**ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF CHEMICAL AND BIOENGINEERING**

Course: Design and Development of Food Products and Equipment

EQUIPMENT DESIGN: PUMPS

Introduction

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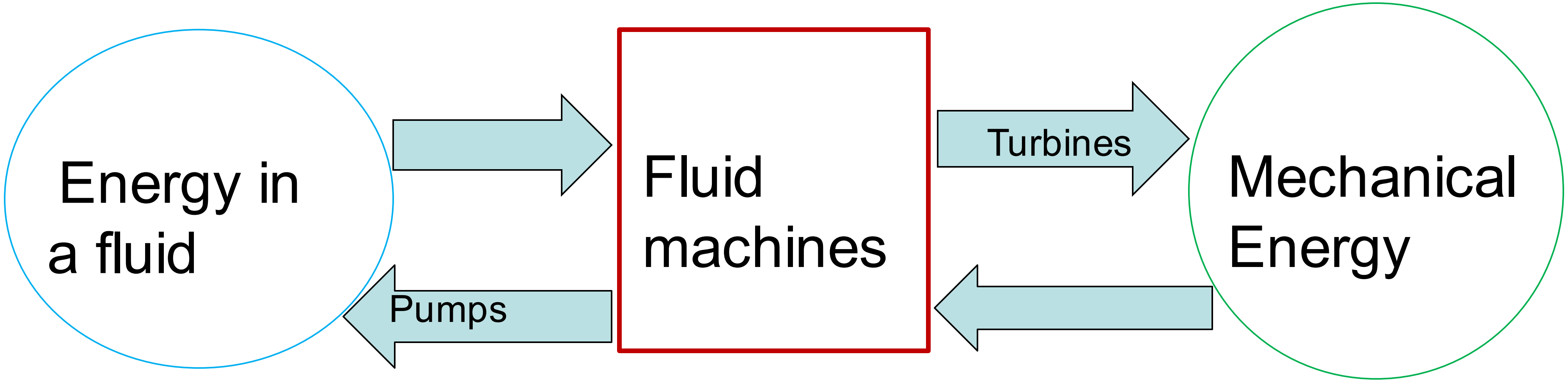

Energy in a fluid
Fluid machines
Turbines
Mechanical Energy
Pumps

Pumps

- Pumps are used to increase the total energy in a fluid
- The increase in energy in a pump is commonly referred to as total dynamic head measured in meters
- The total dynamic head, or short “head”, can be used to increase pressure (pressure head), overcome a height difference (static head), accelerate the flow (velocity head) or overcome a friction head in a system (i.e. friction losses), which can be expressed by the following expressions

Pressure head $H_p = \dfrac{p_2 - p_1}{g\rho}$

Static head $H_s = h_2 - h_1$

Velocity head $H_v = \dfrac{{v_2}^2 - {v_1}^2}{2g}$

Friction head $H_f = h_f$

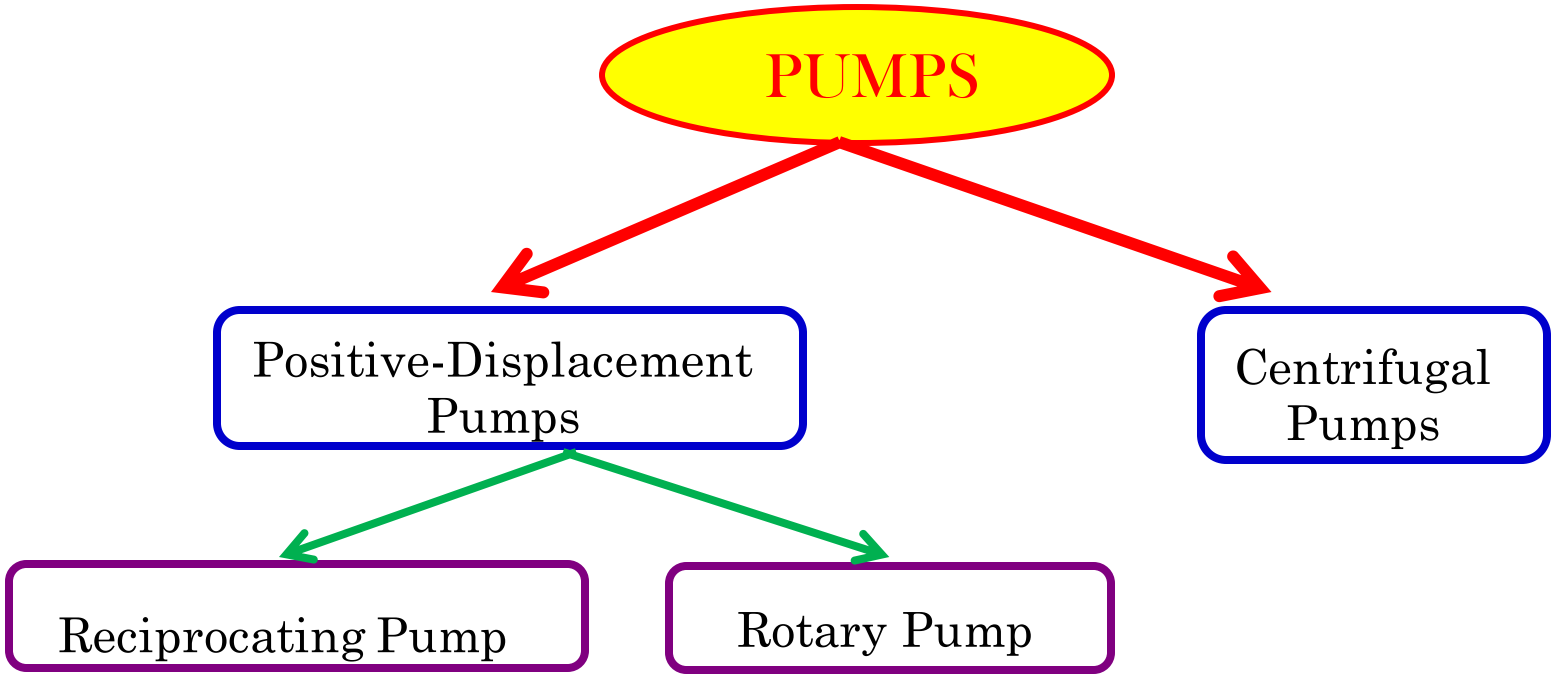
Therefore, to choose an appropriate pump for a given installation all the above heads need to be accounted for as follows

$$H_{tot} = H_p + H_s + H_v + H_f$$

Pump is designed to overcome the static head and flow related losses

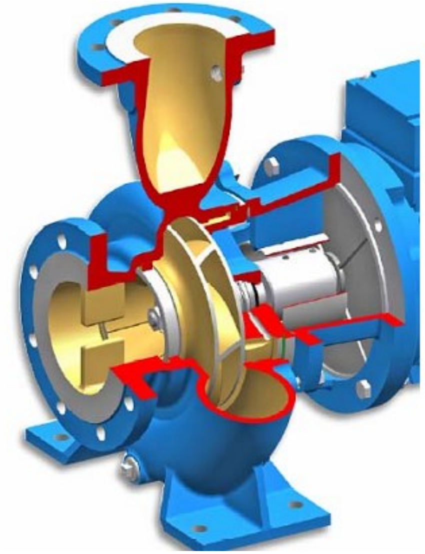
During the pump design, the designer give focus on how to incease the discharge speed/ flow rate

