n

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

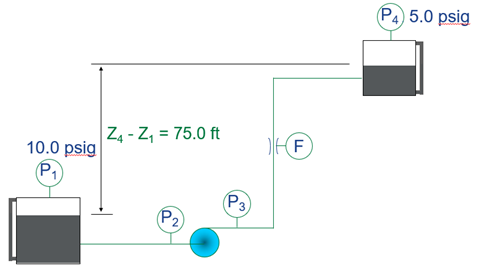
Company: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Please prepare an inventory of one or two pump systems in your facility you wish to analyze and obtain the following data for each one of them.
2. Hours/year of operation
3. Cost of electricity, $/kWh
4. Pump type
5. Pump operating speed, RPM
6. Drive type (Direct, Std V-belt, Notched V-belt, Synchronous belt, VFD)
7. Fluid pumped
8. Fluid Temperature, F
9. Fluid specific gravity
10. Fluid kinematic viscosity, cSt
11. Number of pump stages
12. Motor horsepower rating
13. Motor rated RPM
14. Motor efficiency class (Standard, Energy Efficient, Premium Efficiency)
15. Motor rated voltage
16. Motor full load amps
17. Measured flow rate, GPM
18. Measured pump head, Feet
19. Measured motor power (kW with Power Meter or Volts & Current with clamp on meter)
20. Why do you think this pumping system has energy reduction potential?
21. List your questions about pumping systems in your facilities.

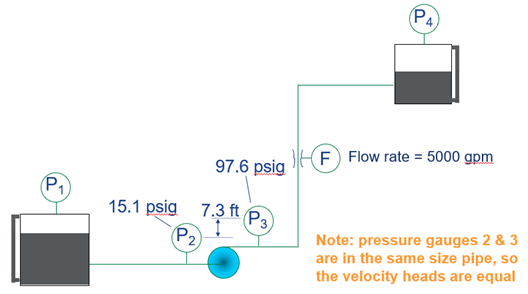
***Go the Extra Mile: If you have time work through some of the following!***

***Answers are on the Next Page.***

1. A pump operates under the following conditions: flow is 500 gpm; suction pressure is 22.9 psig; discharge pressure is 127.4 psig; suction gauge elevation is 4 feet off the floor; discharge gauge elevation is 8 feet off of the floor; suction piping is 6 inch diameter; discharge piping is 5 inch diameter; the suction side loss coefficients total 1.75; the discharge side loss coefficients total 2.5; the fluid is corn oil with a specific gravity of 0.924. Calculate the pump head.
2. Calculate the static head for the system below. Standard water is being pumped.



1. Calculate the pump head for the figure below. The flow rate is 5000 gpm of standard water.



1. Using the static head from Problem 2 and the pump head and flow from Problem 3, calculate the system curve this piping system. The equation should be of the form:



1. A plant has a VFD installed on a fully loaded 100 hp pump. The operators continue to run the pump at 60 Hz and the automatic control system is not connected to the VFD. The VFD efficiency is estimated to be 97%. How much has the operating cost for the pump increased per year if the VFD is operated at 60 Hz continuously? The average net cost of electricity is $0.08/kWh and the electric motor efficiency is 95%.
2. A chilled water closed loop piping system has a 200-ton chiller with the evaporator flow at 480 gpm of water at 42 F. This piping loop has a straight pipe length of 3500 feet, 2-gate valves (wide open), 10-std 90-degree elbows, 1-check valve, and 1-strainer (K = 2.0). The chiller evaporator has a 20-foot head loss and each of the 5 chilled water coils has a 12-foot head loss, all supplied by the chilled water circulating pump. Determine the following:
   1. The size of the pipe is needed for the 480 gpm flow. (See slide 47)
   2. The total head loss for the system assuming schedule 40 black steel pipe.
   3. Go to the following link and select a chilled water pump for this system. [ESP Systemwize (esp-systemwize.com)](https://www.esp-systemwize.com/pumps;catalogs=%5B%5D;fluid_state_id=15449063;list_state_id=;dp=%7B%22flow%22:%7B%22value%22:0,%22unit%22:%22USGPM%22%7D,%22head%22:%7B%22value%22:0,%22unit%22:%22FT_FLUID%22%7D,%22staticHead%22:%7B%22value%22:0,%22unit%22:%22FT_FLUID%22%7D,%22load%22:1,%22overspeed%22:%22Off%22,%22operatingPointHead%22:%22systemCurve_speedAdjustCalc%22,%22plevMode%22:%22MODE_THREE%22,%22pumpCount%22:1,%22pumpStandbyCount%22:0,%22pumpDesignStrategy%22:%22PARALLEL%22,%22operationMode%22:1%7D;s=%5B%5D;sme=1;smst=SIZEtoMAXonDESIGNCURVE;smstd=2;ops=%5B%7B%22note%22:%22%22,%22flow%22:%7B%22value%22:0,%22unit%22:%22USGPM%22%7D,%22head%22:%7B%22value%22:0,%22unit%22:%22FT_FLUID%22%7D,%22static_head%22:%7B%22value%22:0,%22unit%22:%22FT_FLUID%22%7D,%22load%22:42%7D,%7B%22note%22:%22%22,%22flow%22:%7B%22value%22:0,%22unit%22:%22USGPM%22%7D,%22head%22:%7B%22value%22:0,%22unit%22:%22FT_FLUID%22%7D,%22static_head%22:%7B%22value%22:0,%22unit%22:%22FT_FLUID%22%7D,%22load%22:45%7D,%7B%22note%22:%22%22,%22flow%22:%7B%22value%22:0,%22unit%22:%22USGPM%22%7D,%22head%22:%7B%22value%22:0,%22unit%22:%22FT_FLUID%22%7D,%22static_head%22:%7B%22value%22:0,%22unit%22:%22FT_FLUID%22%7D,%22load%22:12%7D%5D;sts=1;sr=false;f=60;co=1)

