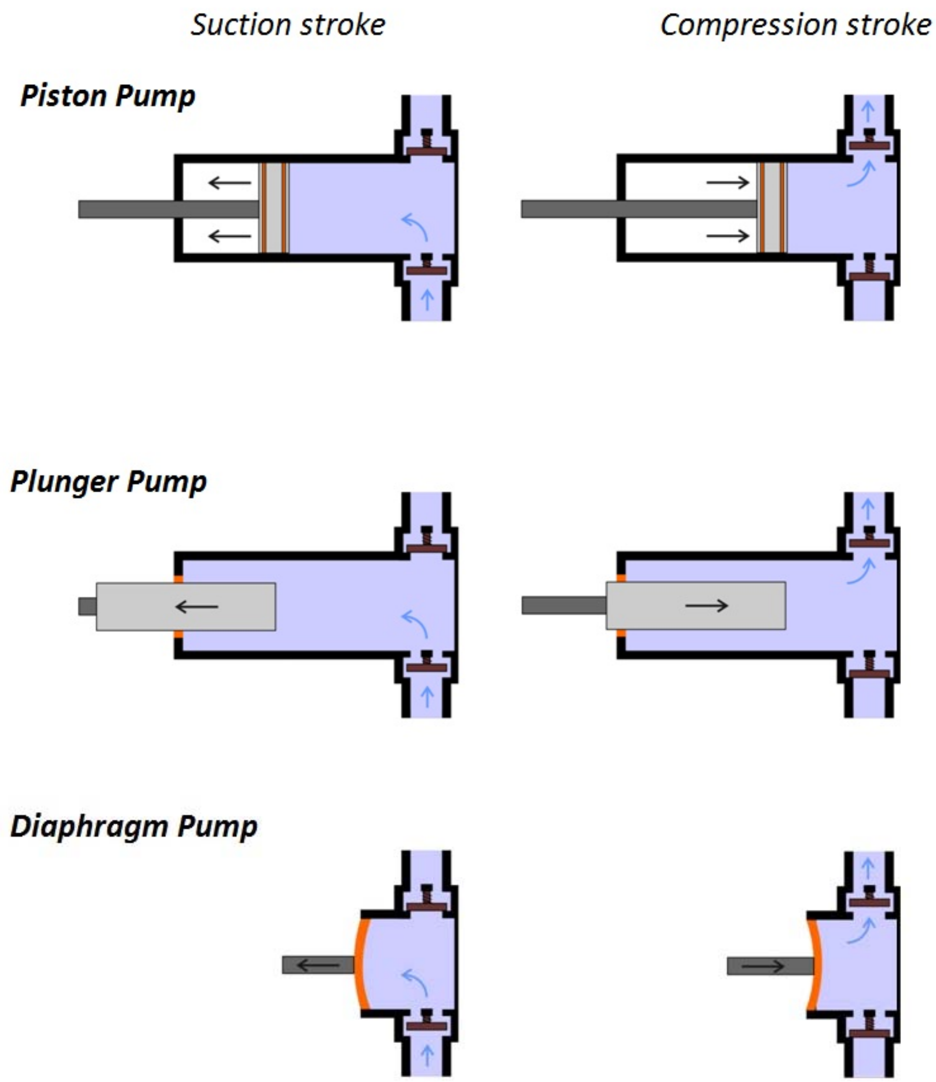


[2]

[1] http://marinersgalaxy.com/what-is-reciprocating-pump-and-how-i/

[2] https://www.brighthubengineering.com/marine-engines-machinery/41121-working-principle-of-rotary-pumps/

- Reciprocating
  - Piston
  - Plunger
  - Diaphragm

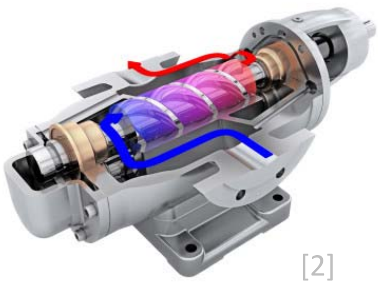


https://www.michael-smith-engineers.co.uk/resources/useful-info/positive-displacement-pumps

Rotary

Single Rotor

Screw



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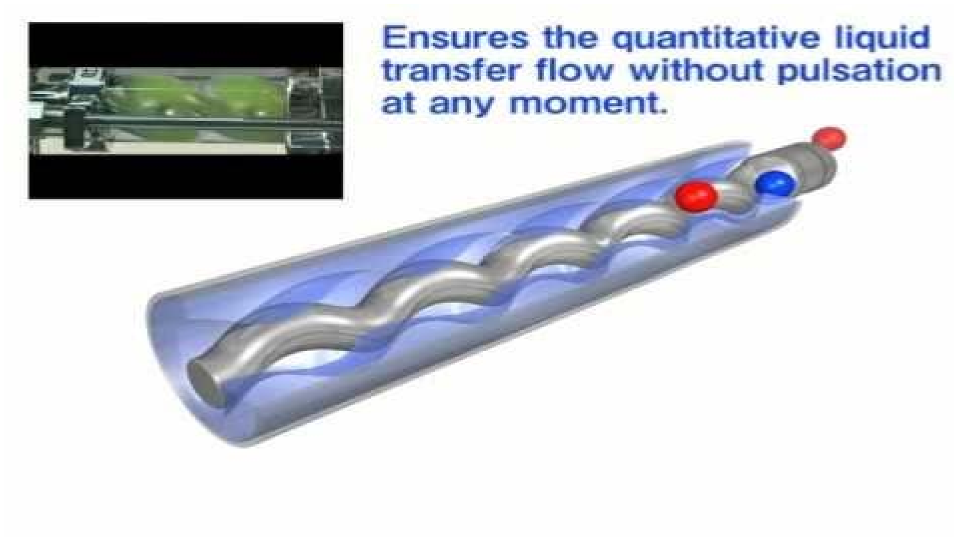
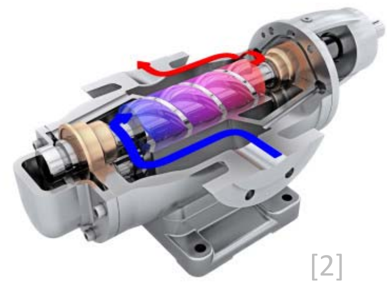


