Pumps, Turbines, and Pipe Networks

Ch 11 Young

Chapter Topics

- Types of pumps and turbines
- Moment of momentum review
- Pump and turbine theory
- Energy and power
- Pump selection
- Pump-pipe networks
- Use of pipe network analysis program EPAnet2

Introduction

- Pumps and turbines appear many places in hydraulics and other civil and environmental engineering applications
  - Water supply, distribution and treatment
  - Power generation
- Civil and Environmental Engineers need to understand how they work, and how to select appropriate machinery

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   - Moment of Momentum Revisited
   - Types of pumps and turbines and uses
   - Pump-pipe systems, networks
2. Open Channel Flow
   - Specific Energy and Rapid Transitions
   - Hydraulic Jumps
   - Slowly varying flow
   - Open channel control structures
3. Introduction to Surface Water Hydrology
   - Hydrologic Cycle
   - Rainfall, Runoff and Design Events
4. Hydraulic Structures
   - Dams, weirs, spillways
   - Culverts
   - Safety and Effects of Hydraulic Structures

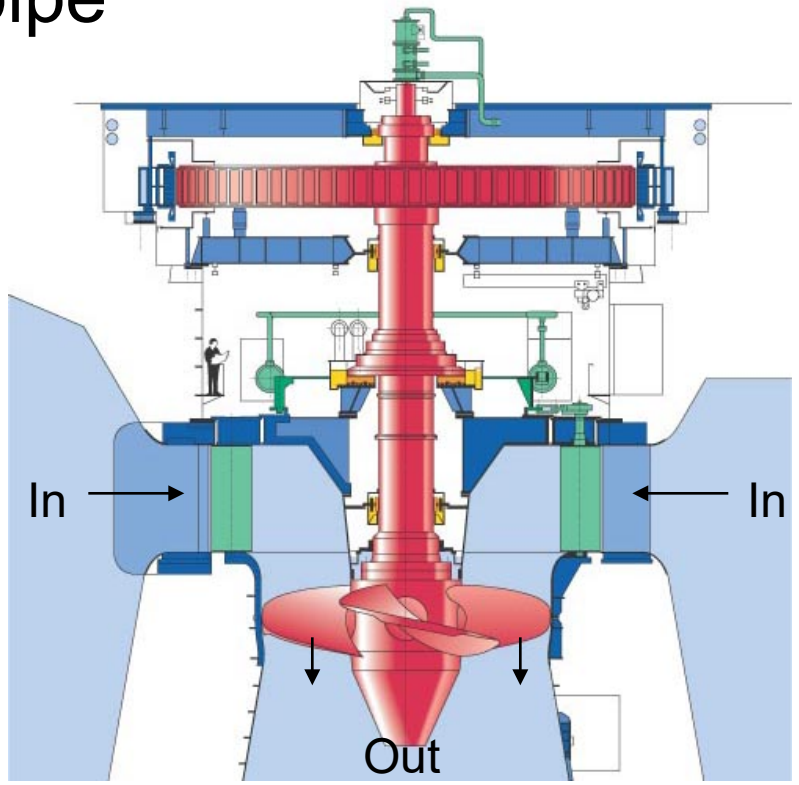
Theory of Turbomachines

- General characteristics of turbomachines can be evaluated from moment of momentum (Ch 5.2.3 Fluid Mech)
  - Modified based on measurements of efficiency, etc.
- Three main types
  - Axial flow (along centerline)
  - Radial flow (outwards from center)
  - Mixed flow (combination)

Axial Flow Machines – Low Head, High Flow Rate

- Propeller-type
- Kaplan turbine – adjustable blades
- Bulb-type – bulge in pipe
- Wind turbine

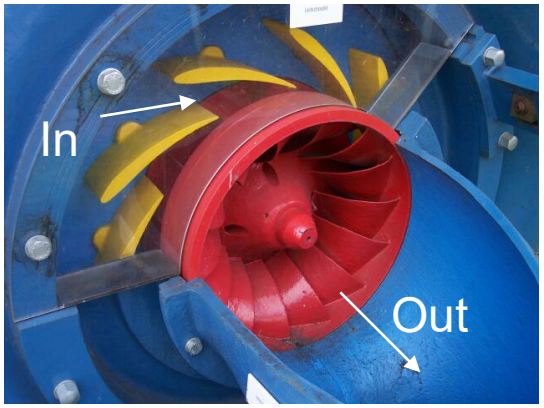
Bonneville Dam Kaplan Turbine



Kaplan turbine schematic

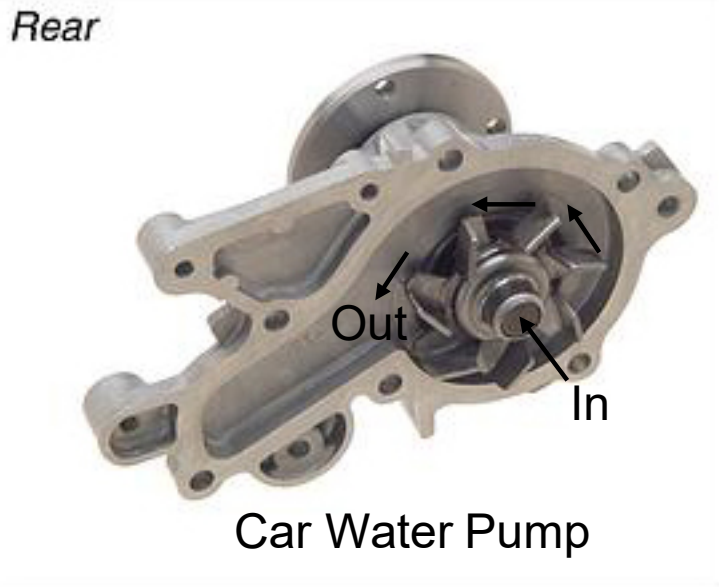
Radial Flow Turbomachines

- Common types
  - Francis Turbine
  - Centrifugal Pump



Francis turbine cut-away

Three Gorges Francis turbine



Car Water Pump

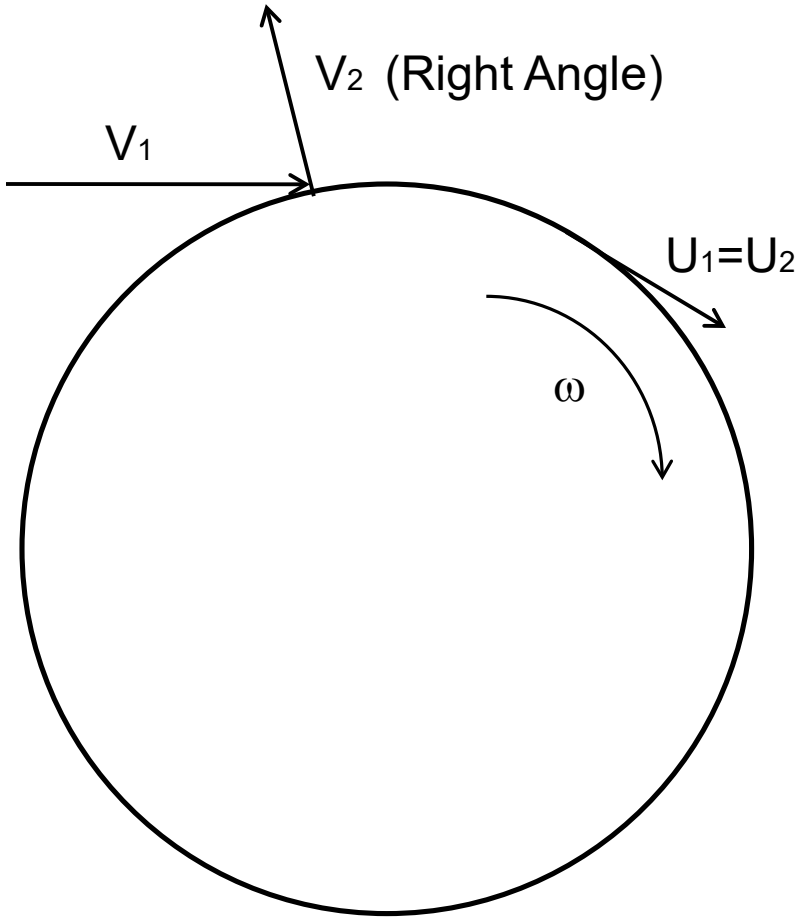
Review - Moment of Momentum

- Rate of change of fluid moment of momentum is work done by machinery
- Geometry very important
- Absolute Velocity = Relative Velocity plus Tangential Rotation Velocity
- Example