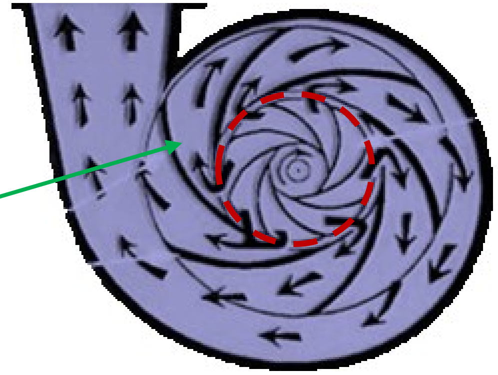
Types of pumps



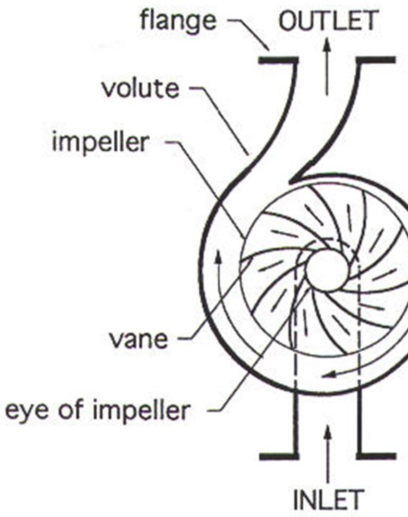
Centrifugal Pumps

- Structures
  - ✓ Impereller
  - ✓(diffuser vanes)
  - ✓Stationary casing/ volute