[1] https://www.michael-smith-engineers.co.uk/resources/useful-info/positive-displacement-pumps
[2] https://www.dynapumps.com.au/pressure-pumps/screw-pumps.aspx

Rotary

Single Rotor

- Screw
- Sliding vane



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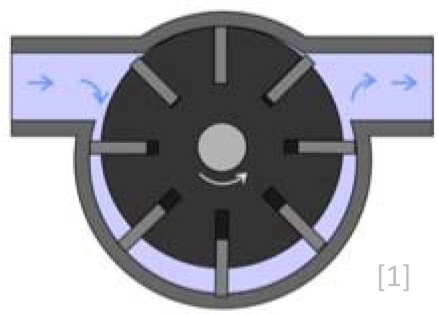


[1]

[1] https://www.michael-smith-engineers.co.uk/resources/useful-info/positive-displacement-pumps

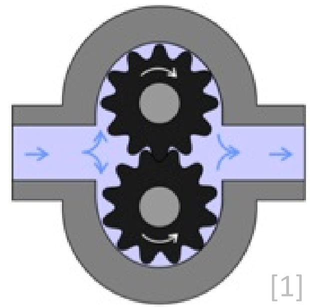
[2] https://www.dynapumps.com.au/pressure-pumps/screw-pumps.aspx

Rotary

Multiple Rotor

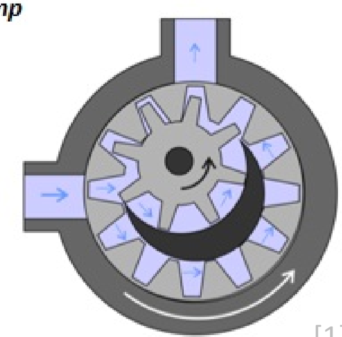
- Gear
- Lobe
- Screw

External Gear Pump



[1]

Internal Gear Pump



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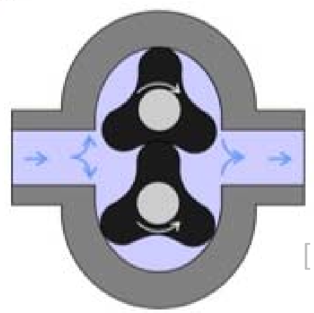
Lobe Pump



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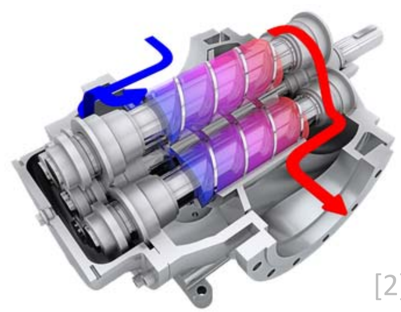


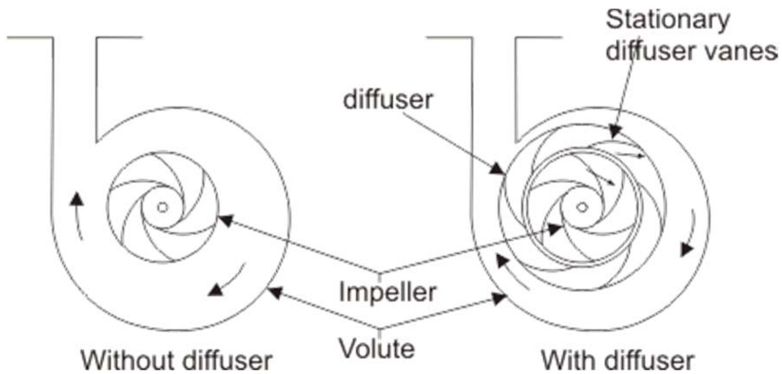
[2]

[1] https://www.michael-smith-engineers.co.uk/resources/useful-info/positive-displacement-pumps

[2] https://www.dynapumps.com.au/pressure-pumps/screw-pumps.aspx

Sub-classifications

- **Shape of casing**: volute, double volute, diffuser, annular, tubular, split casing, etc



Sub-classifications

- **Inlet geometry**: single suction, double suction, axial inlet, side inlet, top inlet, etc.

