CENTRIFUGAL PUMPING SYSTEMS 101 WORKSHOP

NEWEA 2024 Annual Conference

OUR TEAM

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UMass Amherst

slido

Where do you work?

ⓘ Start presenting to display the poll results on this slide.

EXPECTATIONS

- **Interactive session!**
  - You'll get more out of it if you participate
- **We assume you know:**
  - How to use a spreadsheet
  - What a design drawing looks like and basics of reading drawings
- **Meet new friends**
- **Ask questions**

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Think - Pair - Share: What is one thing would you like to get out of this workshop?

ⓘ Start presenting to display the poll results on this slide.

BY END OF WORKSHOP YOU SHOULD…

- Calculate the components of a centrifugal pump system curve

- Identify key components of a centrifugal pump curve

- Generate a list of information to provide a manufacturer for a centrifugal pump system design

OVERVIEW OF WORKSHOP

- Short lecture on pump systems
- Teams develop system curve
- Break
- Come back! Then head to exhibit hall to talk with equipment reps
- Return with pump recommendations
- End (and go to Exhibit Hall Reception)

INTRODUCE YOURSELVES

- Your team is at your table
- Tell them:
  - Your name
  - Where you work
  - One thing you’d like to do or accomplish in 2024

PROBLEM STATEMENT

- We'll be working on calculations to create a system curve
- Your client is looking for options for a new pumping system:
  - Submersible
  - Dry pit submersible
  - Suction lift
  - Close-coupled
- Raw wastewater; 525 gpm max; 150 gpm average; other details on sheet at table

INTRODUCTION TO HYDRAULICS AND PUMPING

NEWEA 2024 Annual Conference

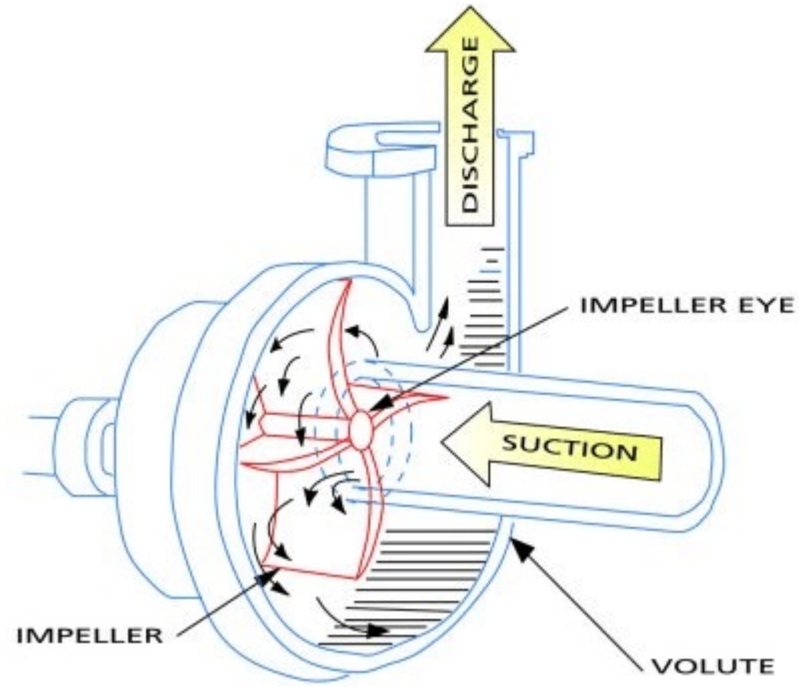
Todd Brown, PE, University of Hartford

OUTLINE

- Kinetic Pumps General Theory
- Typical Applications
- Parts of a Centrifugal Pump
- Basic Hydraulic Concepts – Components of a System Curve
- Manufacturer’s Pump Curves
- Suction Head – Understanding NPSHa and NPSHr

KINETIC PUMP

- Transmits kinetic (velocity) energy to the pumped fluid via an impeller
- The velocity energy is converted to pressure within the pump volute
- The pressure gradient through the pump moves fluid through pump



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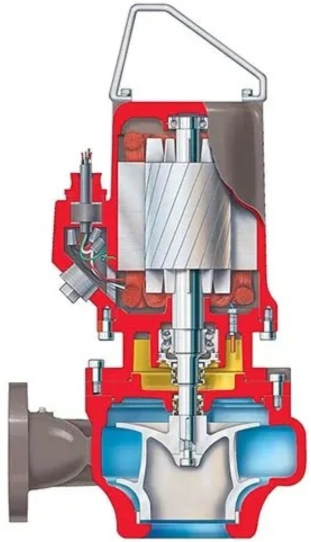