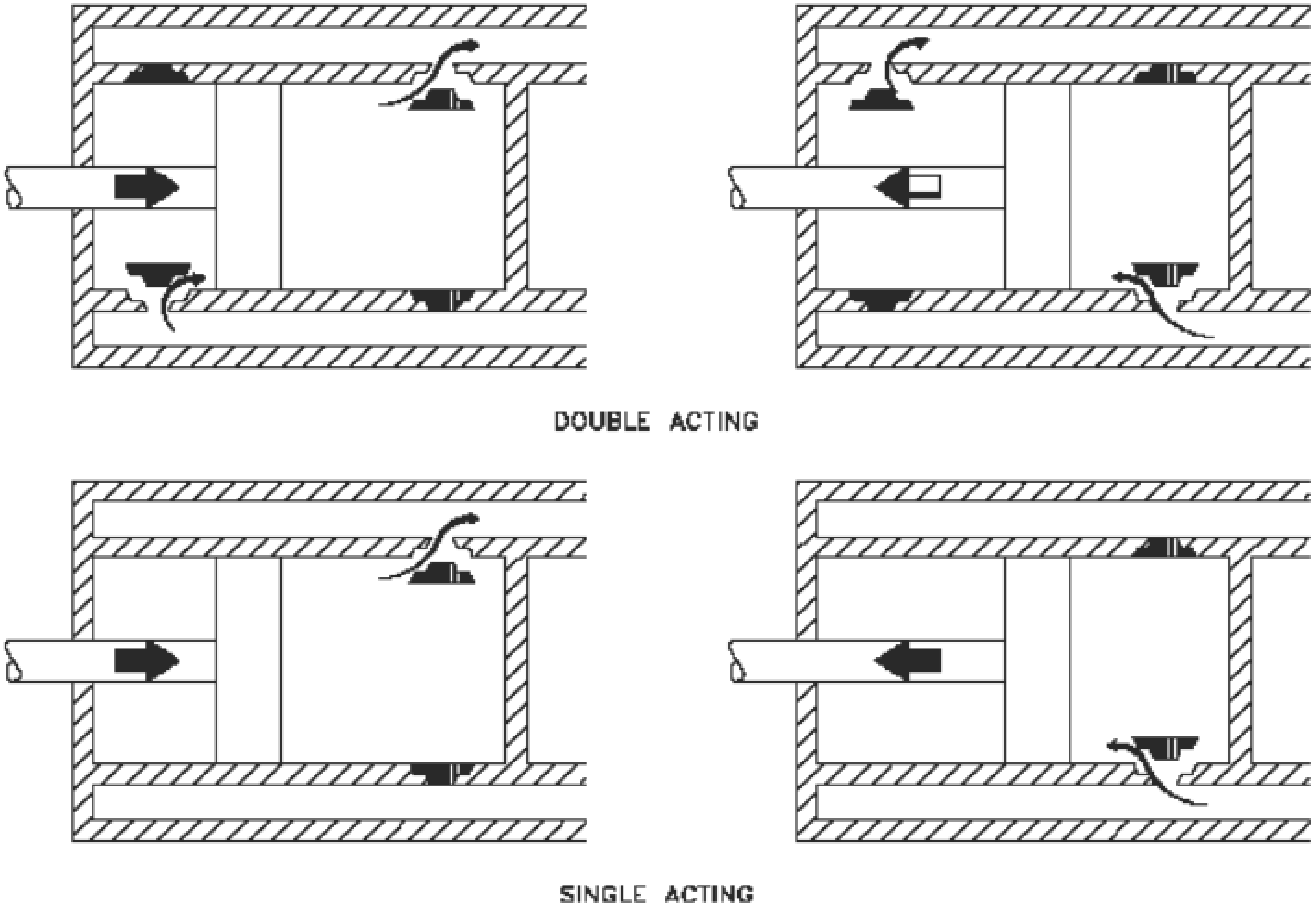




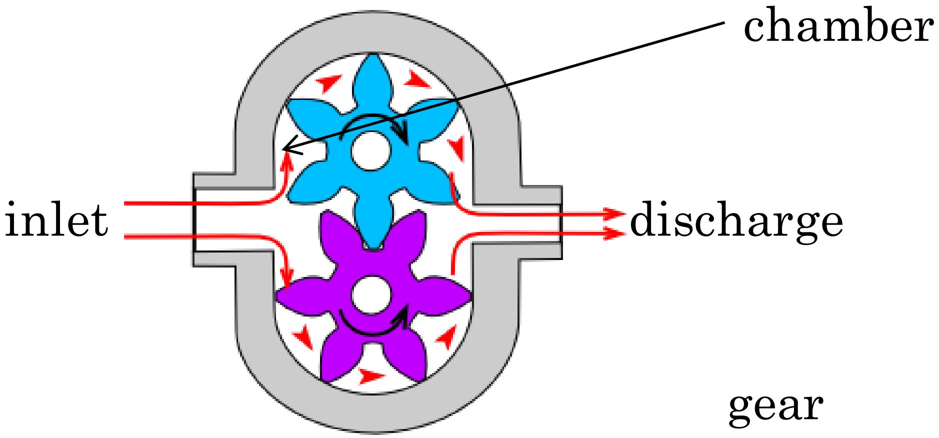
Stationary diffuser vane



Single and double acting piston pumps



Rotary pump



Rotary pump

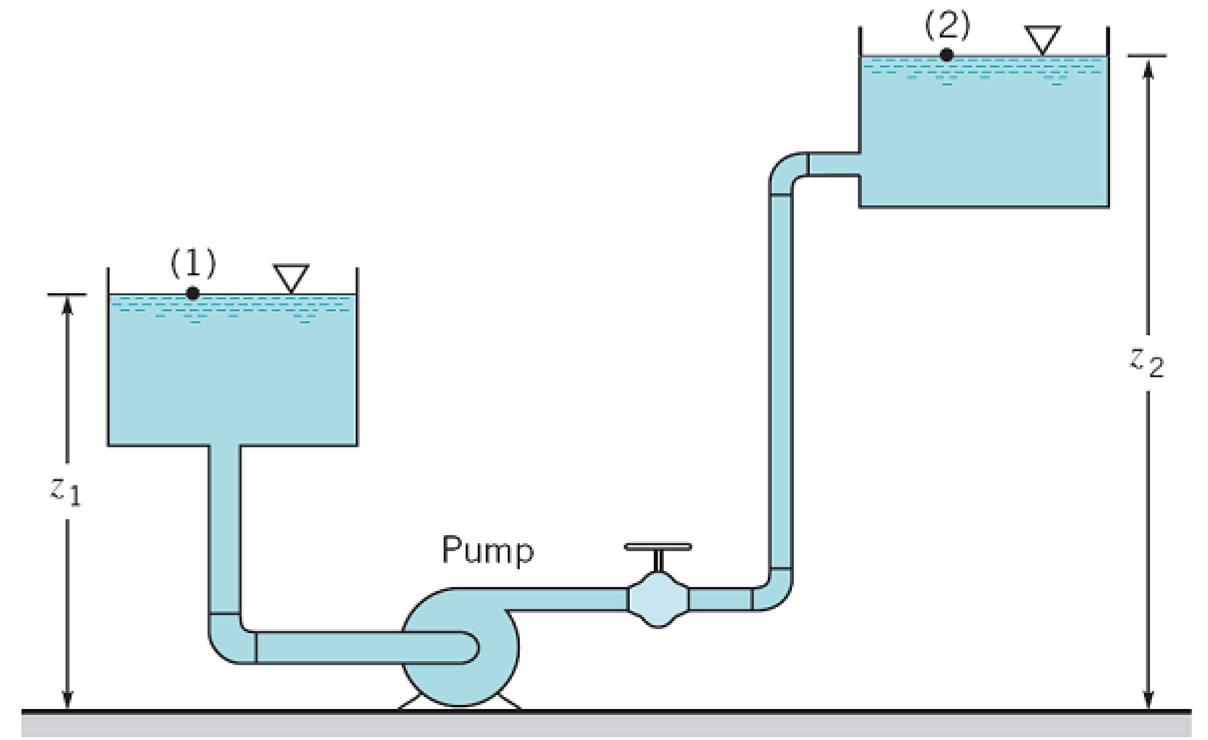
Pump Performance Trade offs

Parameter	Centrifugal Pumps	Reciprocating Pumps	Rotary Pumps
Optimum Flow and Pressure Applications	**Medium/High Capacity, Low/Medium Pressure**	**Low Capacity, High Pressure**	**Low/Medium Capacity, Low/Medium Pressure**
Maximum Flow Rate	**100,000+ GPM**	**10,000+ GPM**	**10,000+ GPM**
Maximum Pressure	**6,000+ PSI**	**100,000+ PSI**	**4,000+ PSI**
Smooth or Pulsating Flow	**Smooth**	**Pulsating**	**Smooth**
Variable or Constant Flow	**Variable**	**Constant**	**Constant**
Space Considerations	**Requires Less Space**	**Requires More Space**	**Requires Less Space**
Costs	**Lower Initial Lower Maintenance Higher Power**	**Higher Initial Higher Maintenance Lower Power**	**Lower Initial Lower Maintenance Lower Power**
Fluid Handling	**Suitable for a wide range including clean, clear, non-abrasive fluids to fluids with abrasive, high-solid content. Not suitable for high viscosity fluids Lower tolerance for entrained gases**	**Suitable for clean, clear, non-abrasive fluids. Specially-fitted pumps suitable for abrasive-slurry service. Suitable for high viscosity fluids Higher tolerance for entrained gases**	**Requires clean, clear, non-abrasive fluid due to close tolerances Optimum performance with high viscosity fluids Higher tolerance for entrained gases**

Operation of Centrifugal Pumps

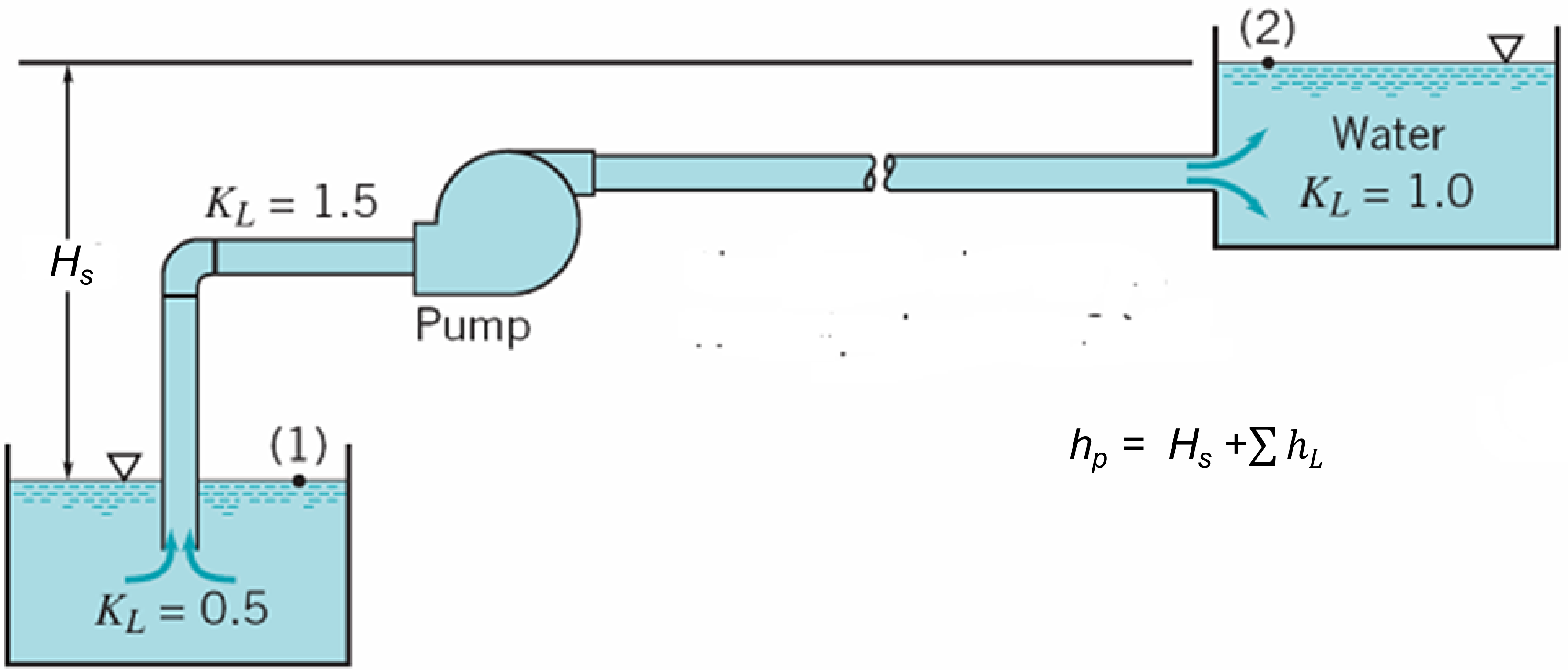
- As the impeller rotates, fluid is sucked in through the eye of the casing and flows radially outward
- Energy is added to the fluid by the rotating blades, and both pressure and absolute velocity are increased as the fluid flows from the eye to the periphery of the blades
- Fluid velocity is decreased in diffuser/and volute, and this decrease in velocity is converted into an increase in pressure