Sub-classifications

- **Layout:** horizontal shaft, vertical shaft, or inclined shaft

Sub-classifications

- **Number of stages**: for radial and mixed flow centrifugal pumps they can be classified as single-stage, double stage, or multiple stage

Sub-classifications

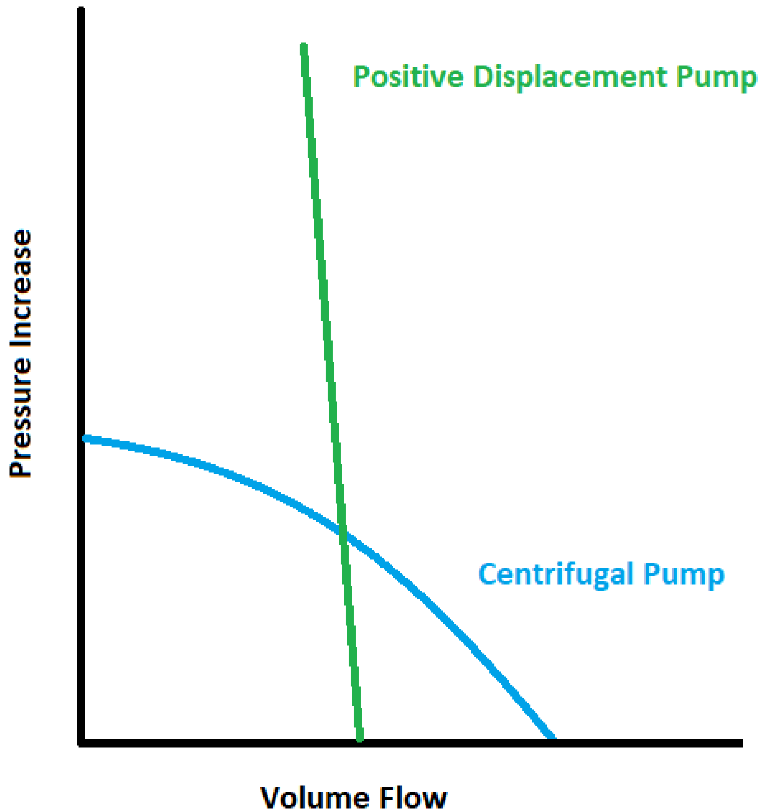
- **Liquid handled** (corrosive, abrasive, solid particles…)
- **Material of pump parts**: material used for manufacturing the impeller and pump casing
- **Type of prime mover**: electric motors, diesel engines, steam or gas turbines
- **Discharge pressure**: low pressure, high pressure, or high energy
- **Operating conditions**: submersibles pumps, wet motor pump, standby, and auxiliary pump:

Determination of Flow Rate in a Pumping System

- *The flow in a pump is determined by the relationship of the specified pump pressure increase to the back-pressure (the resistance in the system)*
- *The pipe system has a characteristic curve*
- *The pump can only operate where the **pump characteristic** intersects the **system characteristic***
- *The pump characteristics can be modified by adjusting the pump speed*
- *The system characteristics can be changed by opening or closing valves or changing levels in tanks*

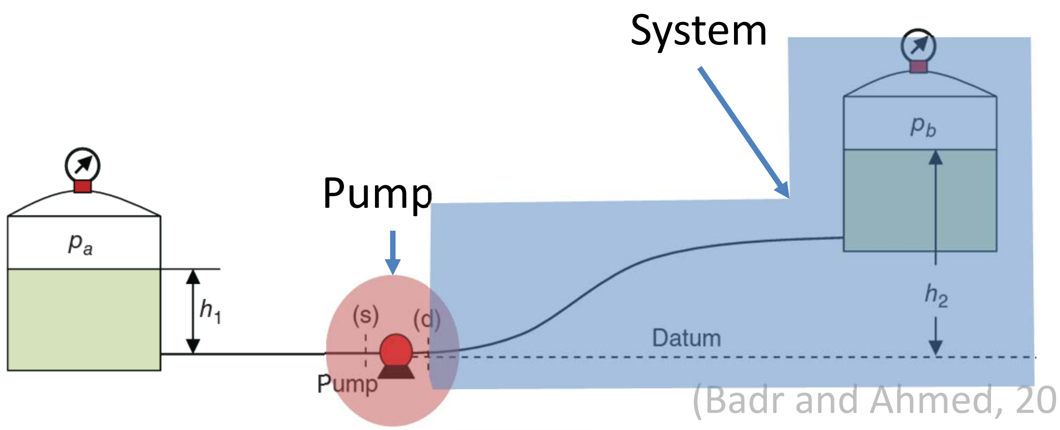
(Nesbitt, 2006)