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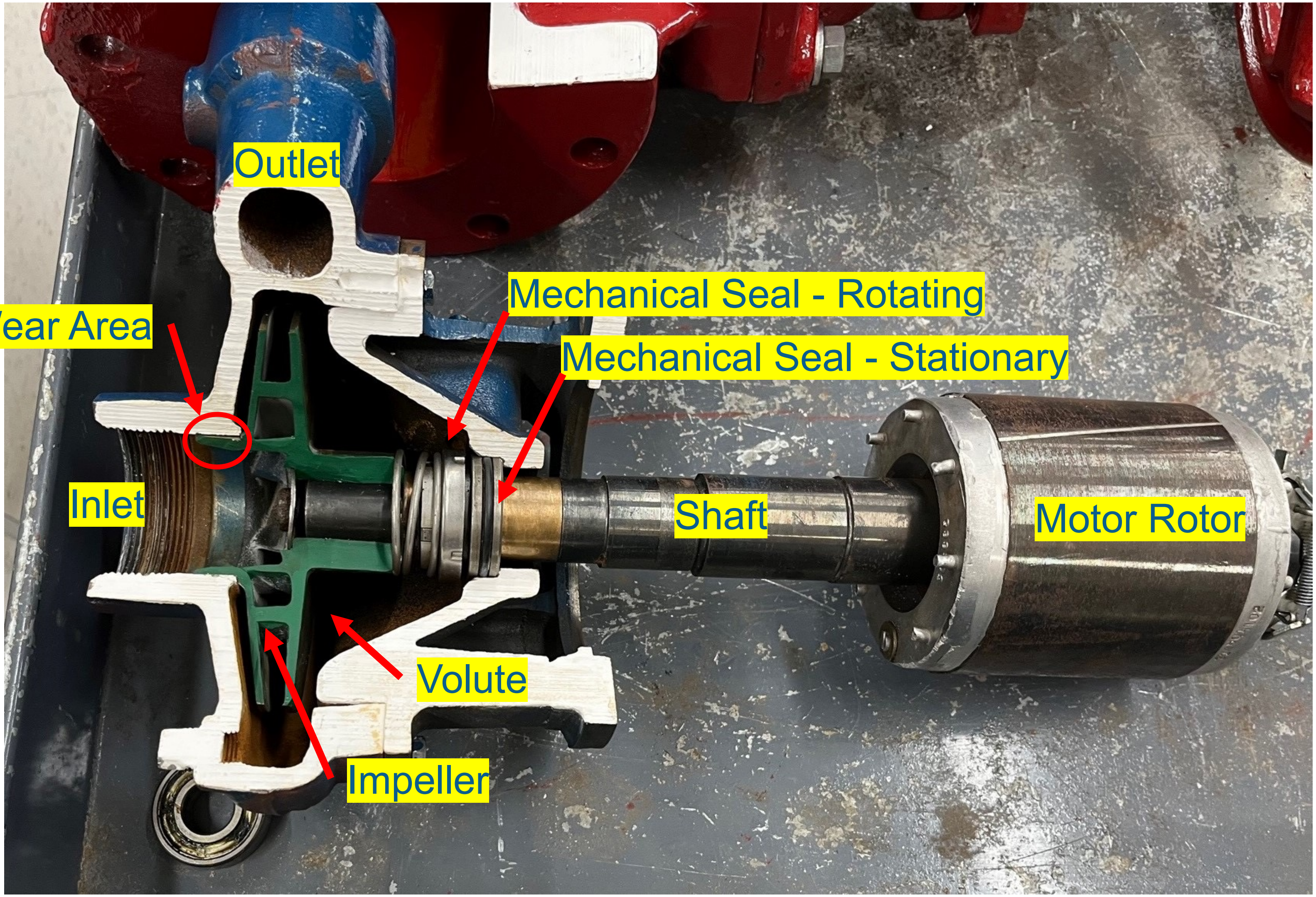
CENTRIFUGAL PUMPS: WATER APPLICATIONS

- **Drinking water**
  - Raw water
  - Finished water
  - Backwash
  - Chemical transfer

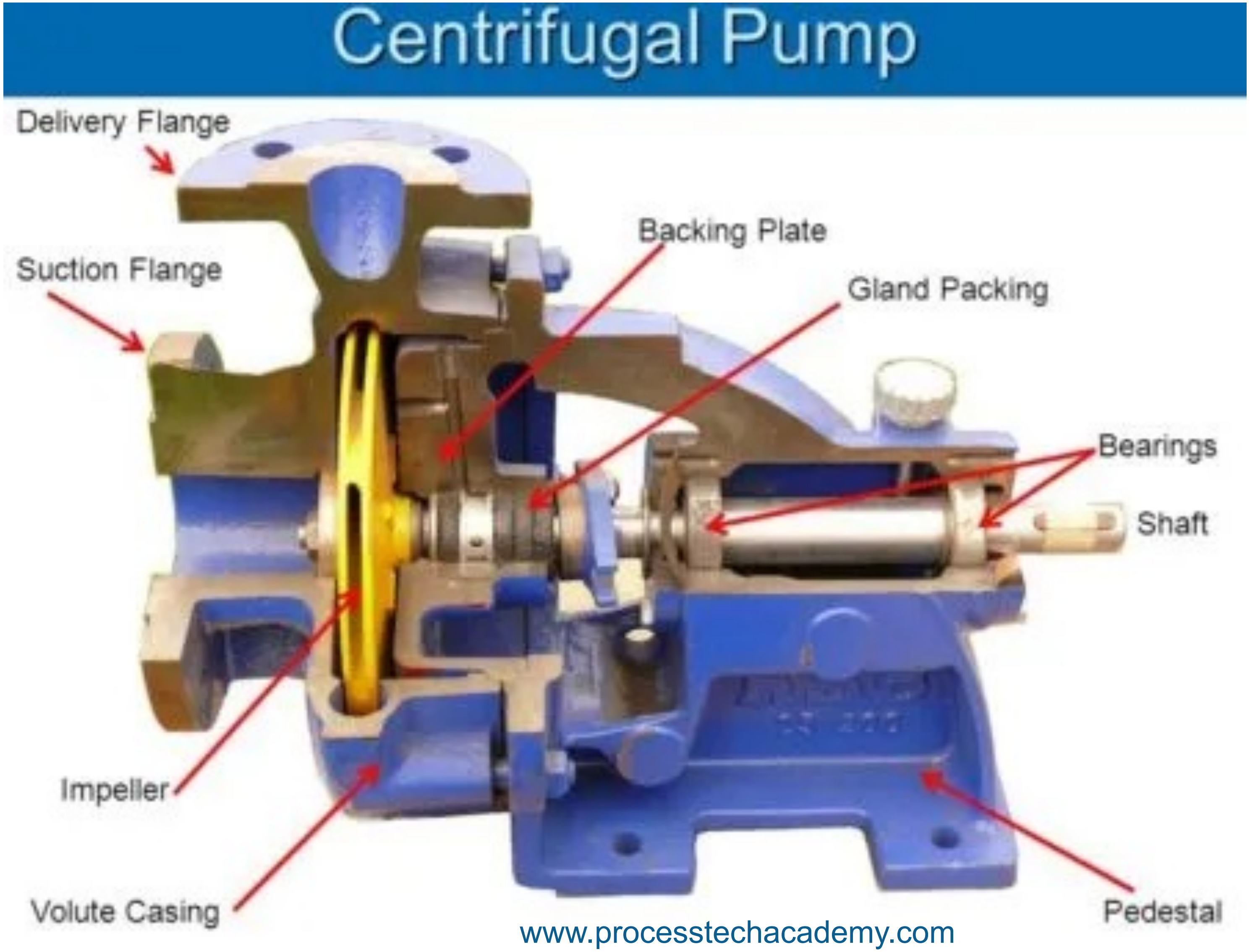
- **Wastewater**
  - Raw WW
  - Intermediate
  - Return activated sludge
  - Waste activated sludge
  - Tertiary process systems
  - Plant water