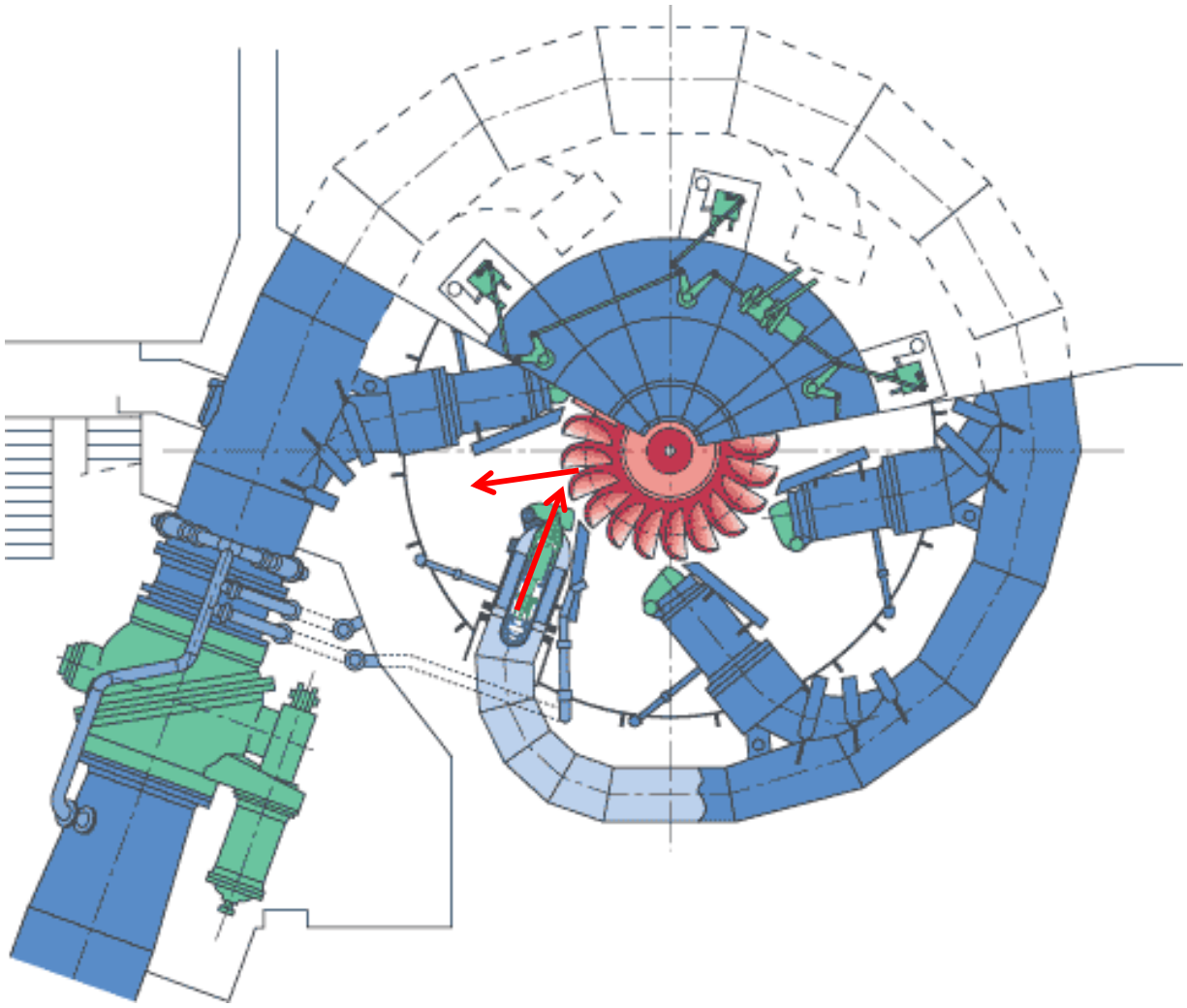
Energy Added/Removed

- As in Chapter 5.2 from Fluid Mechanics
- Depends of direction of rotation and direction of flow
- Many pumps or turbines are essentially the same instrument turning in different directions

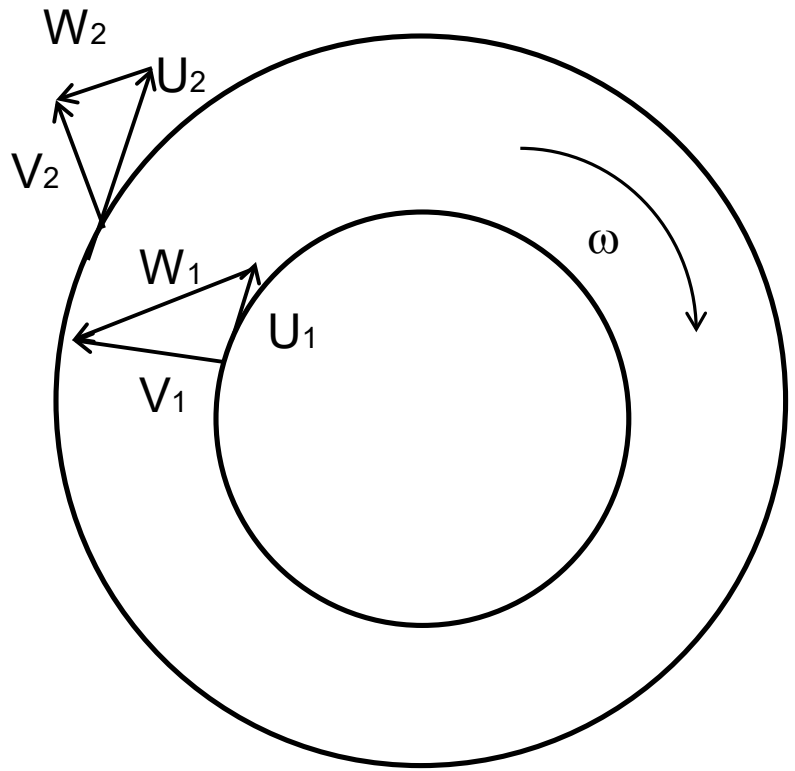
Pump or Turbine?