Pump Design Consideration



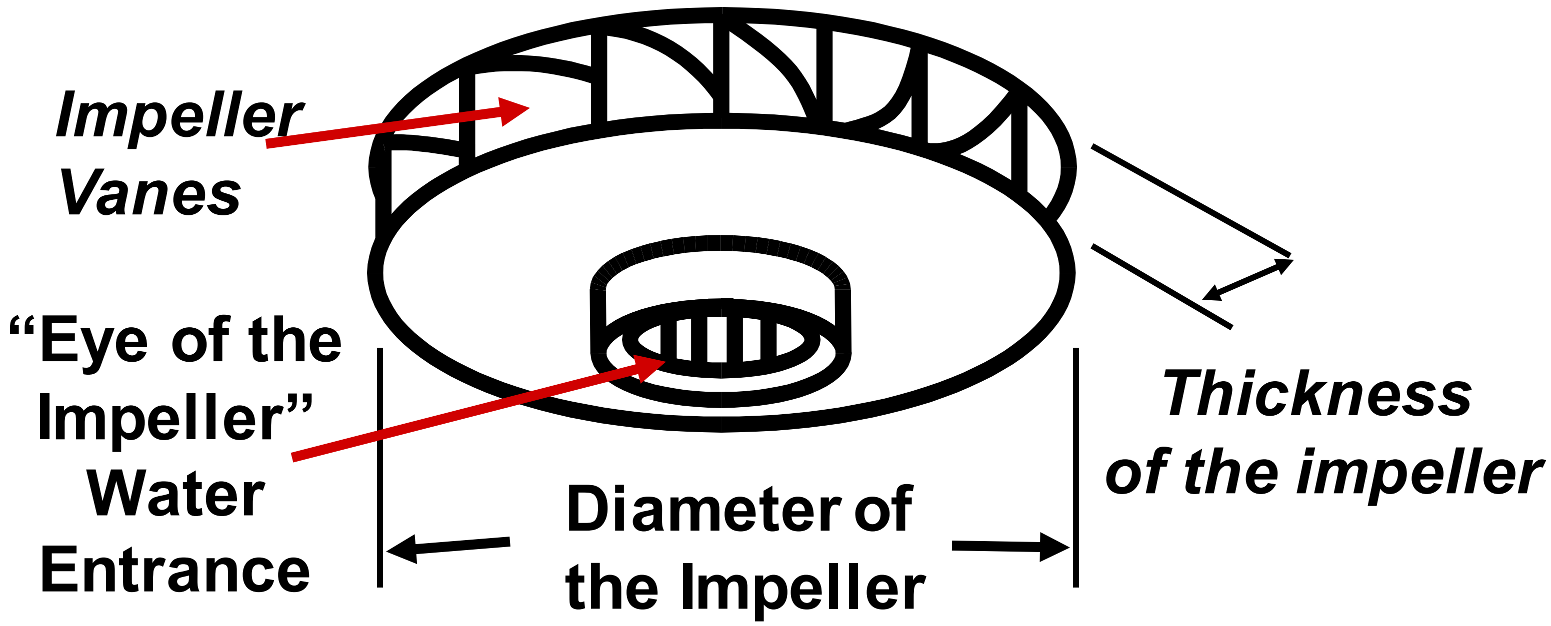
$$h_p = Z_2 - Z_1 + \sum h_L$$

System 2



$$h_p = H_s + \sum h_L$$

- Single stage pump: Only one impeller is mounted on the shaft



- Thicker the impeller → More Water
- Larger the diameter → More Pressure

- Multistage pump: Several impellers are mounted on the same shaft
  - ✓The flowrate is the same through all stages
  - ✓Each stage develops an additional pressure rise
  - ✓For a very large discharge pressure

- Pumps in parallel
  - ✓ For increasing flow rate
  - ✓ The pressure more or less remain the same

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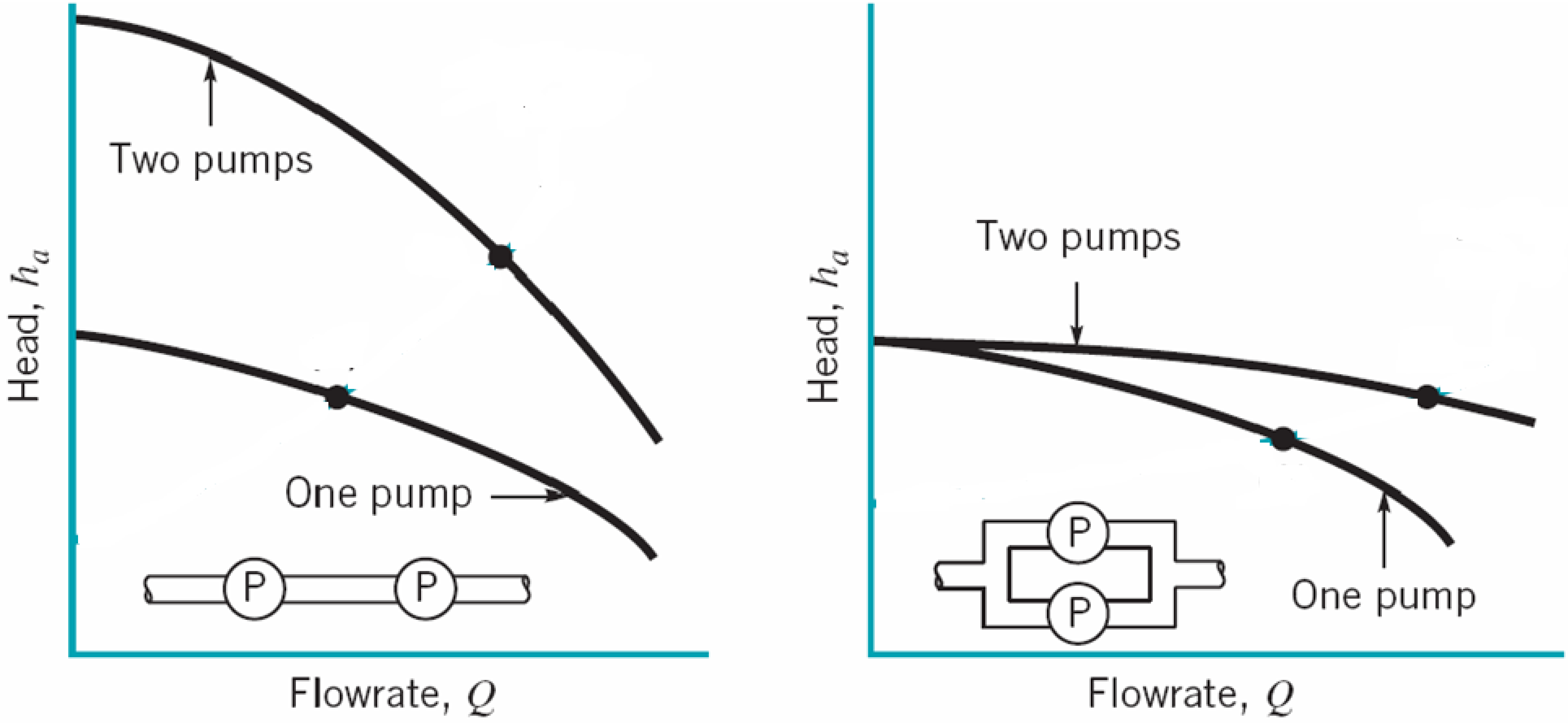
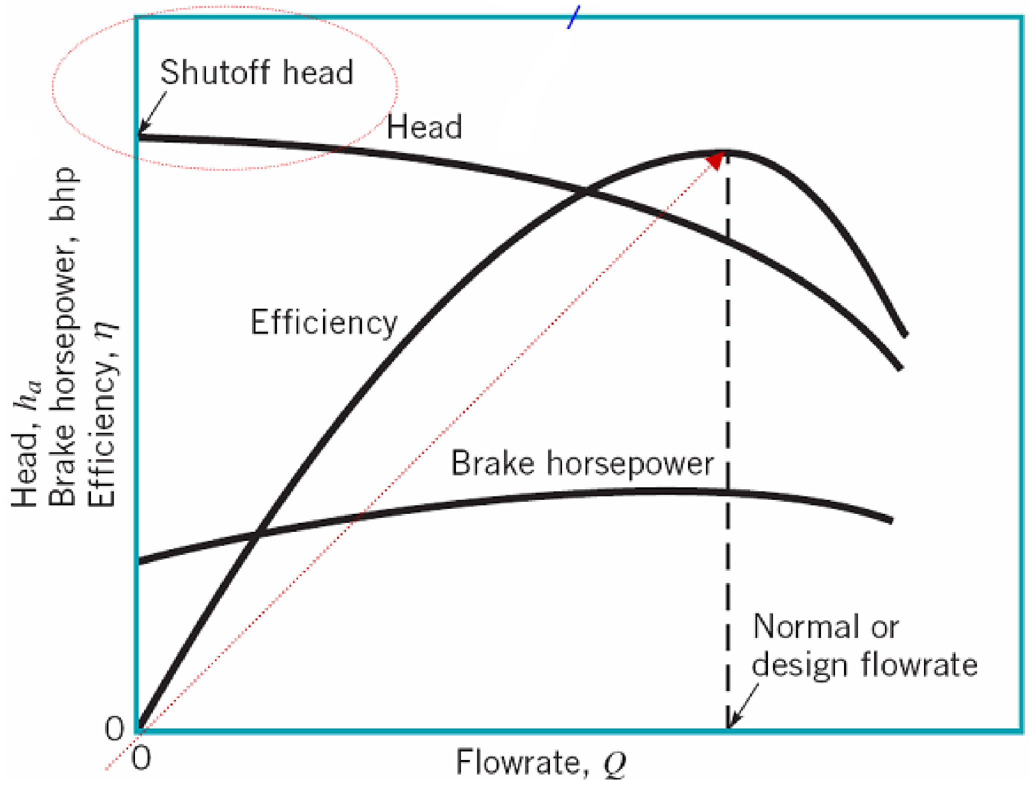