CENTRIFUGAL PUMP PARTS - MECHANICAL SEALS



T. Brown

CENTRIFUGAL PUMP PARTS – PACKINGS



CENTRIFUGAL IMPELLER TYPES (SAMPLE)


CLOSE IMPELLER


CLOSE IMPELLER


CLOSE IMPELLER


METALLIC THREE VANE IMPELLER


OPEN IMPELLER


OPEN IMPELLER


OPEN IMPELLER CENTRIFUGAL PUMP


OPEN IMPELLER


POLYPROPYLENE SEMI OPEN IMPELLER

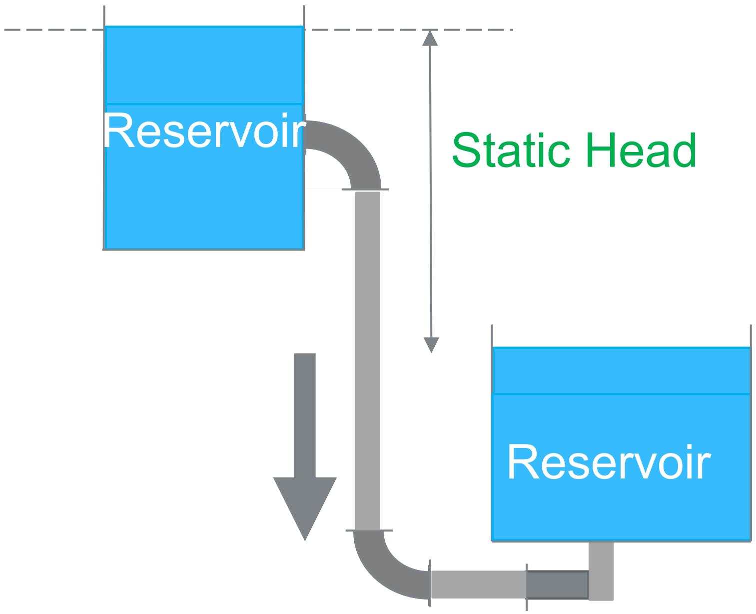

SEMI OPEN IMPELLER


SEMI OPEN IMPELLER


SEMI OPEN IMPELLER

IMPELLER FROM 27 MGD PUMP

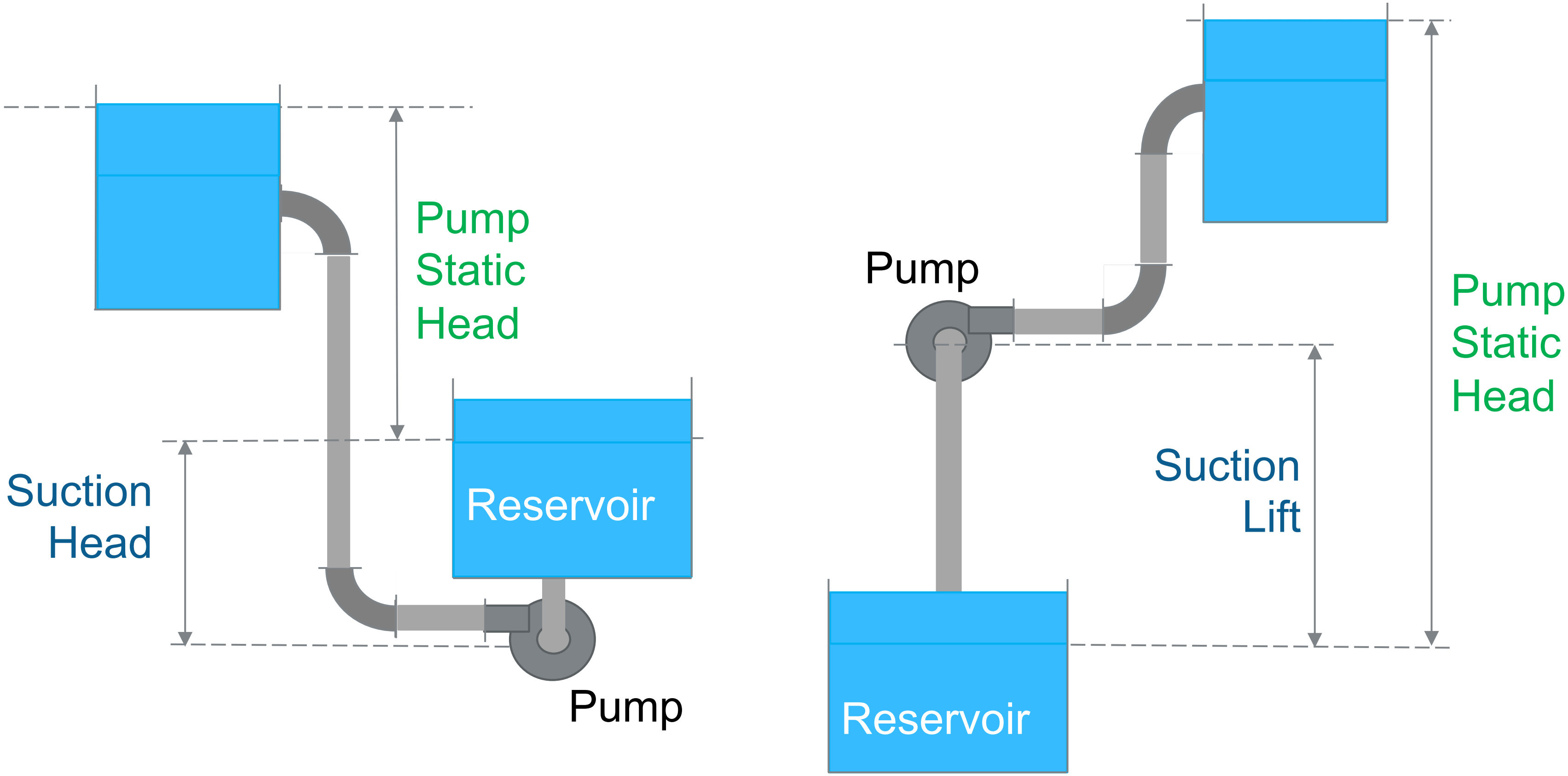
WATER (& MORE) FLOWS DOWN HILL



Flow Increases with

- Higher Static Head
- Larger Diameter Pipe
- Shorter Pipe Distance
- Fewer Bends/Turns
- Smoother Pipe