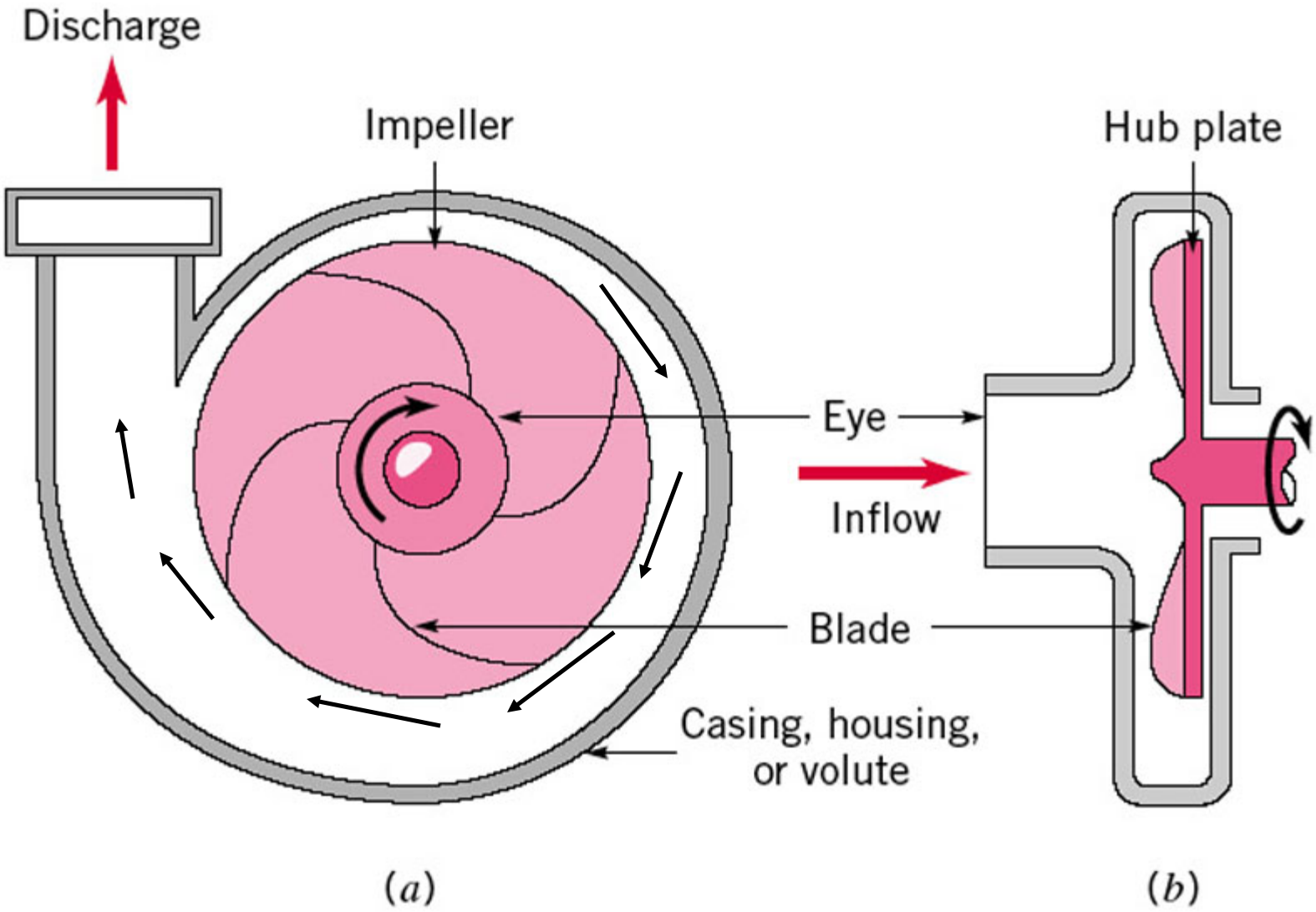
Pelton Wheel Turbine



Pump or Turbine?



Centrifugal Pump



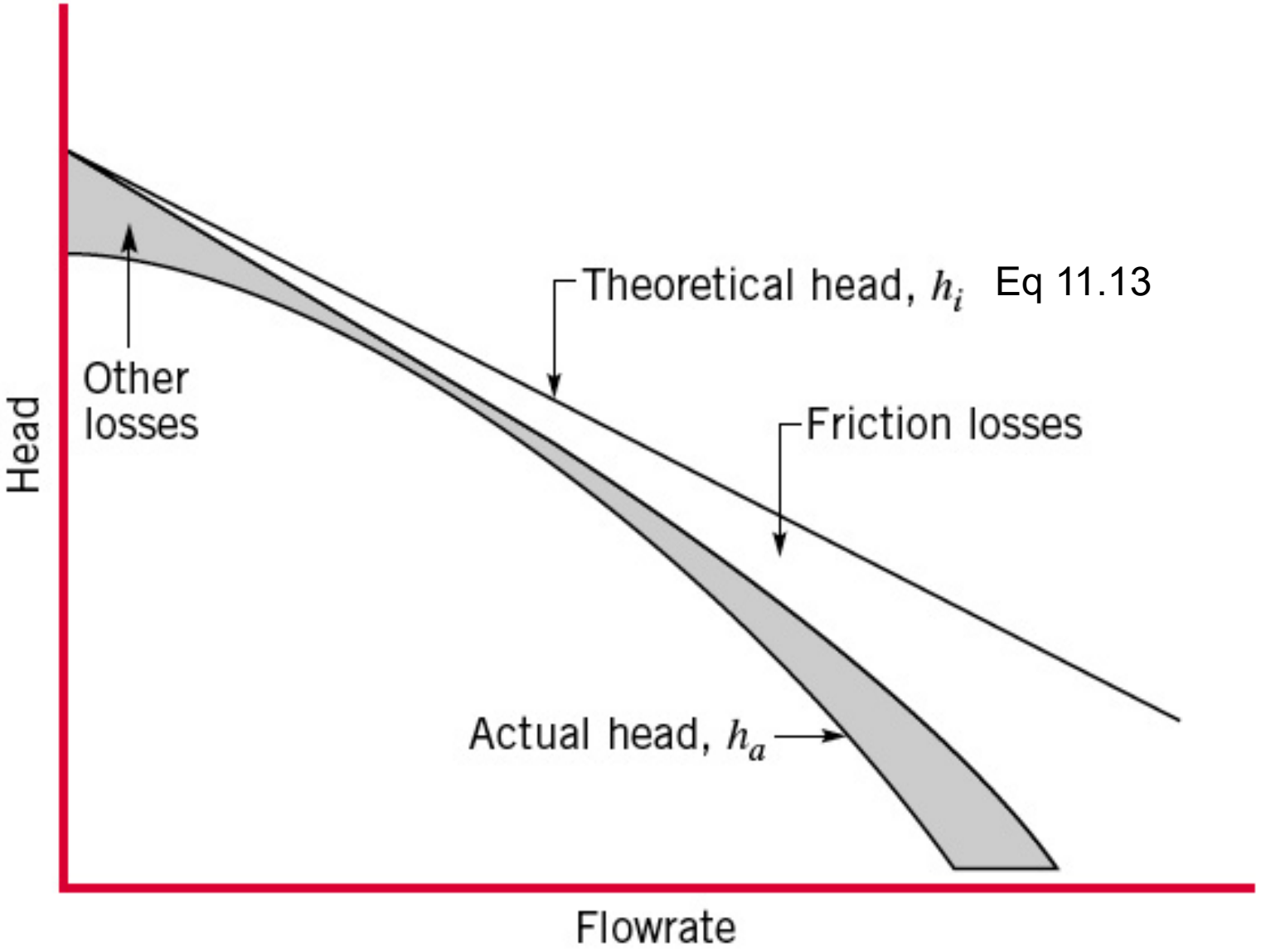
Centrifugal Pumps

- One of the most common Civil & Environmental Engineering machines (and many other branches of engineering)
- Water enters more or less axially, travels into inner impeller blades, exits outer impeller blades
- All sorts of Civil & Environmental Eng. water supply and treatment

Pump Theory

- Follows directly from rotating turbomachine theory
- Often written in terms of head rise across pump
- One exception: efficiency is not 100%

Pump Characteristics



Efficiency

- There are always losses in a pump
  - Turbulence, friction
- Efficiency is never 100%
- Pumps have ranges where they operate most efficiently
- Different types of pumps have different operating ranges
  - What are the types of pumps?
  - What ranges do they operate?