Pump performance characteristics

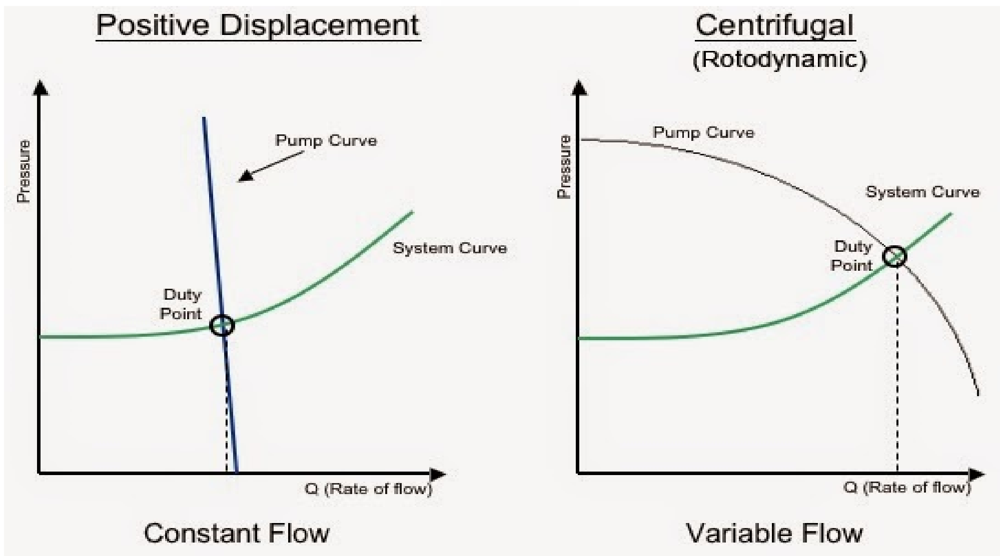


(Nesbitt, 2006)

System characteristic



(Badr and Ahmed, 2014)



http://www.hkdivedi.com/2015/05/difference-between-positive-and-non.html

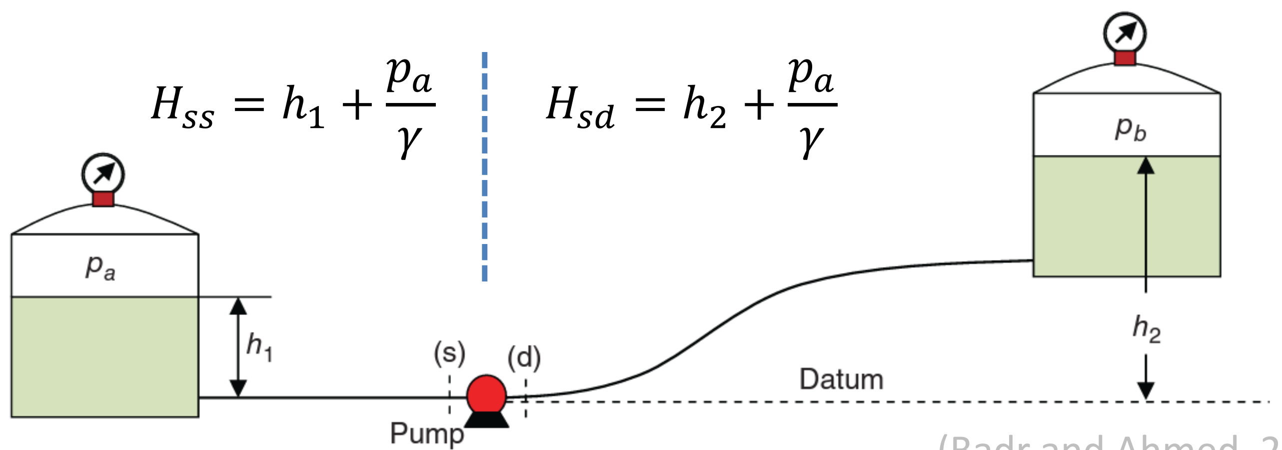
Rotodynamic Pumps

Definitions and Terminology

1. **Pump Capacity (Q)/ displacement:** express the actual volume flow rate delivered by the pump
2. **Pump Heads**:
   - Static suction head ($\boldsymbol{H_{ss}}$) pressure <u>head at the suction nozzle at zero flow rate</u>
   - Static delivery head ($\boldsymbol{H_{sd}}$) *pressure* <u>head at the delivery nozzle at zero flow rate</u>
   - Total static head ($\boldsymbol{H_{st}}$) <u>difference between the H_{ss} and H_{st}</u>

$$H_{ss} = h_1 + \frac{p_a}{\gamma}$$

$$H_{sd} = h_2 + \frac{p_a}{\gamma}$$



(Badr and Ahmed, 2014)

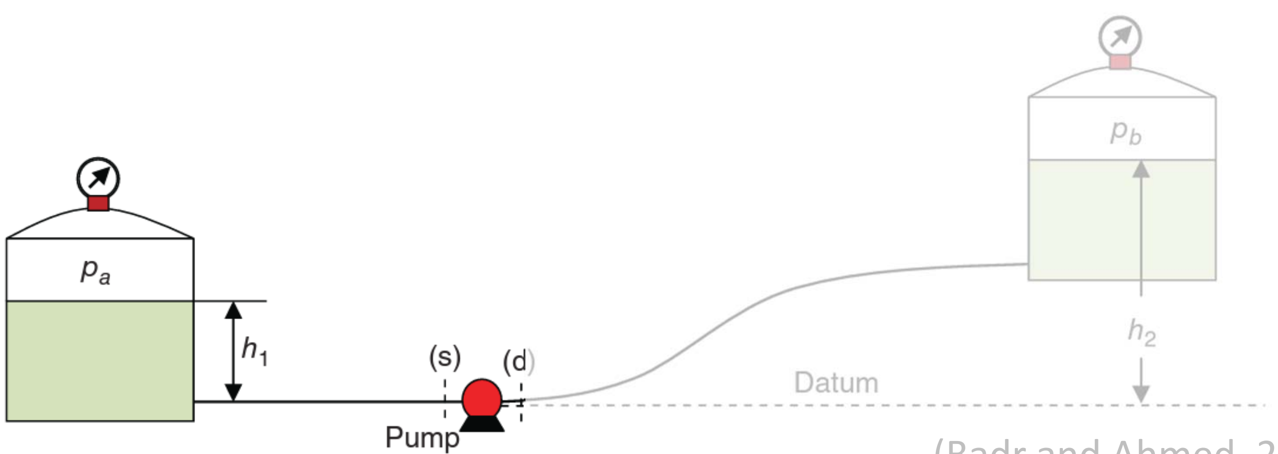
Definitions and Terminology

2. Pump Heads:

- Pump suction head (H_s): pressure head at the pump suction nozzle when the <u>pump is in operating condition</u>

$$H_s = h_1 + \frac{p_a}{\gamma} - \frac{V_s^2}{2g} - h_{Ls}$$

h_{Ls}… friction head losses between the suction reservoir and the suction nozzle