STATIC HEAD AND SUCTION HEAD



Static Head Can:

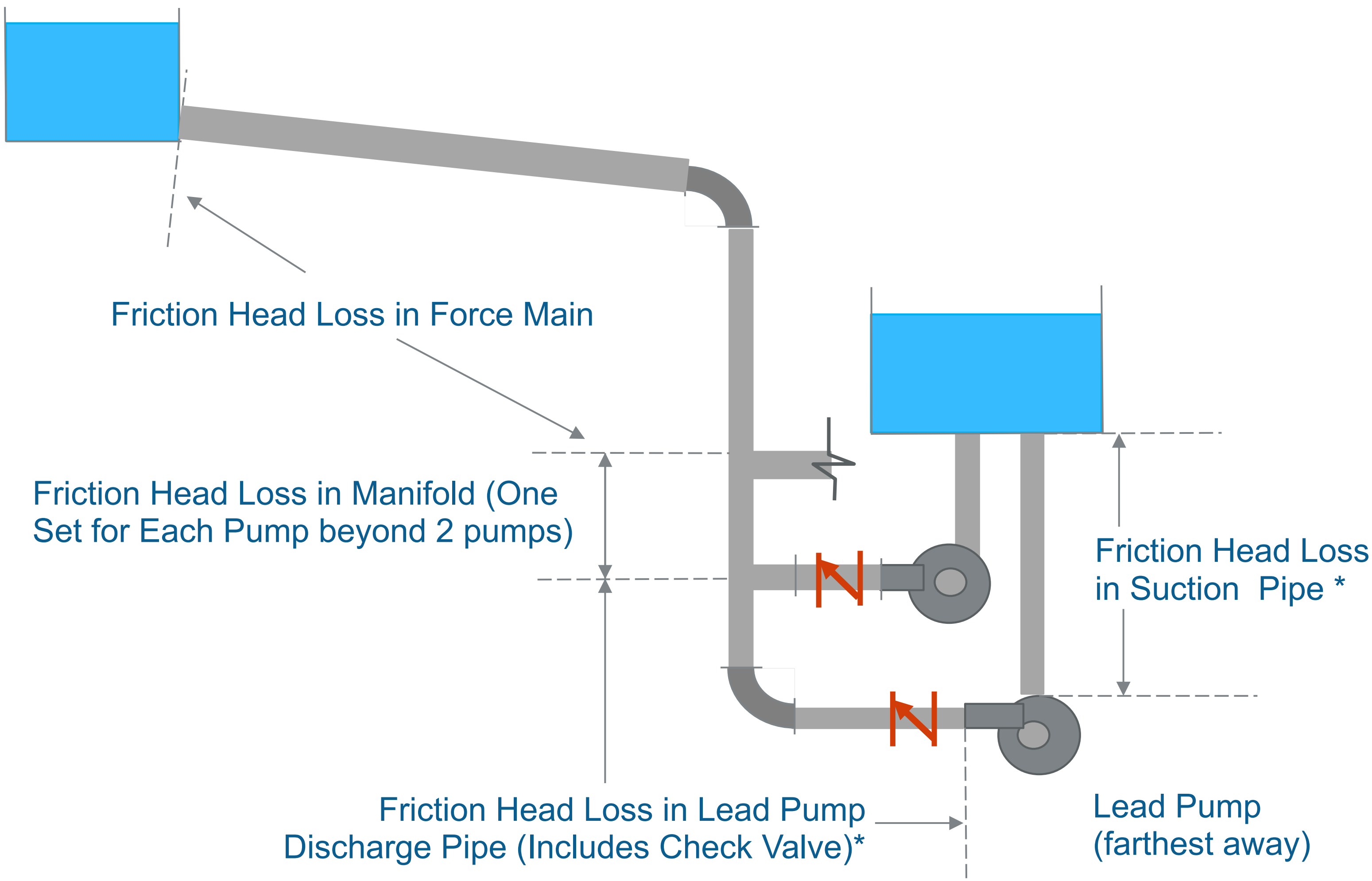
- Vary with Flow (Plant influent – range of wet well levels)
- Vary based on High & Low Wet Well level (start/stop flow)

Suction Lift/Head:

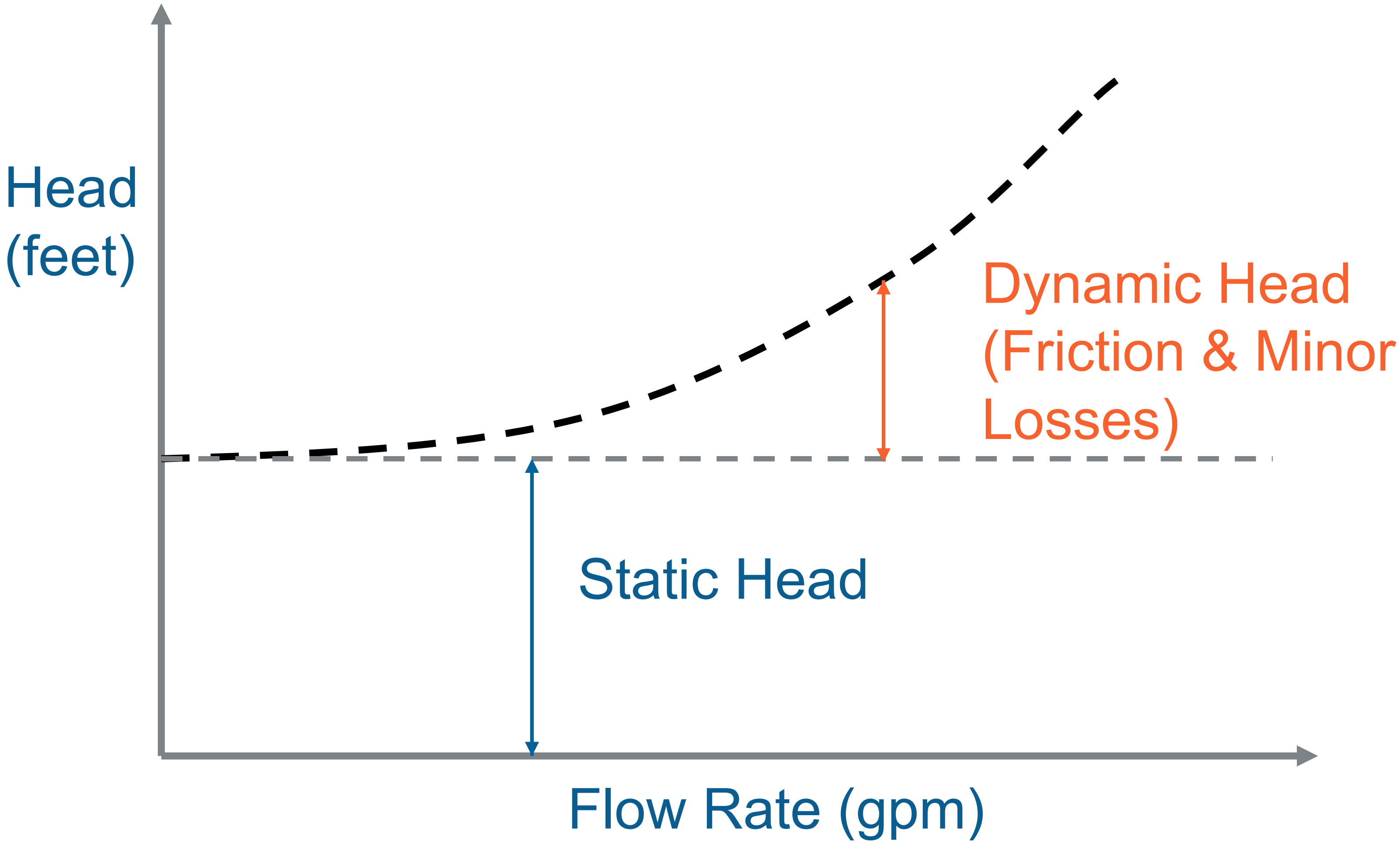
- Determines NPSHA

BASIC HYDRAULIC CONCEPTS

Flows (& Headlosses) Change Through the System



SYSTEM CURVE



FRICTION AND MINOR LOSSES

Hazen Williams Formula (for pipe)

$$h_L = L\frac{10.43Q^{1.852}}{C^{1.852}d^{4.87}}$$

h_L = head loss (ft)
L = pipeline length (ft)
Q = flow rate (gpm)
C = Hazen Williams Coefficient (-)
d = pipe internal diameter (in)

"Minor Losses" (for valves/fittings)

$$h_L = K_L\frac{V^2}{2g}$$

h_L = head loss (ft)
K_L = minor loss coefficient (-)
V = flow velocity (ft/s)
g = gravitational acceleration = 32.2 ft/s^2

HAZEN WILLIAMS COEFFICIENTS

Typical Hazen Williams Coefficients

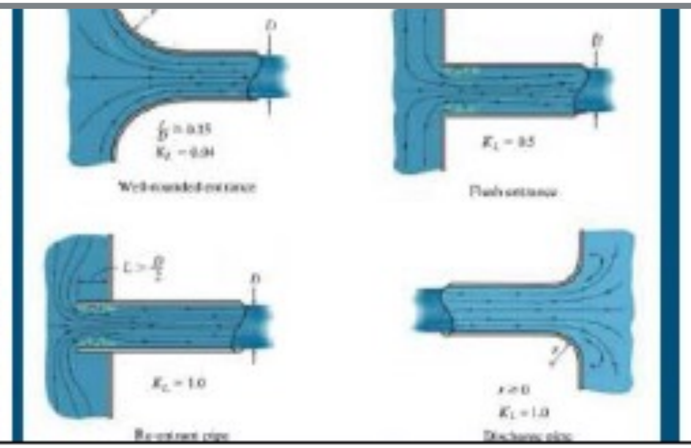
Material	C Factor low	C Factor high
Cast Iron – New	130	130
Cast Iron – 10 years	107	113
Cast Iron – 20 years	89	100
Cast Iron – 30 years	75	90
Cast Iron – 40 years	64	83
Cement-lined DI	140	140
Concrete	100	140
Copper	130	140
Polyethylene	140	140
PVC	150	150
Steel	90	110
Asbestos Cement	140	140

Higher # Means Smoother Pipe (Less Head Losses)

MINOR LOSS COEFFICIENTS

Pipe Entrances & Exits

Pipe Exit - All	1.00
Pipe Entrance Inward Projecting L > D/2	1.00
Pipe Entrance Inward Projecting L < D/2	0.80
Pipe Entrance Flush & Sharp	0.50
Pipe Entrance Slight Rounded r/d=0.02	0.28
Pipe Entrance Slight Rounded r/d=0.04	0.24
Pipe Entrance Rounded r/d=0.6	0.15
Pipe Entrance Rounded r/d=0.10	0.09
Pipe Entrance Well Rounded r/d>0.015	0.04
Pipe Entrance Well Rounded Bellmouth	0.04