General Pump Characteristics

- All manufacturers of pumps for Civil Engineering provide performance curves
- Flow rate vs head increase and efficiency
  - Usually in gallons per minute (GPM), feet
- For Civil Engineering, pick from a range of pumps
- Pick for good efficiency over the desired range of application

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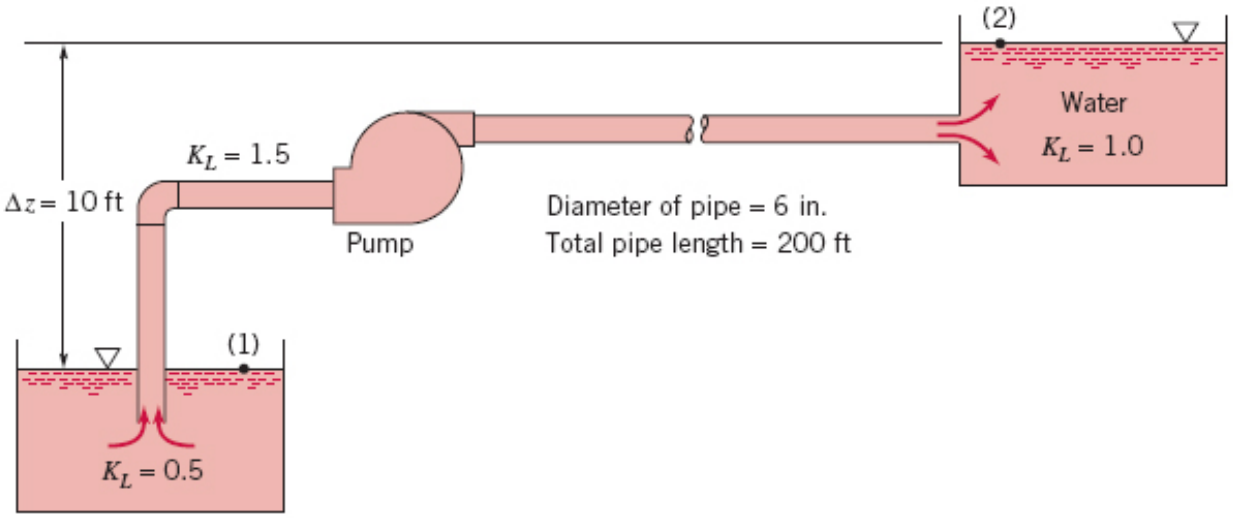
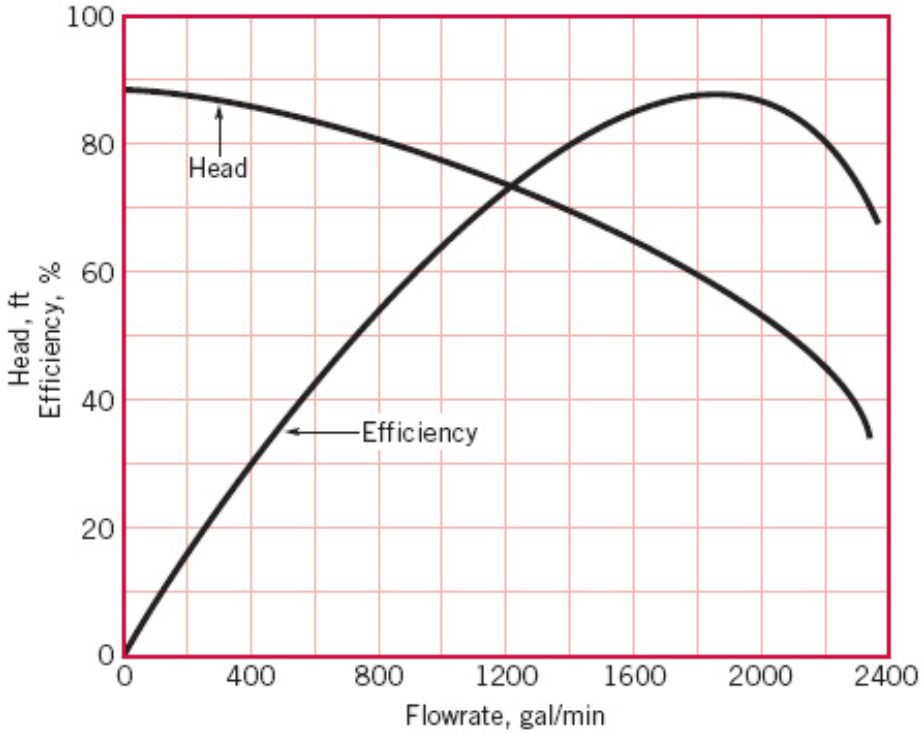
Pump Selection

- Intersection of system characteristics and pump characteristics gives flow rate and head increase
- Example 11.3
  - Often calculate head/flow rate and then go through pump literature
  - Centrifugal pumps often have moderately narrow efficient operational ranges

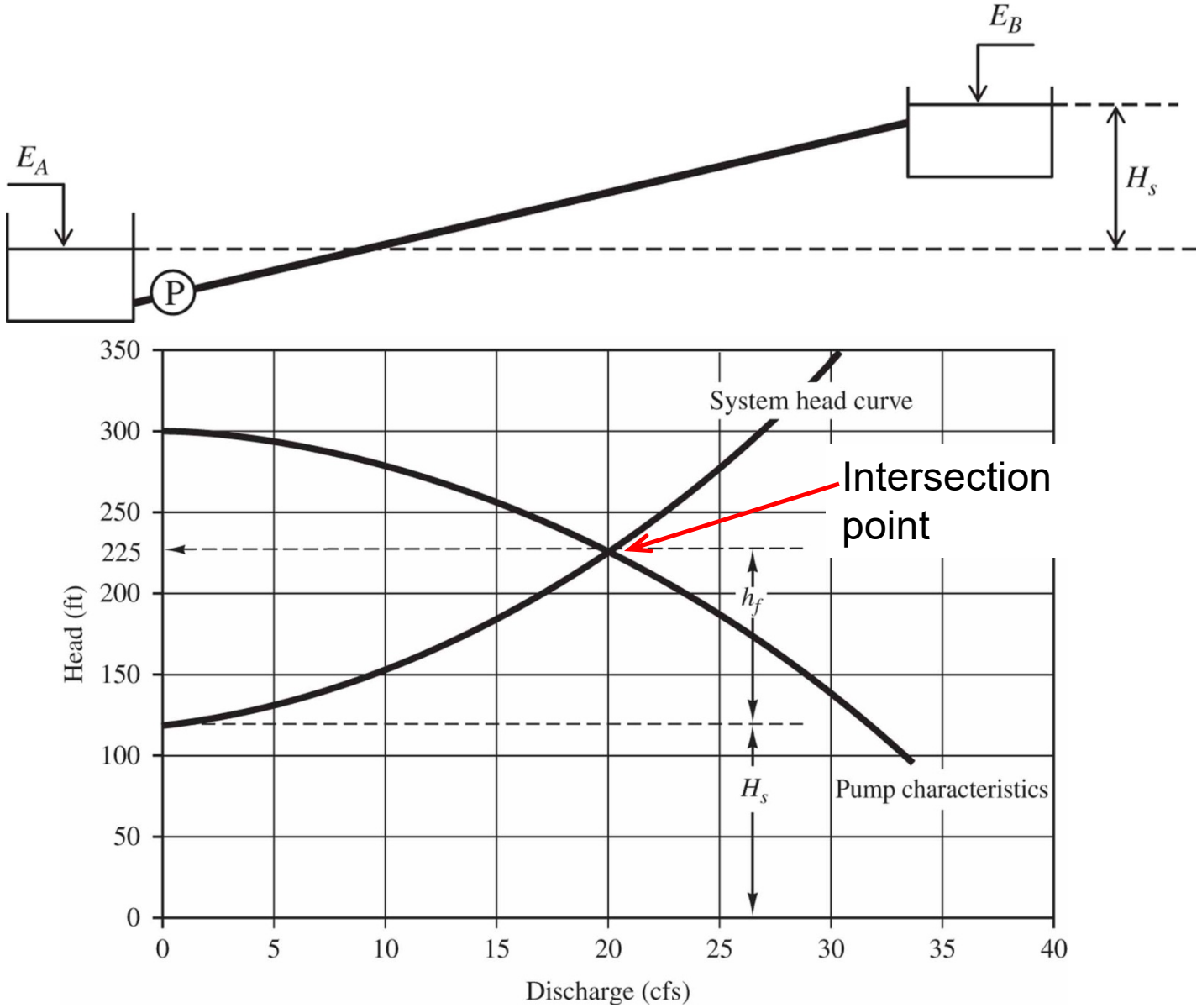

(2)
Water
$K_L = 1.0$
$K_L = 1.5$
$\Delta z = 10$ ft
Pump
Diameter of pipe = 6 in.
Total pipe length = 200 ft
(1)
$K_L = 0.5$