(Badr and Ahmed, 2014)

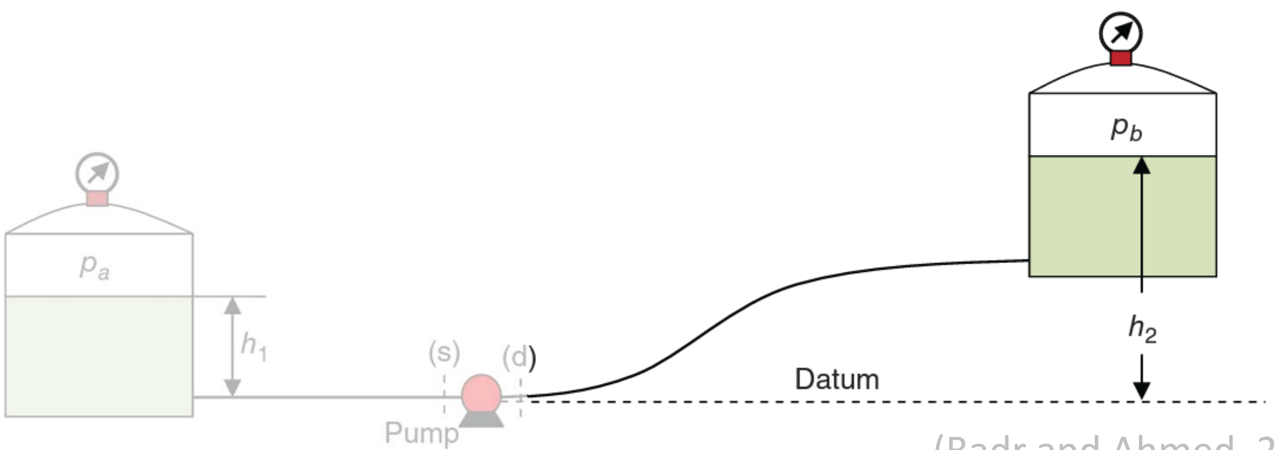
Definitions and Terminology

2. Pump Heads:

- Pump suction head (H_s): pressure head at the pump suction nozzle when the pump is in operating condition
- Pump delivery head (H_d): pressure head at the pump delivery nozzle when the pump is in operating condition

$$H_d = h_2 + \frac{p_b}{\gamma} - \frac{V_d^2}{2g} + h_{Ld}$$

h_{Ld}… *friction head losses between the delivery nozzle and the receiving tank*

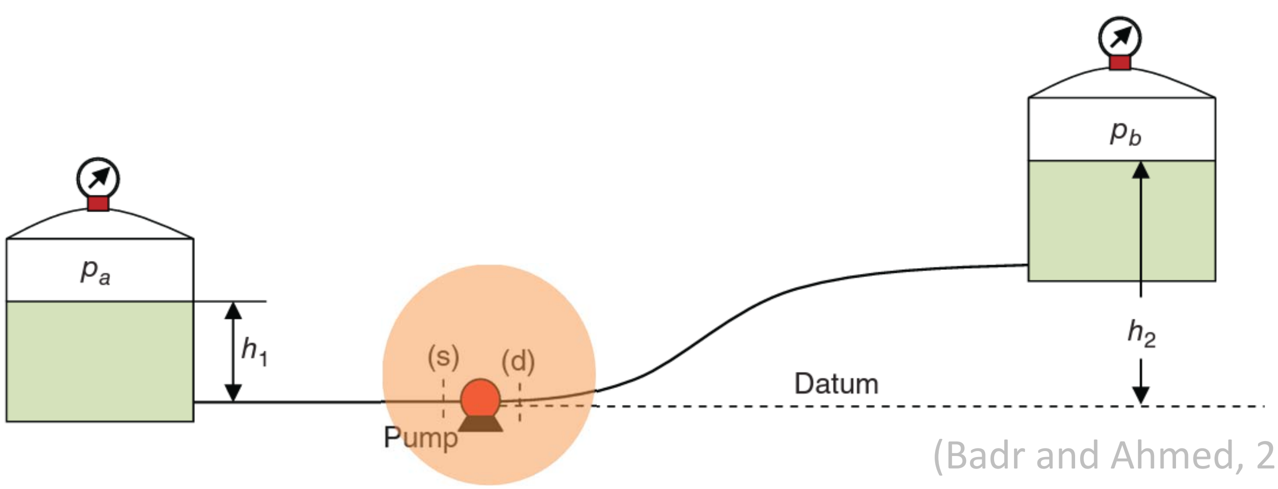


(Badr and Ahmed, 2014)

Definitions and Terminology

2. Pump Heads:

- Pump suction head (H_s): pressure head at the pump suction nozzle when the pump is in operating condition
- Pump delivery head (H_d): pressure head at the pump delivery nozzle when the pump is in operating condition
- Pump total head (ΔH): represents the energy added to the fluid by the pump (between the suction and delivery nozzles) per unit weight of fluid.