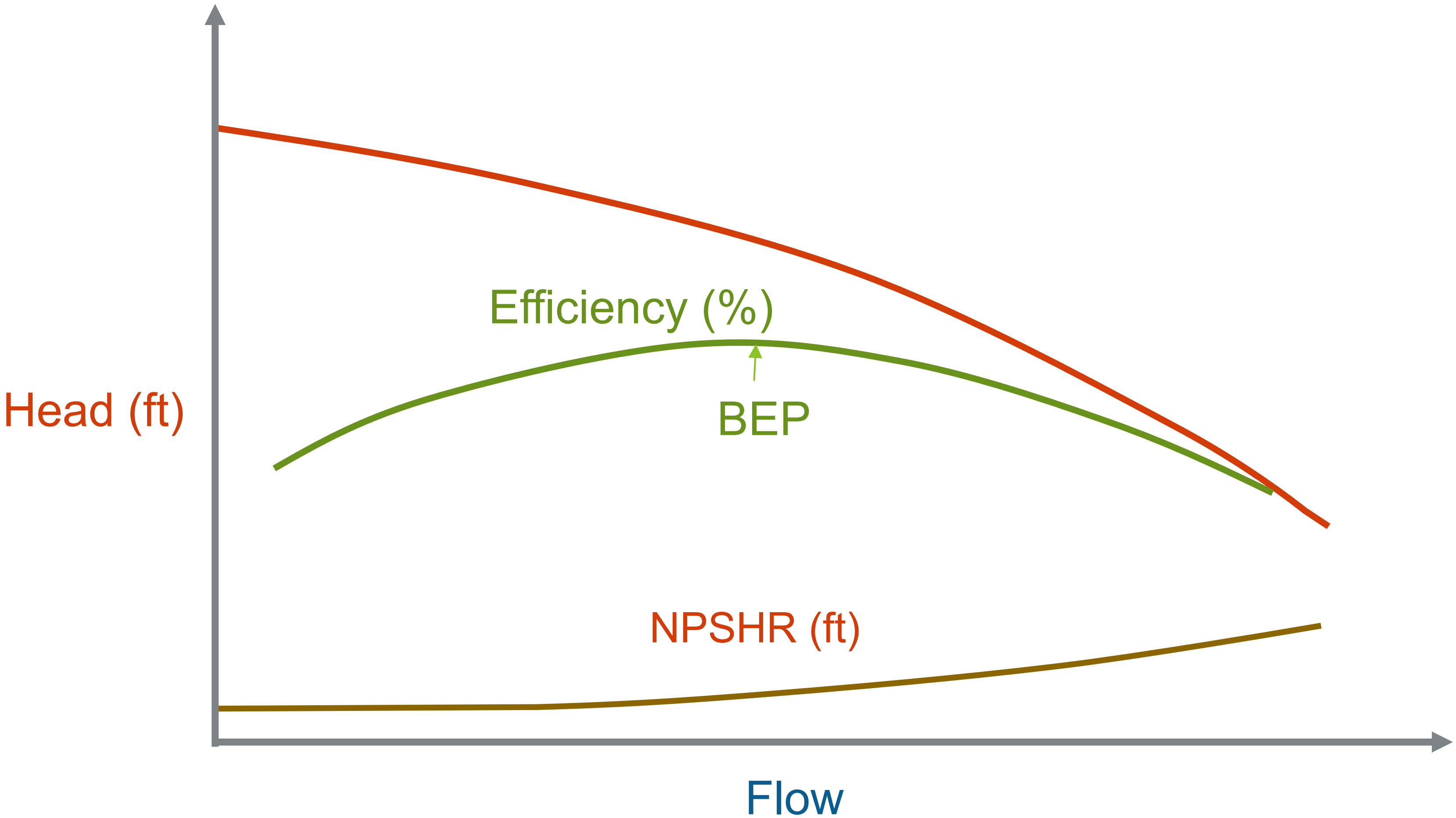


Valves

Pipe Size =	0.25	4	5	6	8	10	12	14	16	18	20	24
Consensus - From Crane 410 Unless Noted												
Angle	8.78	5.53	5.20	4.88	4.55	4.55	4.23	4.23	4.23	3.90	3.90	3.90
Ball-Full-Port	0.08	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Butterfly-Full-Port		0.77	0.72	0.68	0.63	0.49	0.46	0.46	0.33	0.30	0.30	0.30
Gate	0.22	0.14	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10
Globe	9.18	5.78	5.44	5.10	4.76	4.76	4.42	4.42	4.42	4.08	4.08	4.08
Plug-Full-Opening	0.49	0.31	0.29	0.27	0.25	0.25	0.23	0.23	0.23	0.22	0.22	0.22
Plug-3-Way-Thru-FullOpening	0.81	0.51	0.48	0.45	0.42	0.42	0.39	0.39	0.39	0.36	0.36	0.36
Plug-3-Way-Branch-FullOpening	2.43	1.53	1.44	1.35	1.26	1.26	1.17	1.17	1.17	1.08	1.08	1.08
******* From Mfg Literature***********												
Plug-Flanged 80% Port		0.89	0.91	1.08	1.13	1.10	1.02	0.90	0.97	0.92	0.94	
Knife Gate - Flanged		0.16	0.16	0.16	0.20	0.19	0.19	0.18	0.18	0.18	0.17	0.17
Knife Gate V Port - Flanged		1.32	1.66	1.52	1.58	1.56	1.46	1.40	1.30	1.26	1.21	1.43