(*a*)

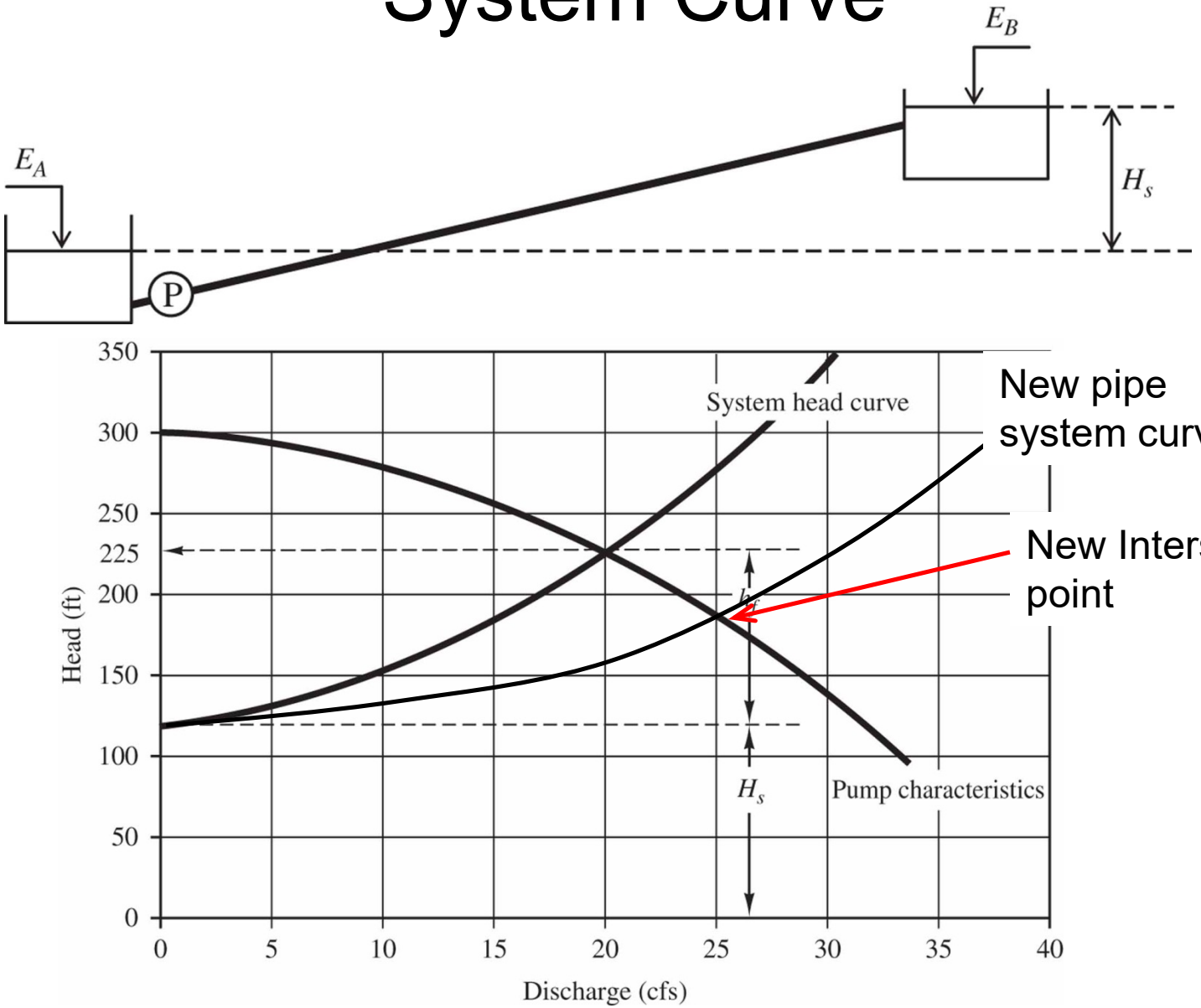

100
80
60
40
20
0
Head, ft
Efficiency, %
Head
Efficiency
0
400
800
1200
1600
2000
2400
Flowrate, gal/min

(*b*)

