CM3215

Fundamentals of Chemical Engineering Laboratory

Analysis of a Centrifugal Pump: Pumping Head Curves

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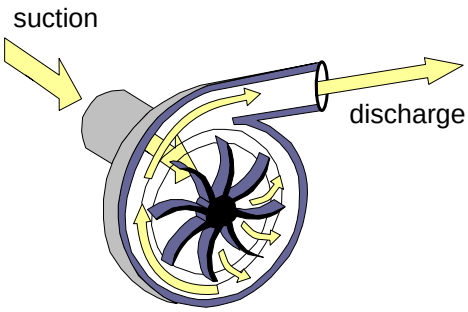
Centrifugal Pumps

- Centrifugal force is used to fling fluid from the suction side to the discharge
- Centrifugal pumps put out **neither** constant flow rate **nor** constant pressure
- We must use the mechanical energy balance to figure out how a centrifugal pump will perform in a given situation



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System Curve Assignment (week 9; due Friday)

How do you choose a centrifugal pump for a given duty?

- Calculate the flow-rate-dependent **demands** of a system = **system head curve** (this assignment)
- Compare the system-head curve (demands) to the available pumping-head curve (**supply**), and choose the right pump

Pumping Head Lab (week 10)

- Pumping Head Characteristic Curves are plots of what an existing pump can do under various loads (duties)
- We measure the pump characteristic curve by determining $\Delta p = p_{discharge} - p_{suction}$ on the suction/discharge system

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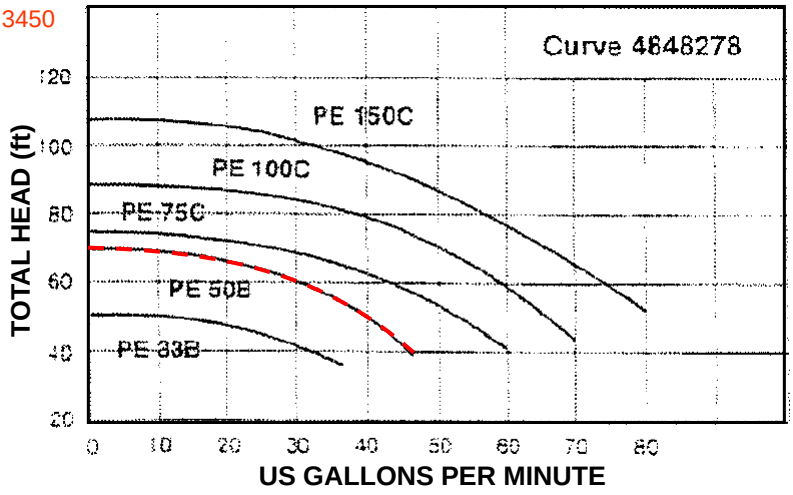
Krum Pump Company
Kalamazoo, MI
Model: Peerless pump
Type: PE50B
Performance Curve No: 4848278
RPM: 3450



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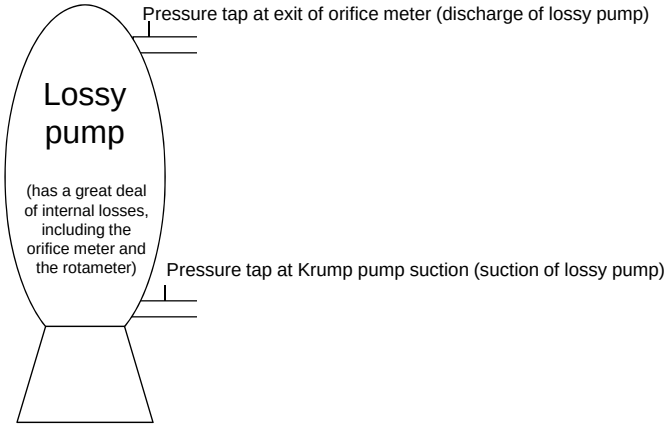
The CM3215 "Lossy" Pump

•Extends from the pump suction to the exit of the orifice meter.