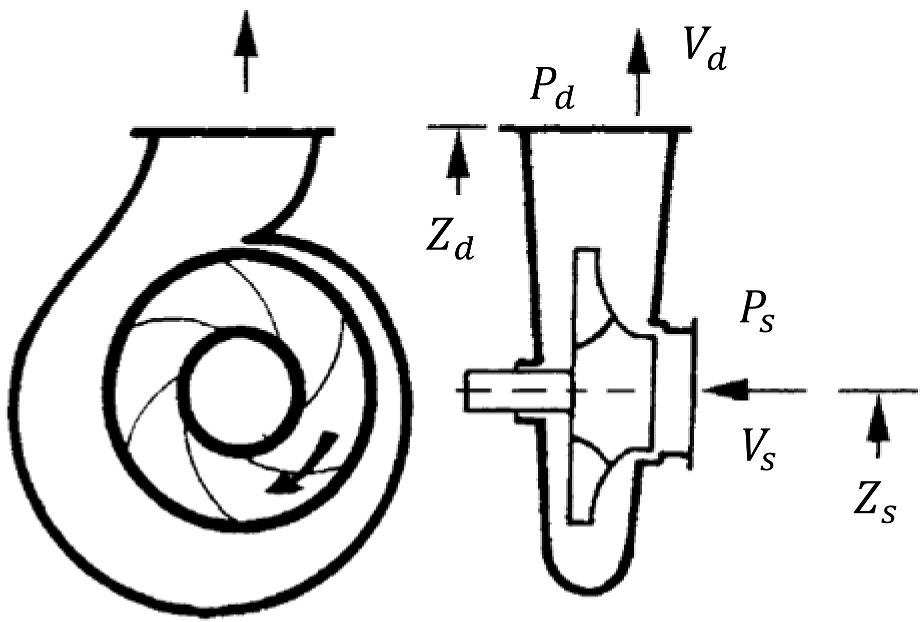


(Badr and Ahmed, 2014)