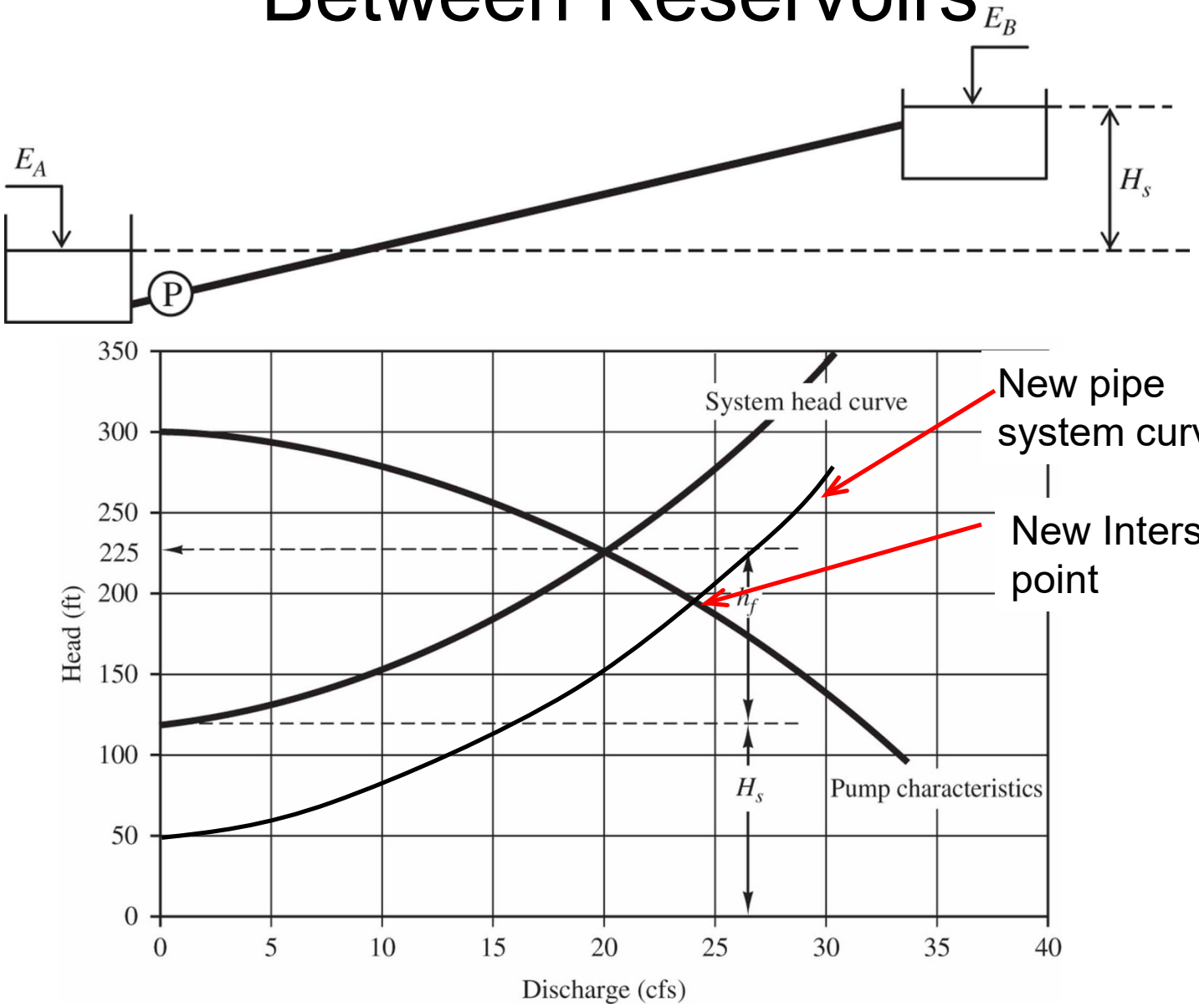
Single Pump-Pipe Systems



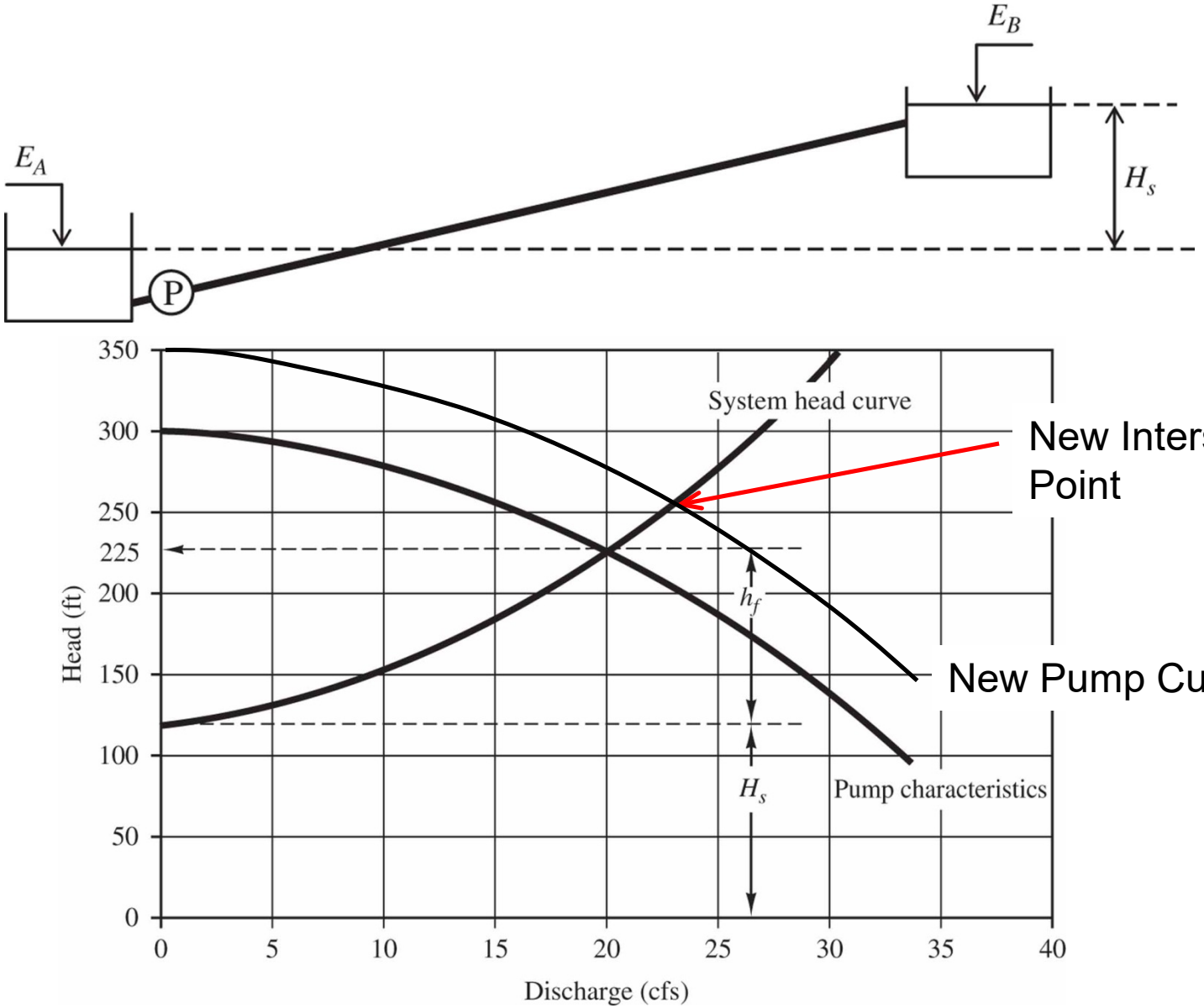
Increase Pipe Diameter – Lower System Curve



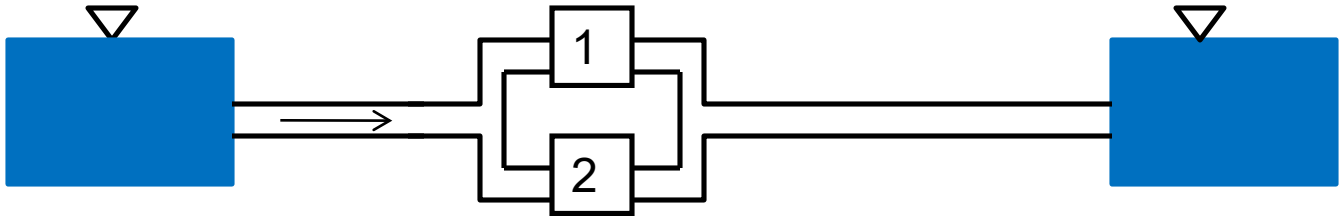
Decrease Elevation Difference Between Reservoirs