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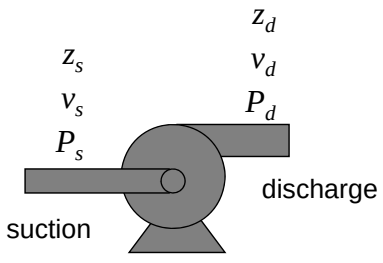
To report the performance of a centrifugal pump, we apply the Mechanical Energy Balance around the pump to see what we need to measure.

$$\frac{\Delta P}{\rho}+\frac{\Delta\left(v^2\right)}{2\alpha}+g\Delta z+F_{friction}=\frac{W_{s,on}}{\dot{m}}$$



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Centrifugal Pumps - MEB written on suction/discharge system

$$\frac{P_d - P_s}{\rho} + \frac{\langle v \rangle_d^2 - \langle v \rangle_s^2}{2} + g(z_d - z_s) + F_{d,s} = \frac{W_{s,on,ds}}{\dot{m}}$$

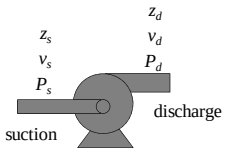
$$\frac{P_d - P_s}{\rho} + \frac{\langle v \rangle_d^2 - \langle v \rangle_s^2}{2} + g(z_d - z_s) = \frac{W_{s,on,ds}}{\dot{m}} - F_{d,s}$$

Losses inside pump only

pump efficiency

$$\frac{\eta W_{s,by\ pump}}{\dot{m}}$$

brake horsepower



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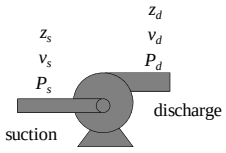
Centrifugal Pumps - MEB written on suction/discharge system

Measuring these quantities on suction discharge system

$$\frac{p_d - p_s}{\rho} + \frac{\langle v \rangle_d^2 - \langle v \rangle_s^2}{2} + g(z_d - z_s) = \left(\frac{W_{s,on,ds}}{\dot{m}} - F_{d,s} \right) = \frac{\eta_{eff} W_{s,by\ pump}}{\dot{m}}$$

Tells us about the net capability of the pump



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Calculating the Pumping Head curve:

- Write the MEB on the suction-discharge system
- Measure pressures, velocities, elevations at (d) and (s)
- Pump friction is moved to the RHS and combined with the work, leaving H_p as usable (delivered); we do not need to measure pump friction (unless measuring efficiency, η)

$$\frac{P_d - P_s}{\rho g} + \frac{\langle v \rangle_d^2 - \langle v \rangle_s^2}{2g} + (z_d - z_s) = \left(\frac{W_{s,on}}{\dot{m} g} - \frac{F_{d,s}}{g} \right) \equiv H_p$$

$$H_p \equiv \frac{P_d - P_s}{\rho g} + \frac{\langle v \rangle_d^2 - \langle v \rangle_s^2}{2g} + (z_d - z_s)$$

Total head $= \left(\frac{\text{energy}}{\text{weight}} \right)$

H_p is a function of flow rate (through the average velocity).

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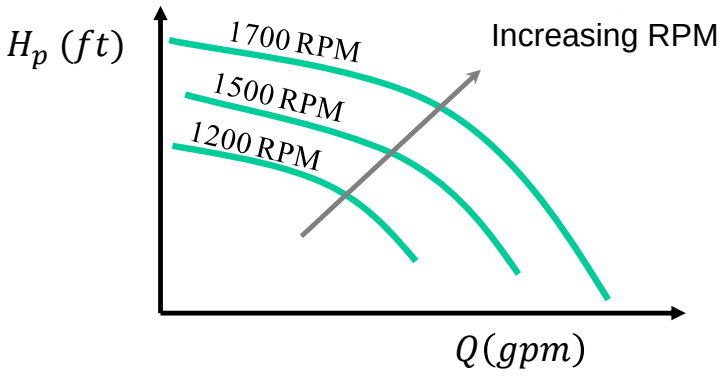
Pumping Head - pump characteristic curve