Two pumps
One pump
P
P
Head, h_a
Flowrate, Q
Two pumps
One pump
P
P
Head, h_a
Flowrate, Q

Pump Performance Characteristics

- Performance characteristics for a given pump geometry and operating speed are usually given in the plots of h_a, η,and *bhp* versus Q

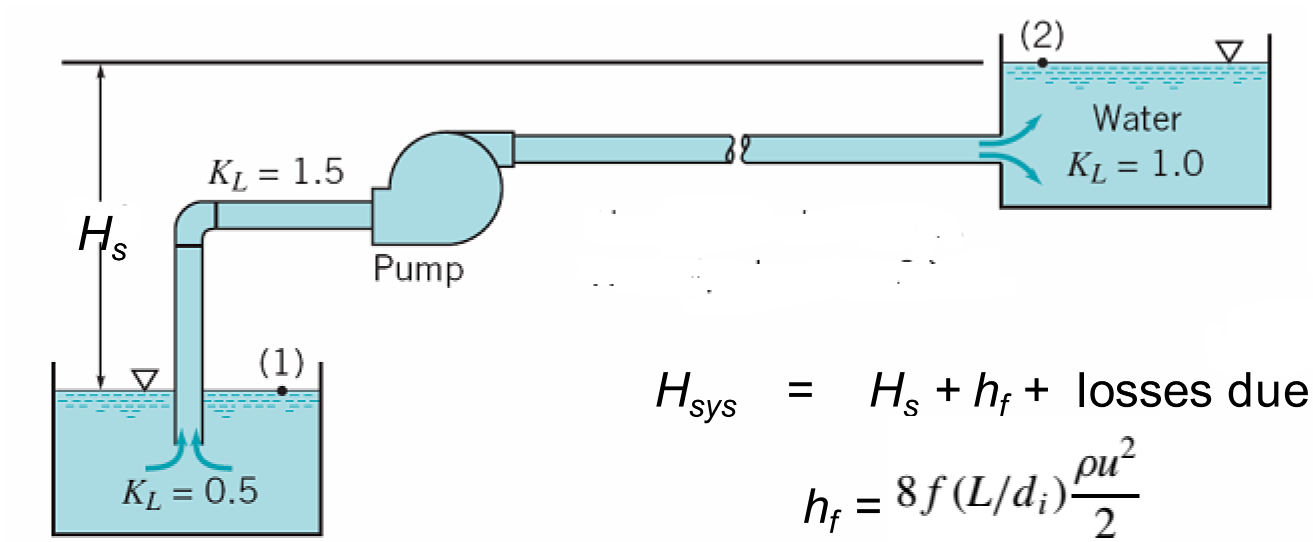


Pump Efficiency

- Hydraulic efficiency: compare actual head increase to theoretical head increase. Accounts for friction and hydraulic losses in pump
- Volumetric efficiency: compare actual volume flow to theoretical volume flow .Accounts for internal leakage and backflow
- Mechanical efficiency: compare actual power supplied by motor to power received by impeller. Accounts for mechanical friction power losses

$$\eta_{tot} = \eta_{hyd} \cdot \eta_{vol} \cdot \eta_{mech} = \frac{Q \cdot H \cdot g \cdot \rho}{\text{P (shaft power)}}$$