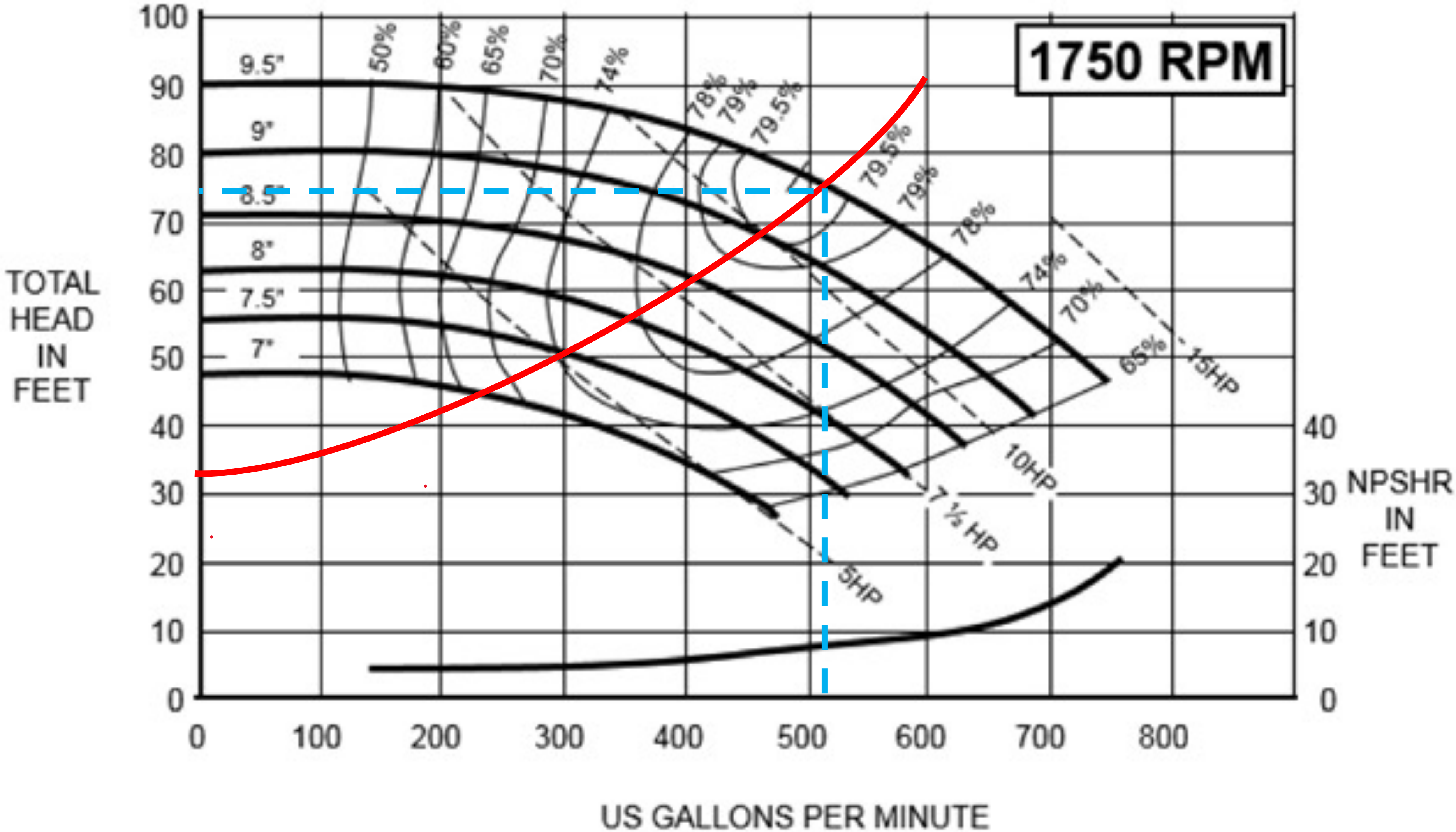
Lower # Means Less Head Losses

CENTRIFUGAL PUMP CURVES



NPSHR Net Positive Suction Head Required (to avoid cavitation)

Typical Single Stage Pump Curve



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NET POSITIVE SUCTION HEAD

- ***All centrifugal pumps create a partial vacuum near the impeller vane entrance***
- ***Too much vacuum can cause pumped liquid to vaporize, creating a water vapor "cavity"***
- ***Cavity collapses violently when it passes to the pressurized portion of the impeller***

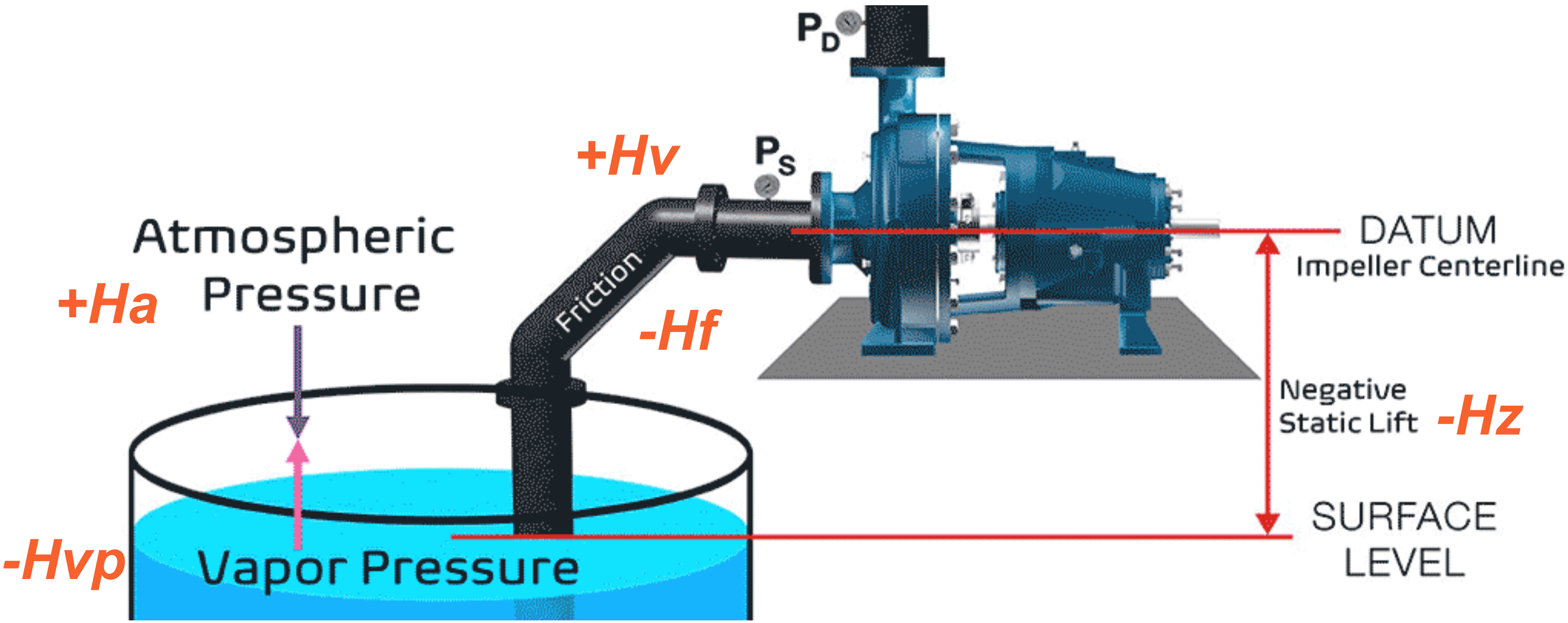
NPSH – AVAILABLE VS. REQUIRED

- ***Therefore, NPSHa must be > NPSHr***

- ***NPSHa = Ha +/- Hz – Hf + Hv – Hvp***
- ***where** (all expressed in same units)**:***
  - *Ha = atmospheric pressure = 34’ at sea level*
  - *Hz = Δ elevation between water surface & pump center line*
  - *Hf = friction losses*
  - *Hv = velocity head = $V^2/2g$ at pump inlet (usually negligible)*
  - *Hvp = vapor pressure of liquid at its ambient temperature*