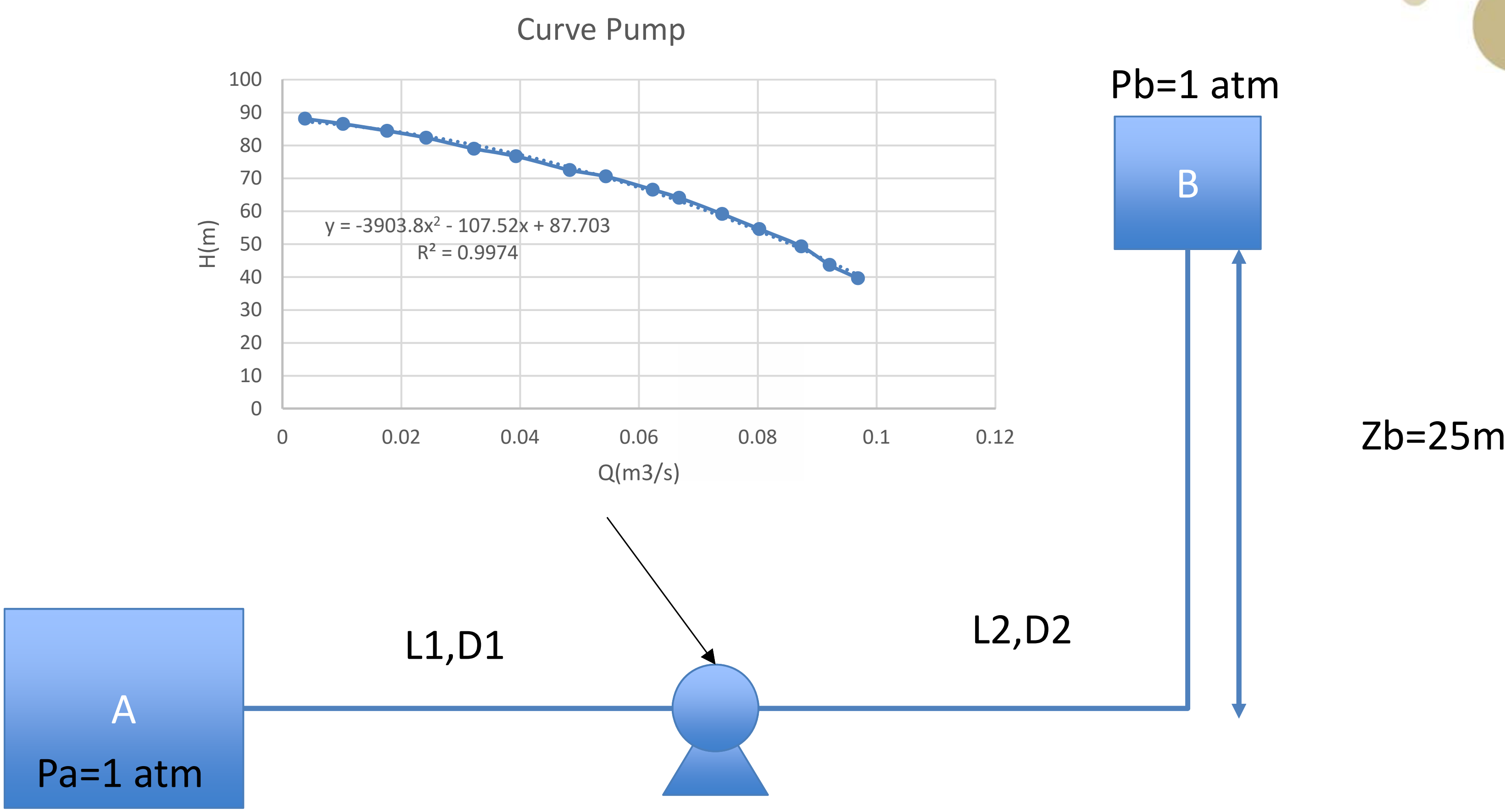
Definitions and Terminology

2. **Pump Heads**:

$$\Delta H = \left(\frac{P_d - P_s}{\rho g}\right) + \left(\frac{V_d^2 - V_s^2}{2g}\right) + (Z_d - Z_s)$$



System and Curve Example



L1=6.7cm
D1=15cm
L2=205m
D2=15cm

$h_{l\,minors} = 5.9m$

f=0.018

operating point??

System and Curve Example

System characteristic	$\Delta H = H_d - H_s$
Suction line	From A to Pump suction $H_s = \frac{P_A}{\rho g} - \frac{V_s^2}{2g} - \Delta h_{l1}$
Discharge line	From Pump discharge to B $H_d = \frac{P_B}{\rho g} - \frac{V_d^2}{2g} + (Z_B - Z_d) + \Delta h_{l2}$

$$\Delta H = H_d - H_s = \frac{P_B - P_A}{\rho g} + \frac{V_s^2 - V_b^2}{2g} + (Z_B - Z_d) + \sum \Delta h_l$$

$$\Delta H = (Z_B - Z_d) + \sum \Delta h_l$$

System and Curve Example

Head losses

f=0.018

$$\sum \Delta h_l = \Delta h_{l1} + \Delta h_{l2} = \frac{f L_1 V_s^2}{2gD_1} + \frac{f L_2 V_d^2}{2gD_2} + h_{l\,minors}$$