System Characteristics

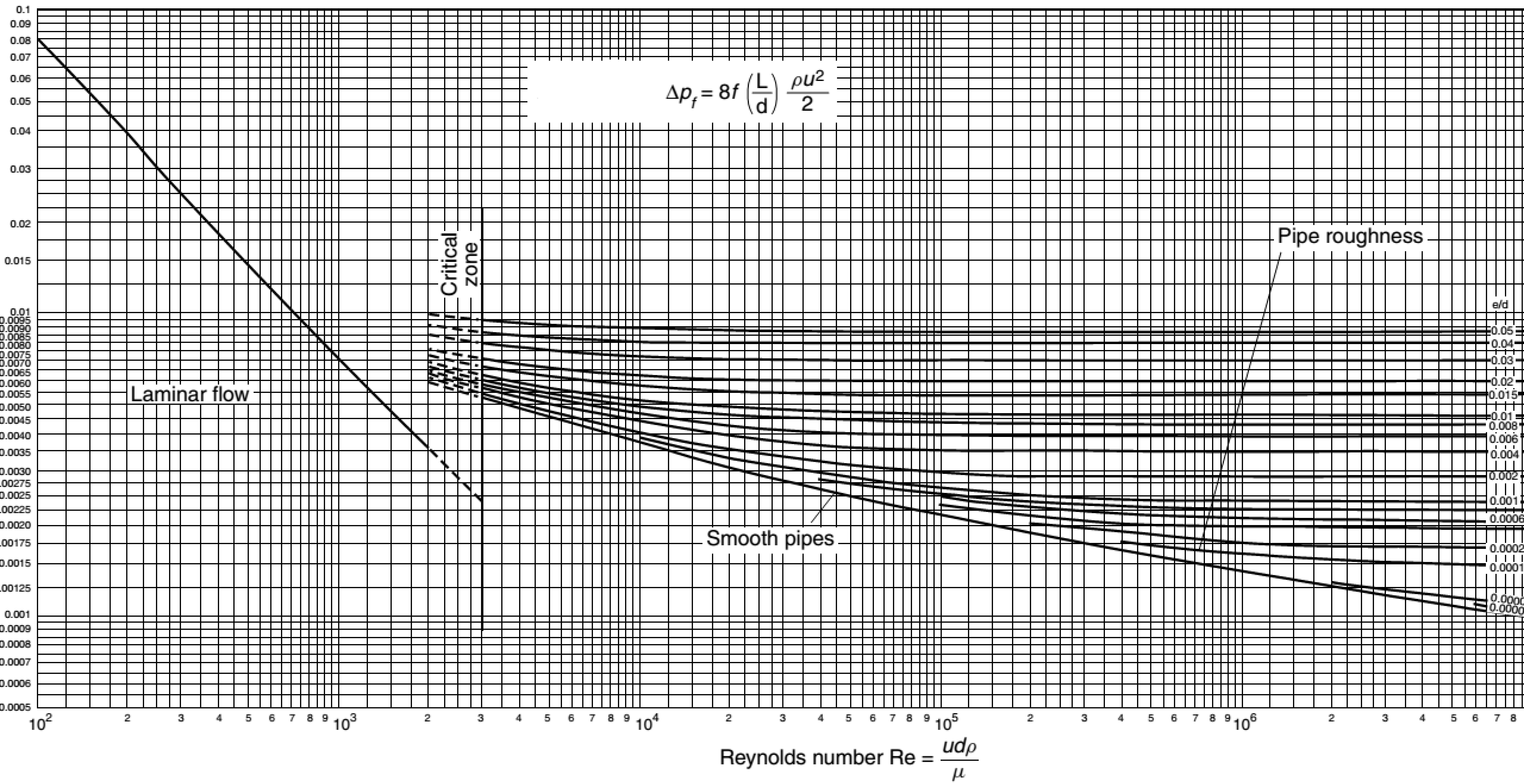


$$H_{sys} = H_s + h_f + \text{ losses due to fittings and valves}$$

$$h_f = 8f(L/d_i)\frac{\rho u^2}{2}$$

$$\text{Losses due to fittings and valves} = K_L u^2/2g$$

$$H_{sys} = H_s + CQ^2$$

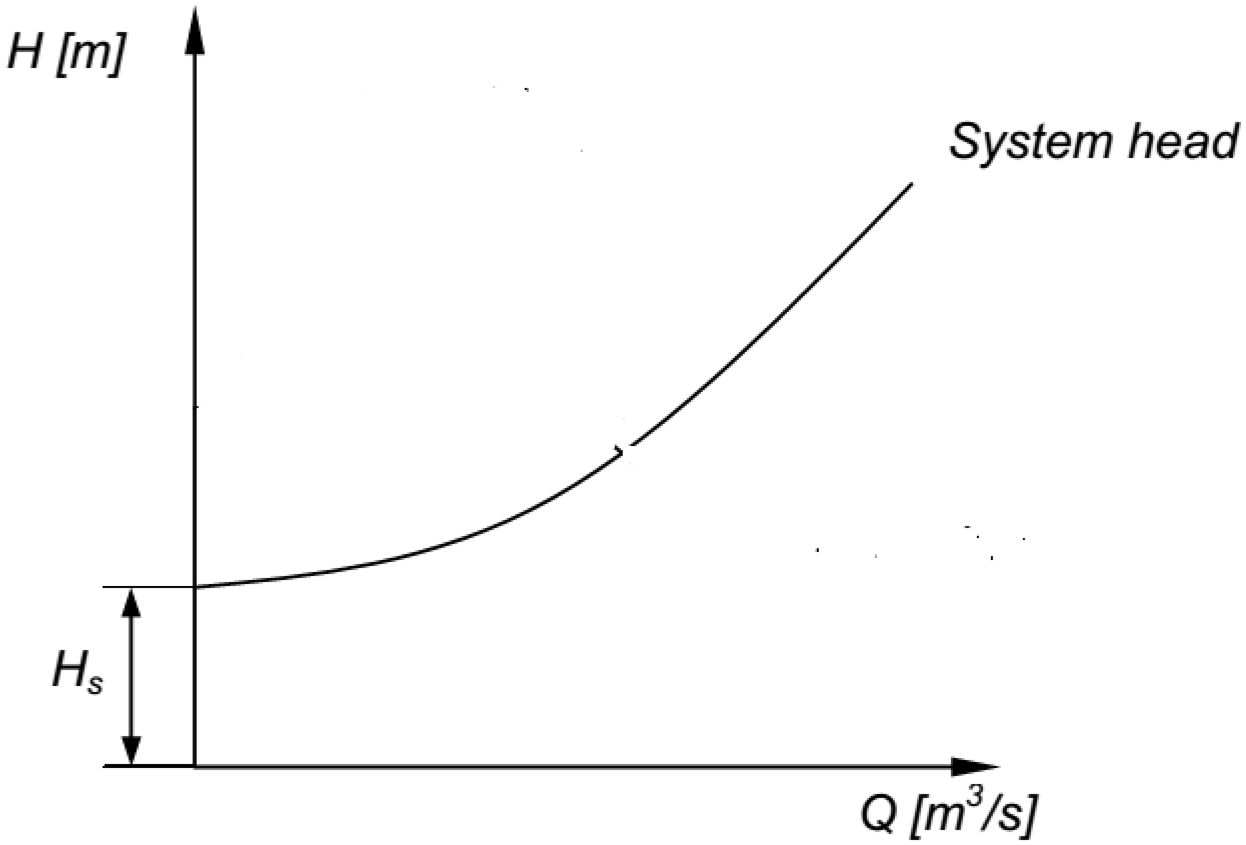


Pipe friction versus Reynolds number and relative roughness

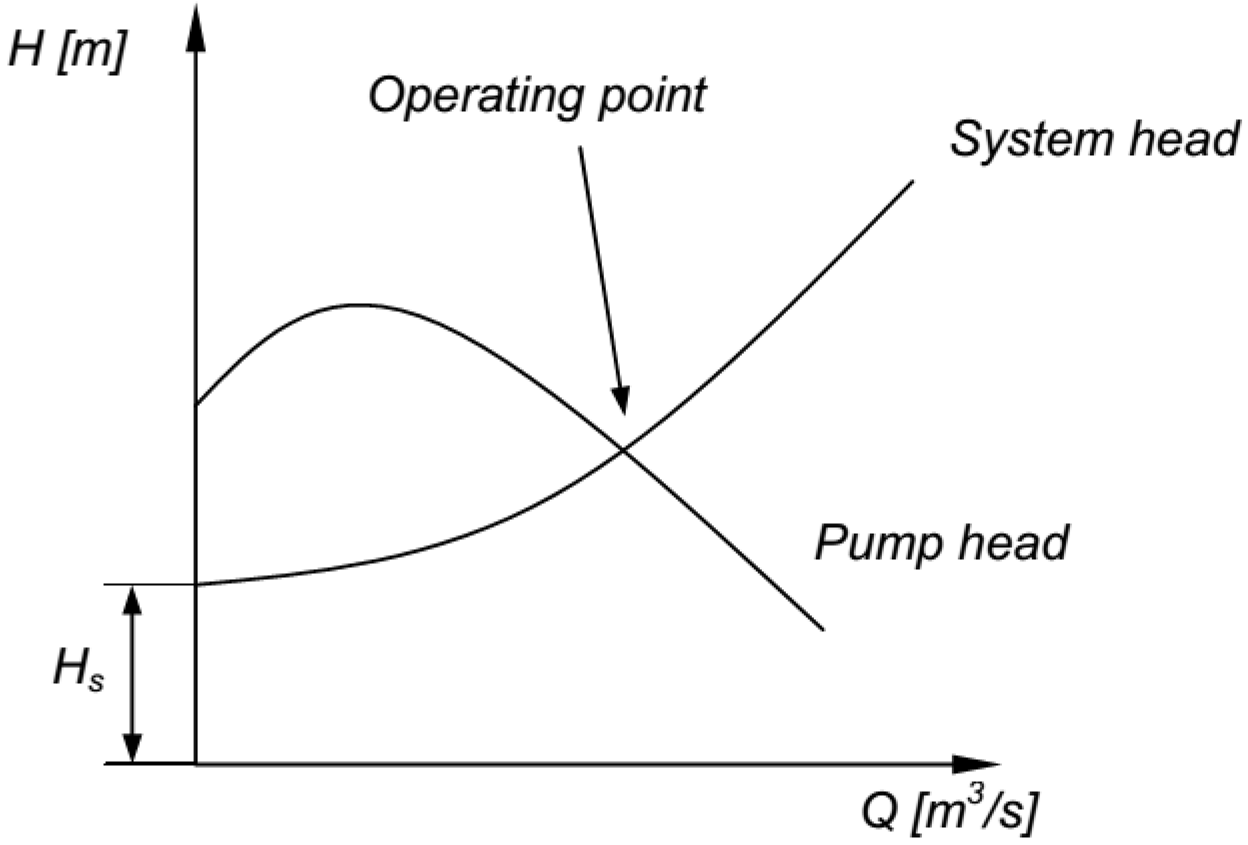
Pipe roughness

Material	Absolute roughness, mm
Drawn tubing	0.0015
Commercial steel pipe	0.046
Cast iron pipe	0.26
Concrete pipe	0.3 to 3.0