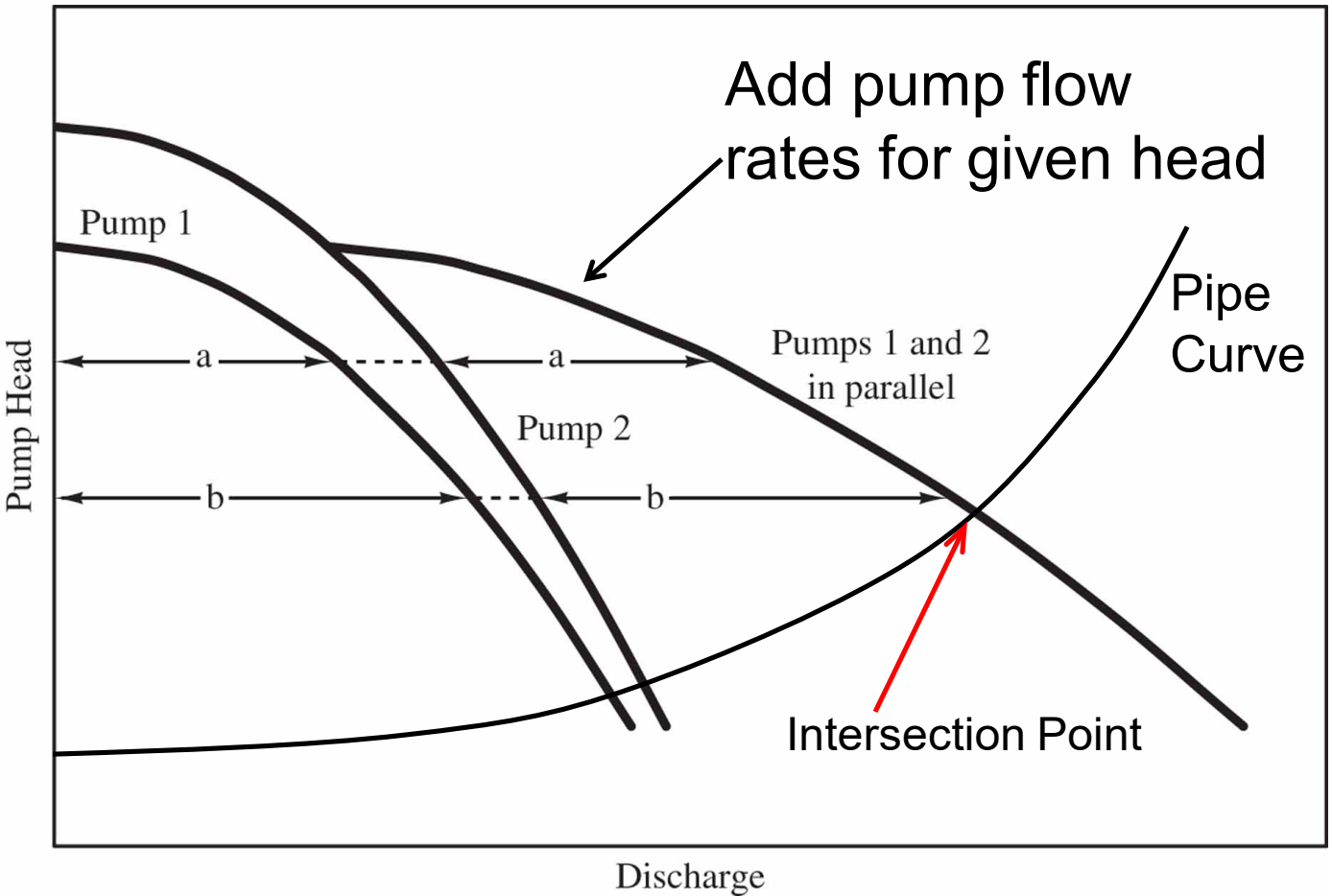


Run Pump at Faster Speed

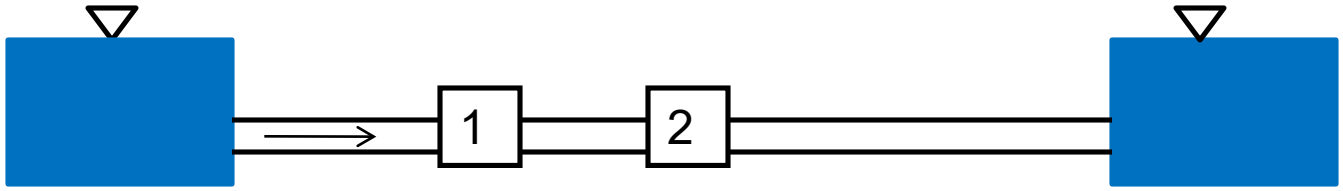


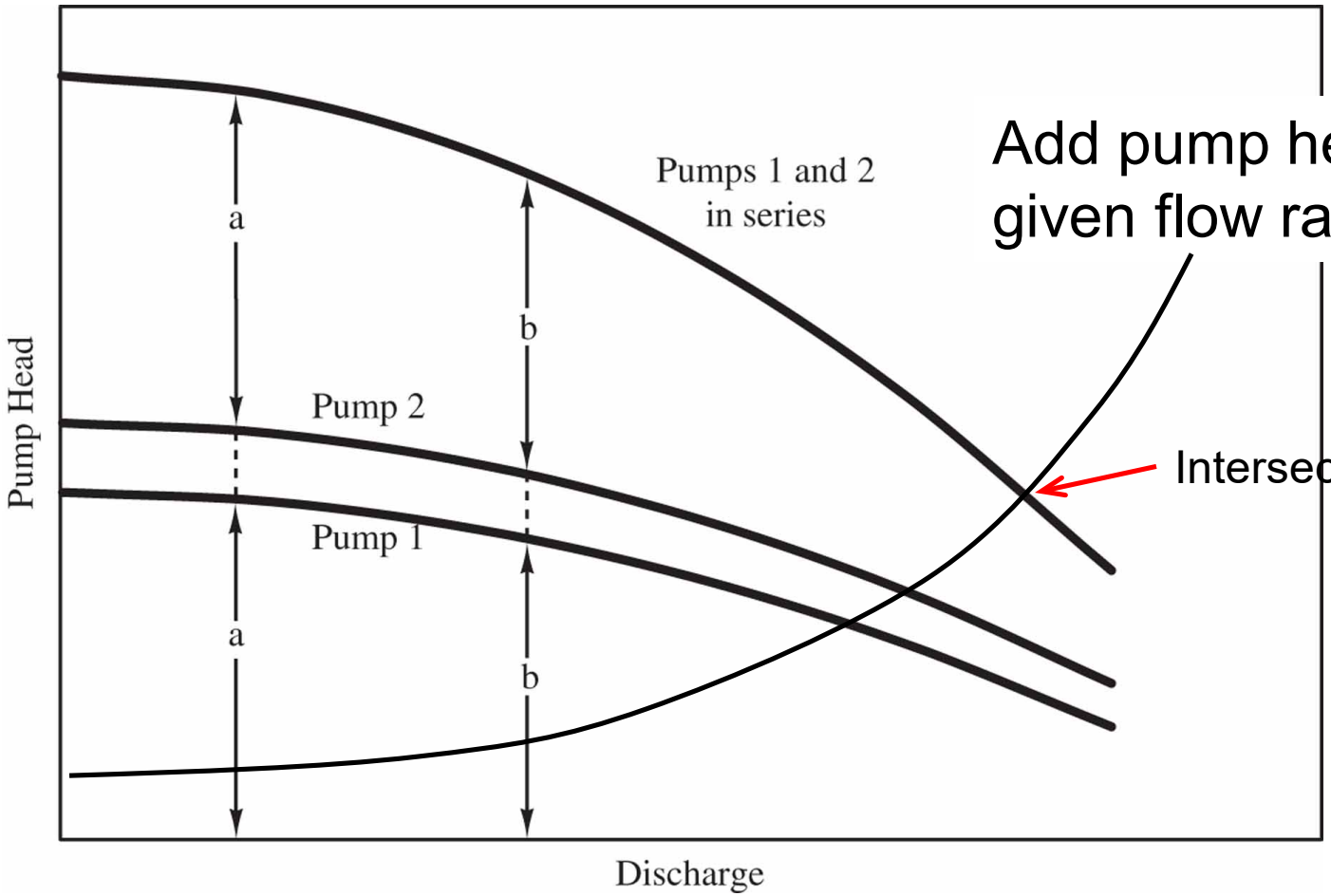
Pumps in Parallel





Pumps in Series

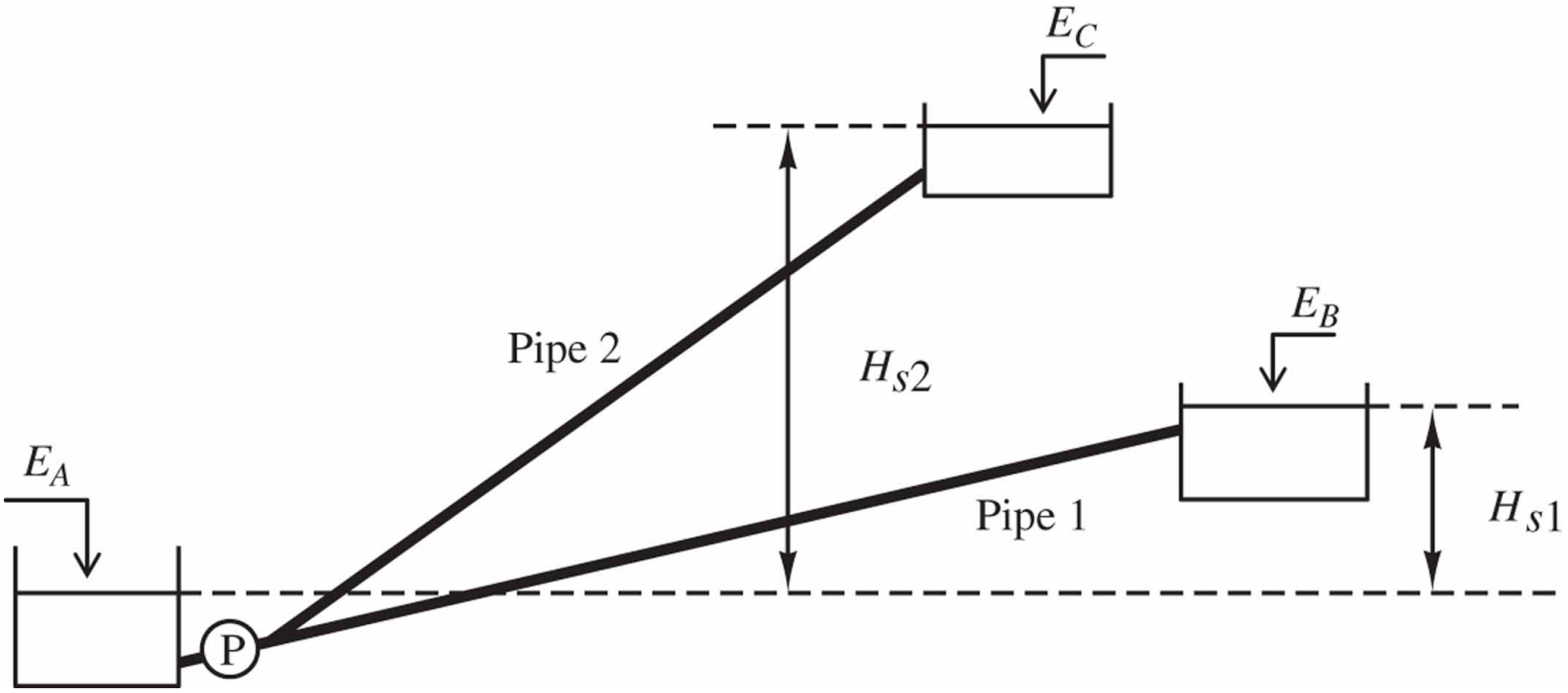




Add pump heads for given flow rates

Intersection Point

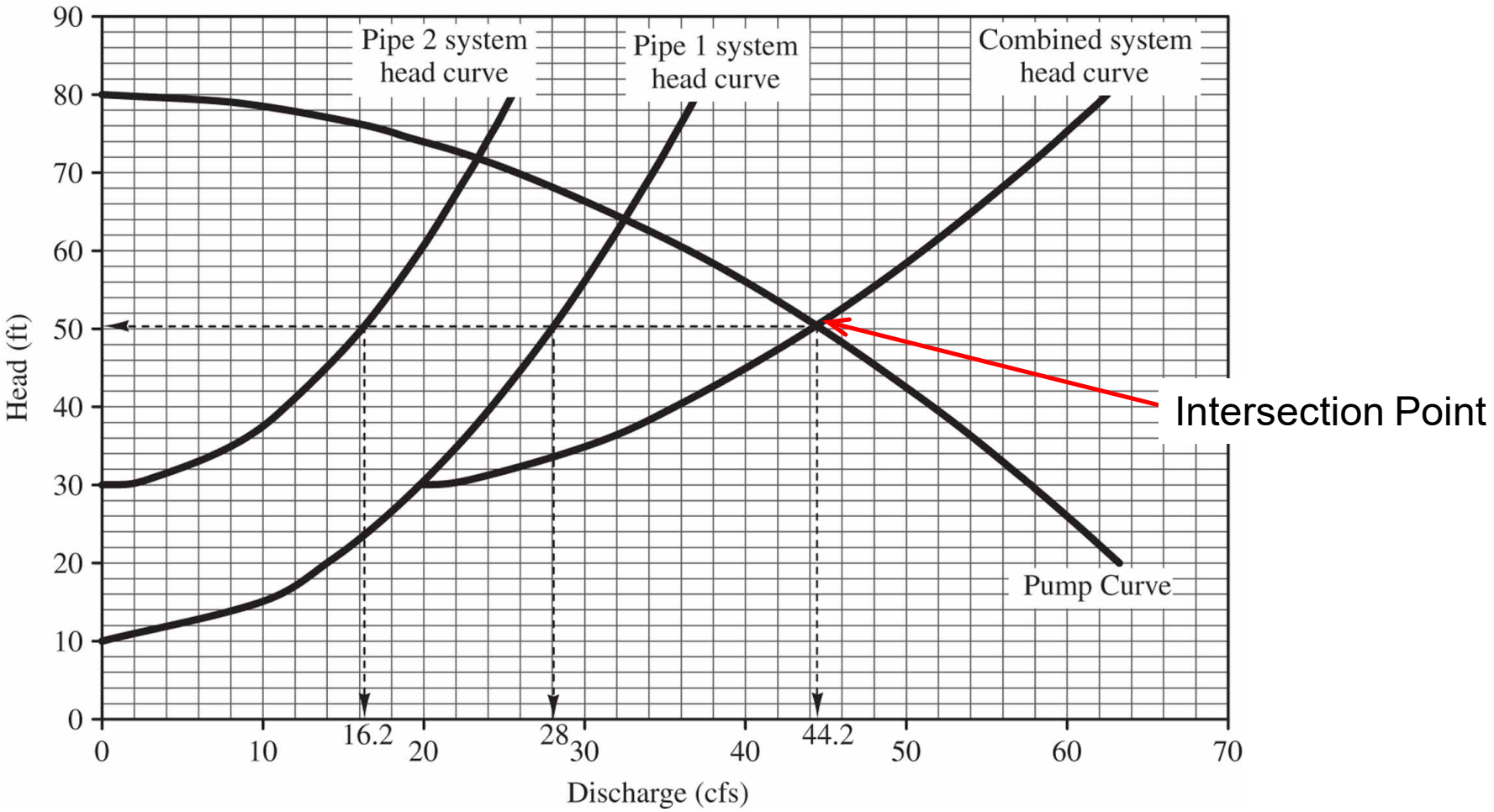
One Pump and Two Pipes



Head available to each pipe is the same after the pump

Pipe System Curves for Two Pipes

For given pipe head, add flow rates



Pump Cavitation

- When absolute pressure drops below vapor pressure, cavitation occurs
  - When occurring in pump, damage to impellers, premature wear, loss of head
- Bernoulii's equation between start of pipe, pump
  - Unknown V in pump represented by net positive suction head (NPSH) on manufacturer's pump curves
- To prevent:
  1. Place pump close to intake
  2. Seat pump at low elevation
  3. Lower losses (major and minor) before pump
  4. Run pump at slower speed if possible

Cavitation Examples

- Tends to show wear on impellers
- Severe cavitation can be heard clearly, mild cavitation can be heard with instruments

http://www.youtube.com/watch?v=0O5W2JrFhc4
http://www.youtube.com/watch?v=Qw97DkOYYrg&NR=1
https://www.youtube.com/watch?v=N3WwQKZ05Uk