$$\sum k\frac{V^2}{2g} = 5.9m$$

$$V_d^2 = V_s^2 = V^2 = \left(\frac{Q}{A}\right)^2$$

$$\sum \Delta h_l = 5093Q^2$$

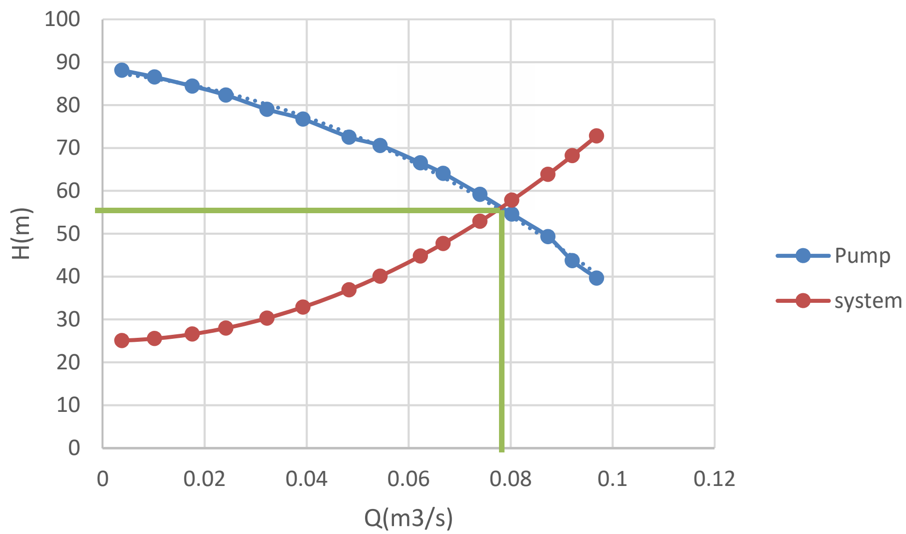
System Curve

$$\Delta H = (Z_B - Z_d) + \sum \Delta h_l = 25 + 5093Q^2$$

System and Curve Example

System Curve

$$\Delta H = (Z_B - Z_d) + \sum \Delta h_l = 25 + 5093Q^2$$

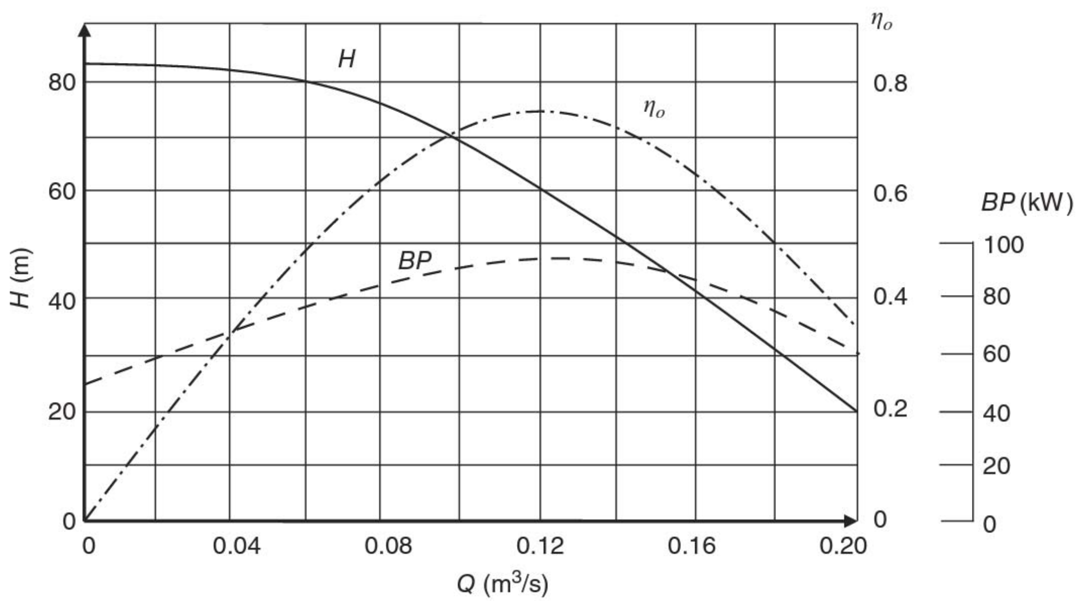


$$Q = 0.077\, m^3/s \qquad H = 56\, m$$

Definitions and Terminology

3. Pump performance characteristics

– It refers to the relationship between each of the **total head (H),** the **pump power consumption (BP),** the pump overall **efficiency (η_o)**



Typical performance curve for a radial-type centrifugal pump operating at a constant speed

(Badr and Ahmed, 2014)

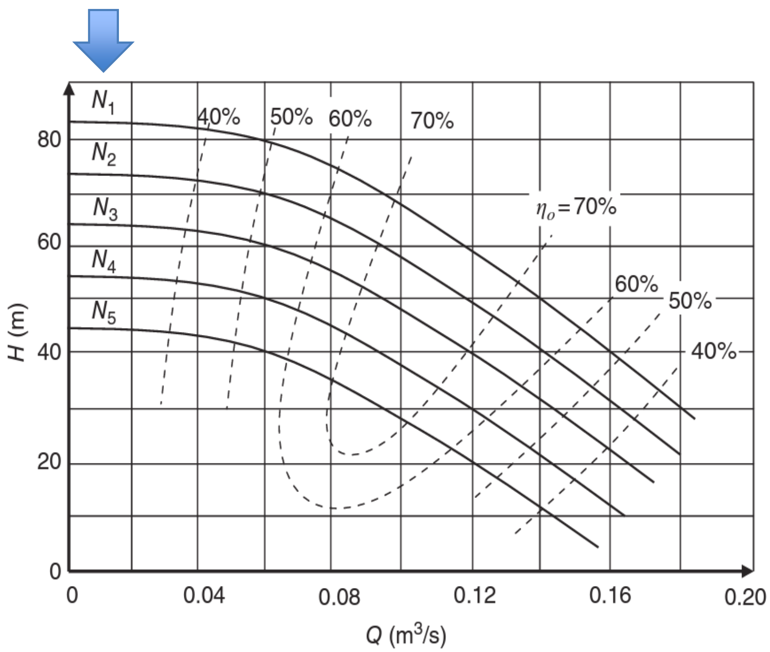
Definitions and Terminology

3. Pump performance characteristics

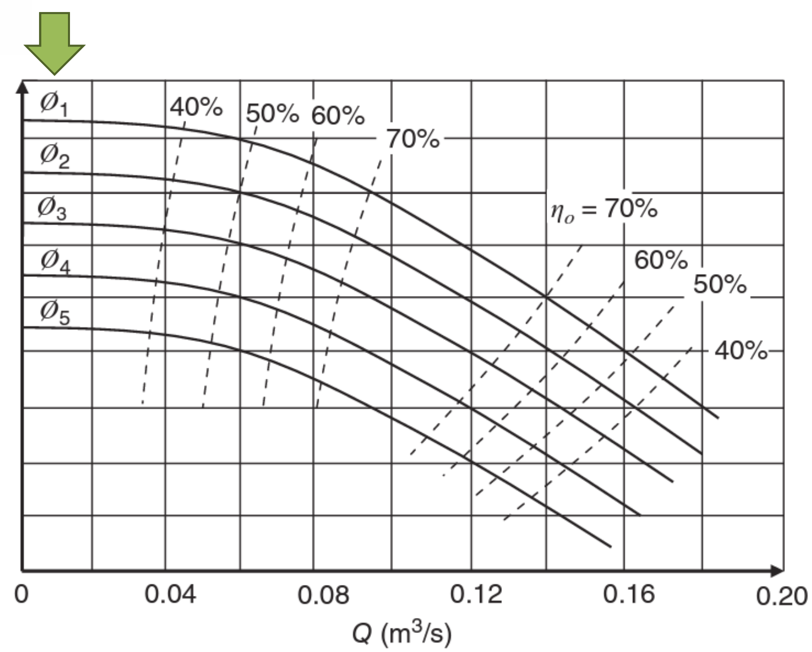
– Presented as a set of **Iso-efficiency curves** at:

- Different speeds
- Different size for geometrically similar pumps at constant speed

Different speeds



Different Impeller Diameter



Typical for a radial-type centrifugal pump

(Badr and Ahmed, 2014)