System Characterstic curve



Pump operating point



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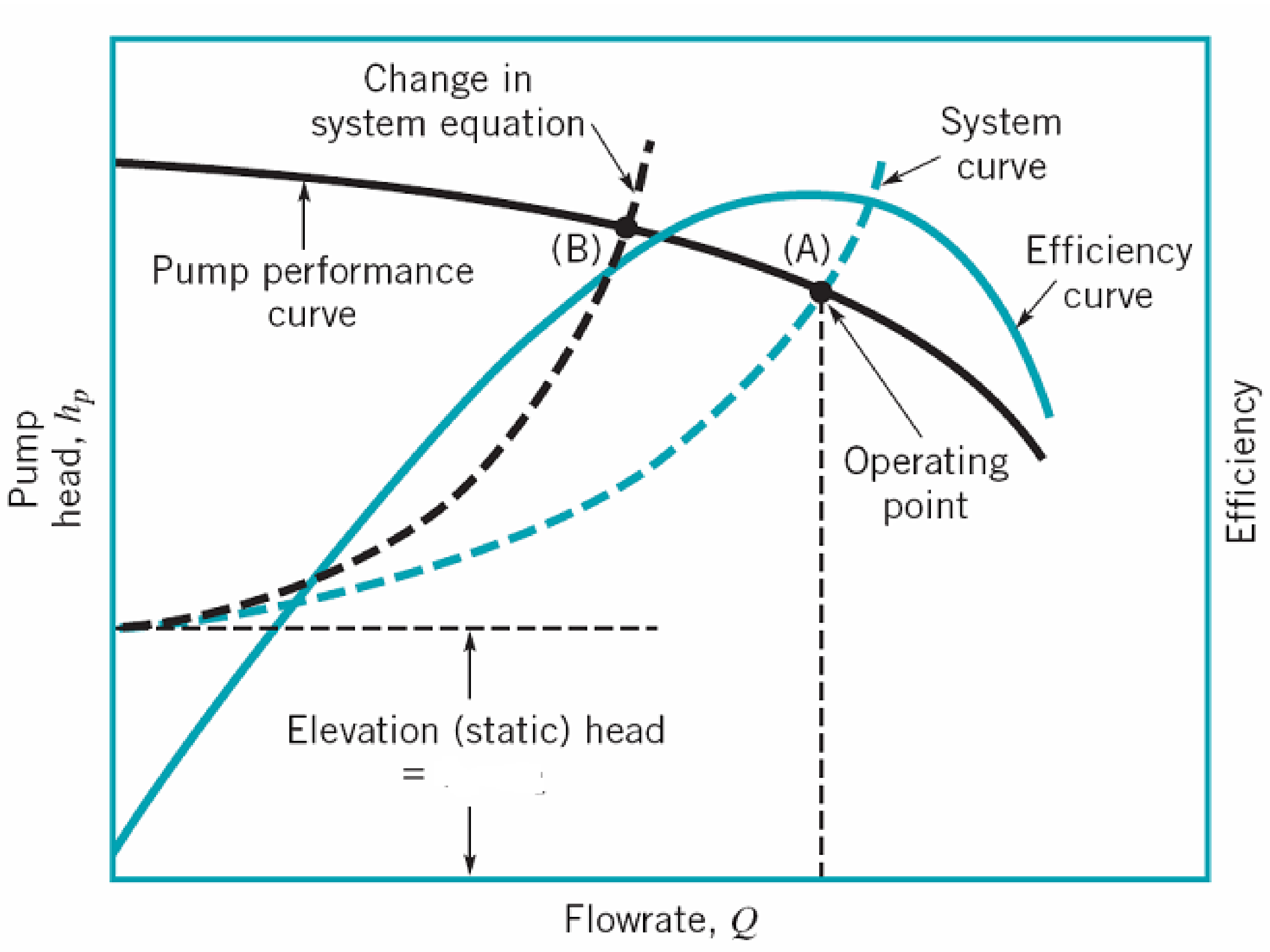


Change in
system equation
System
curve
Pump performance
curve
(B)
(A)
Efficiency
curve
Pump
head, h_p
Operating
point
Efficiency
Elevation (static) head
=
Flowrate, Q

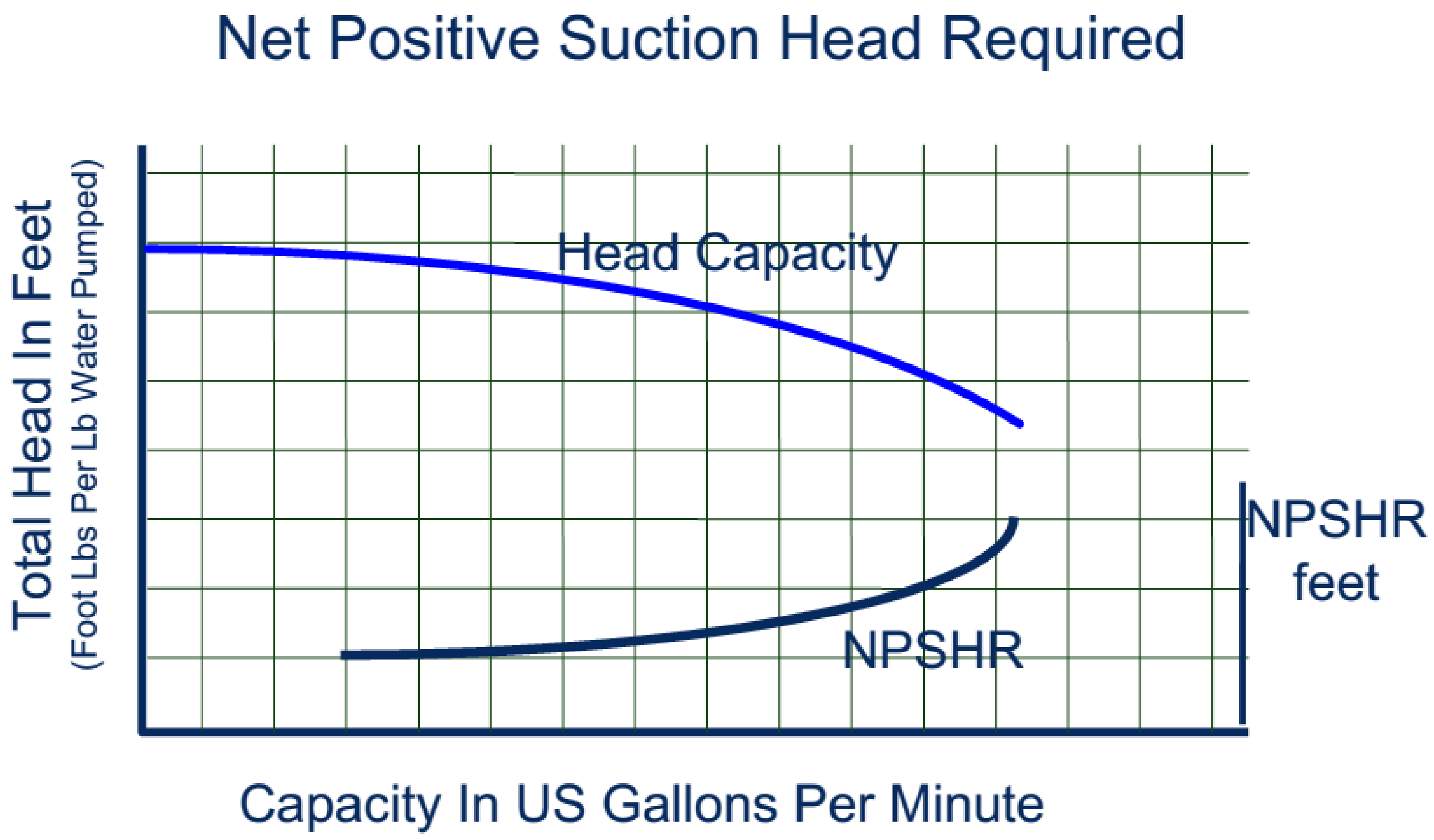
Net Positive Section Head (NPSH)

- One of the most harmful effects of machines working with liquid fluids is cavitation
- A measure that is used when designing a pump application for cavitation-free operation is the so called "net positive suction head" or NPSH
- The NPSH is a value in meter and indicates, what minimum head is allowed at the pump inlet to avoid cavitation

Cont.