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- Pumping Head Characteristic Curves are usually supplied by the manufacturer
- In this lab we measure the pumping head characteristic curve by varying the load on a custom pump, the CM3215 "Lossy" pump (the orifice meter prevents us being able to vary directly the load on the Krump pump)
- Once we measure the pump characteristic curve for our "Lossy" pump, we use this to predict operating points as if we were designing a new system with this "Lossy" pump
- Finally, we check these predicted operating points against the actual operating points we measure in the lab. This gives us a feel for how accurate these types of design predictions are.

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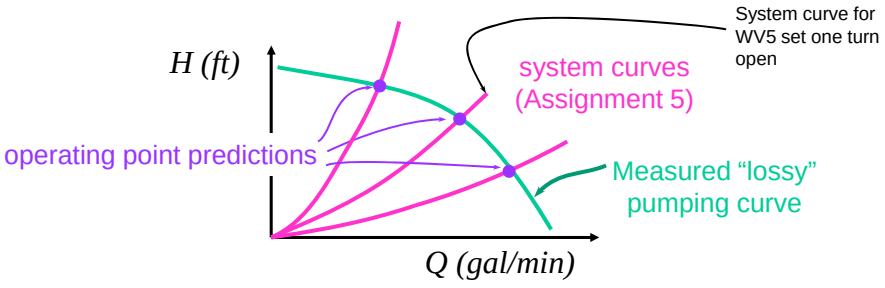
We can use the methods of Assignment 5 to predict the operation of the "Lossy" pump against the laboratory system

In Assignment 5 we calculated three curves for our lab system with different settings of WV5: 0.5 turn, 1.0 turn, and 1.5 turns open.

We now need to operate under those conditions (set WV5: 0.5 turn, 1.0 turn, and 1.5 turns open).

With the theoretical system curves, we can predict operating points for the settings of the valve above and compare to actual.



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Pumping Lab: Analysis of a Centrifugal Pump

- Measure pressure changes over suction/discharge system for the Lossy pump over a wide range of flow rates;
- Operate the Lossy pump against the system you modeled in *Assignment 5 System Head Curves.* That is, when taking the data above, be sure to include operating the flow loop with WV5: ½ turn open, 1 turn open, and 1 ½ turn open
- Acquire the appropriate replicates on all data
- Report measured pumping head curve for the Lossy pump (fit to a curve)
- Using the system-head calculations from Assmt 5 to predict operating points for three systems: WV5: ½ turn open, 1 turn open, and 1 ½ turn open
- Compare the predictions with the actual flow rates and delivered head when the Lossy pump pumps against the three systems calculated.

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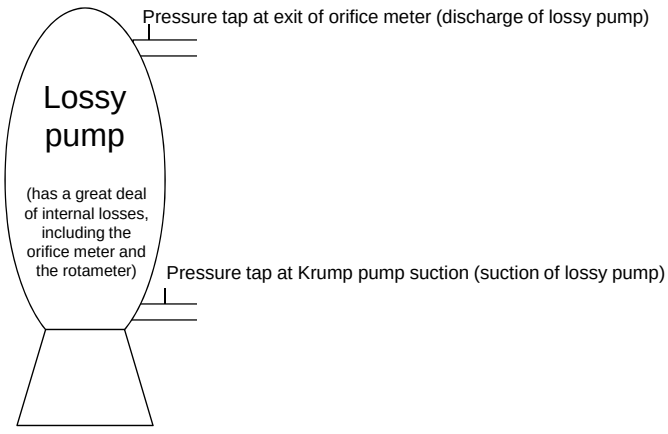
The CM3215 "Lossy" Pump

- Extends from the pump suction to the exit of the orifice meter.



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