- **NPSHr is pump/impeller specific and is obtained from a pump curve**

NPSH – AVAILABLE VS. REQUIRED



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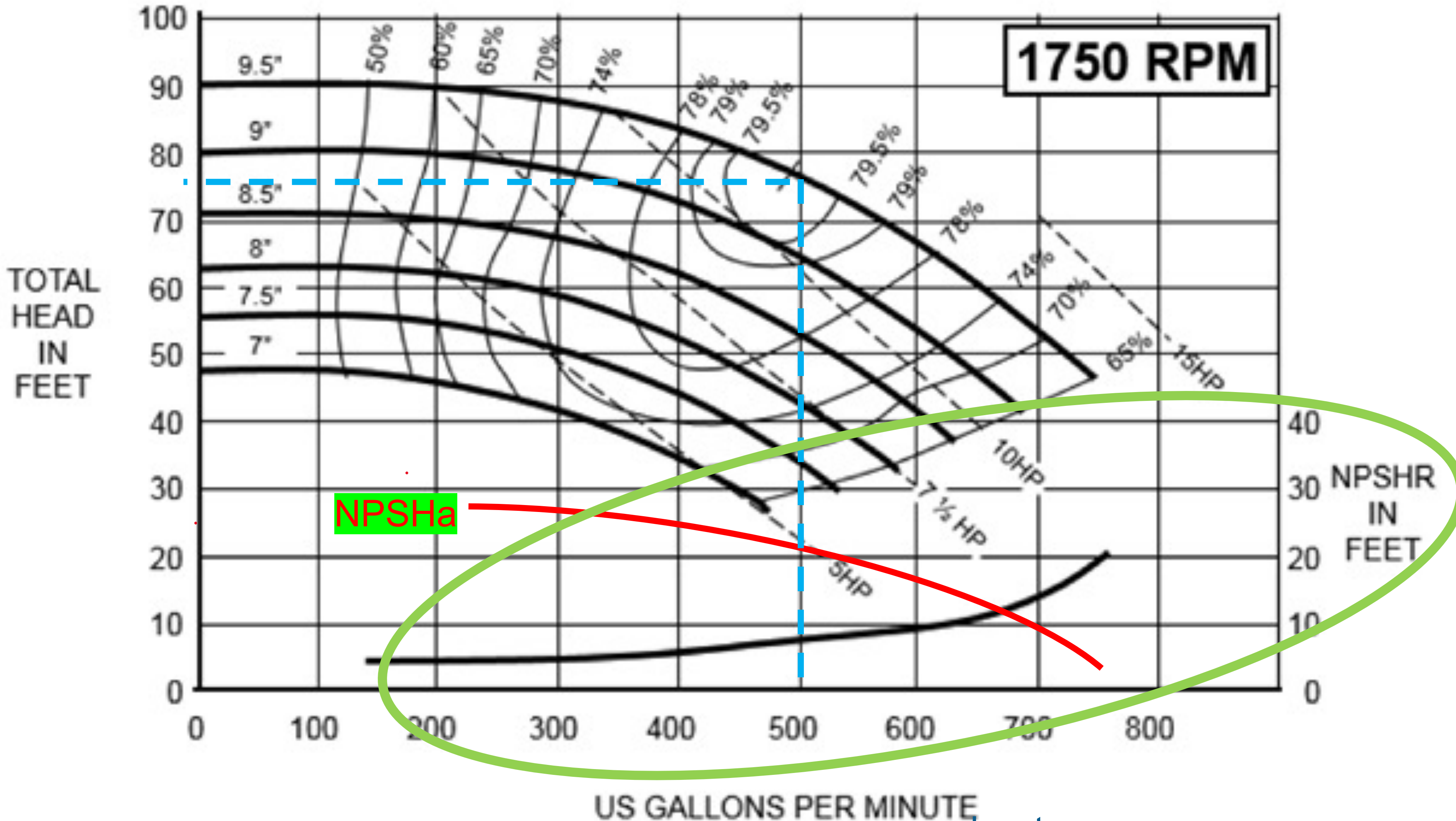
Typical Single Stage Pump Curve



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OLLIE INTERLUDE

TIME FOR CALCULATIONS

- Using the spreadsheet (QR code at your table), **calculate the total head required for your system at the design conditions.**
- You'll be using this as your design point to take to the reps after the break.
- Our team will have someone at your table to help guide the group.

NOW, WHAT IF…

- **We have less static head? How does that impact the shape of the curve?**

- **We have smaller force main piping? How does that impact the head requirement?**
  - Note: be aware of how changing the pipe diameter impacts velocity!

- **We have more bends and fittings?**

OFF TO THE BREAK!

- **When we return, get back with your team.**
- **You’ll be walking to the exhibit hall together.**

INTO THE EXHIBIT HALL

- Team 1: Aqua Solutions then Carlsen Systems
- Team 2: Carlsen Systems then Mechanical Solutions
- Team 3: Mechanical Solutions then Flygt
- Team 4: Flygt then Russell Resources
- Team 5: Russell Resources then Hayes Pump
- Team 6: Hayes Pump then FR Mahony
- Team 7: FR Mahony then Aqua Solutions

COME BACK WHEN YOU FINISH

- We'll chat about what you learned and wrap up.

HELP US IMPROVE!

- Please fill out this short survey