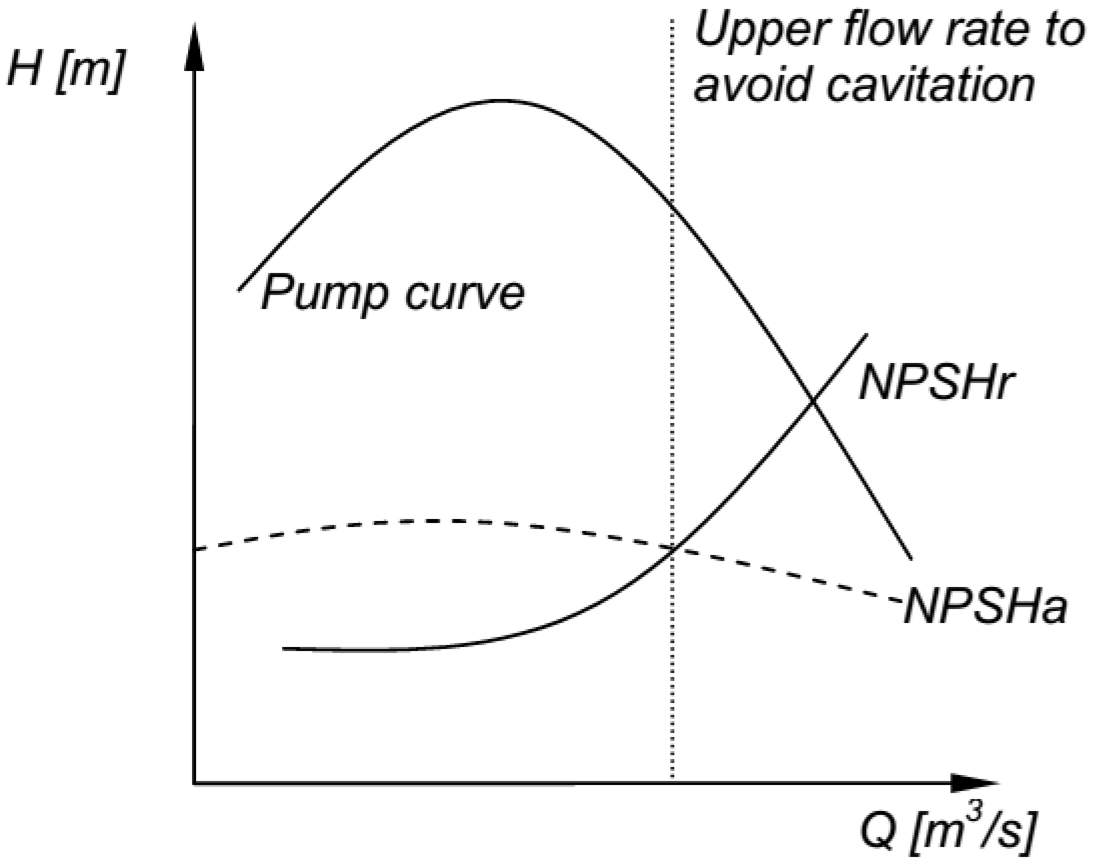
- Net Positive Section Head
  - ✓ (NPSH)*r* = Mfr. f(speed, diameter)
  - ✓ (NPSH)*a* = System. f(L, D, f, Z_{res}, Z_{pump}, P_v)
- The criteria applied for avoiding cavitation is finally (NPSH)*a* > (NPSH)*r*

Cont.



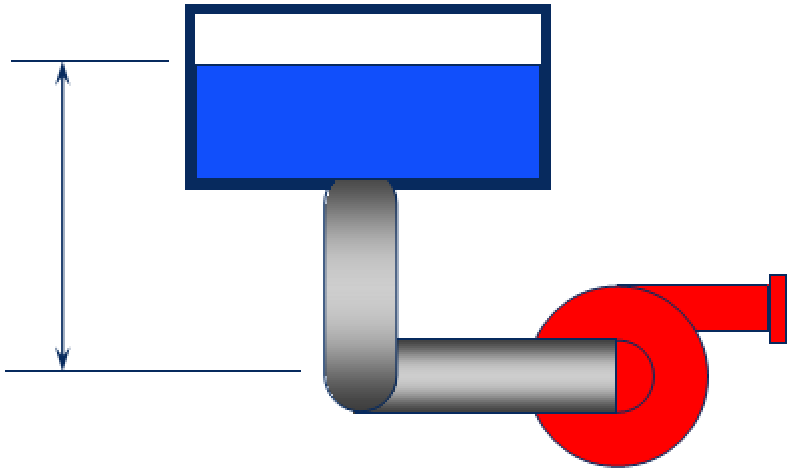
Net Positive Suction Head Required
Head Capacity
NPSHR
NPSHR
feet
Total Head In Feet
(Foot Lbs Per Lb Water Pumped)
Capacity In US Gallons Per Minute

Cont.



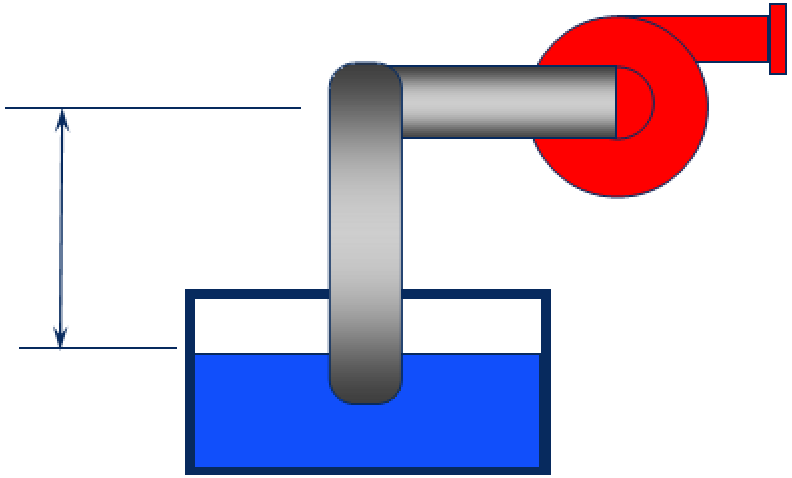
H [m]
Upper flow rate to
avoid cavitation
Pump curve
NPSHr
NPSHa
Q [m3/s]

Cont.



Static Suction Head

- from surface to centerline
- adds to NPSHA



Static Suction Lift

- from surface to centerline
- subtracts from NPSHA

Cont.

- To characterize the potential for cavitation, define the net positive suction head (NPSH) as

$$NPSH = \frac{p_s}{g\rho} + \frac{v_s^2}{2g} - \frac{p_v}{g\rho}$$

The total head on the suction side near the pump impeller inlet

Thank you