***Answers***

1. Suction pipe diameter = (Pi x (6/12)2)/4 = 0.19635 ft2

Discharge pipe diameter = (Pi x (5/12)2/4 = 0.13636 ft2

Suction flow velocity = (500 gal/min)/(7.4805 gal/ft3 x 60 s/min x 0.19635 ft2) = 5.6736 ft/s

Suction pipe velocity head = (5.6736 ft/s)2/(2 x 32.174 ft/s2) = 0.50024 ft

Discharge flow velocity = (500 gal/min)/(7.4805 gal/ft3 x 60 s/min x 0.13635 ft2) = 8.1700 ft/s

Discharge pipe velocity head = (8.1700 ft/s)2/(2 x 32.174 ft/s2) = 1.03731 ft

**Pump elevation head = (8 ft – 4 ft) = 4 feet**

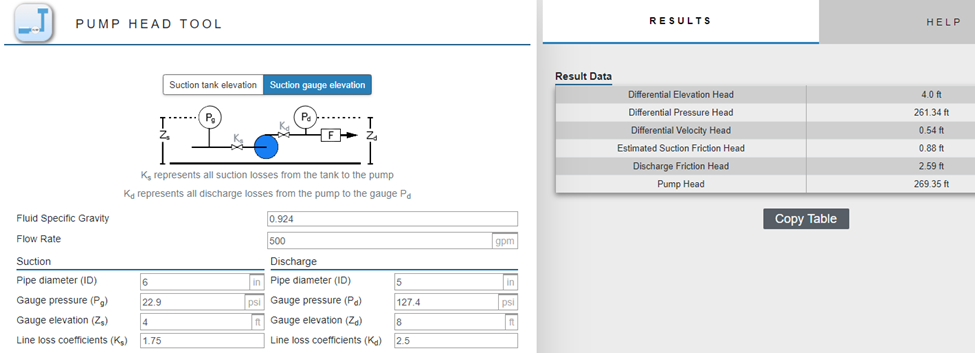
**Pump pressure head = (127.4 – 22.9) x 2.31 / 0.924 = 261.25 feet**

**Differential velocity head = 1.03731 – 0.50024 = 0.53707 feet**

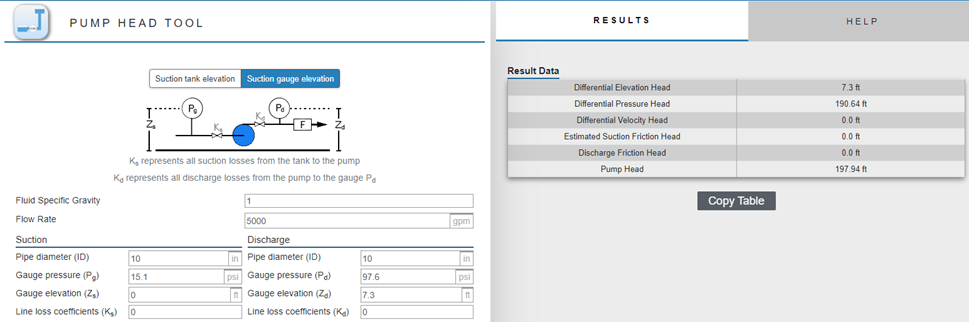
**Suction line losses = 1.75 x 0.50024 ft = 0.8754 feet**

**Discharge line losses = 2.50 x 1.03731 ft = 2.5933 feet**

**Total Pump Head = 269.26 feet**



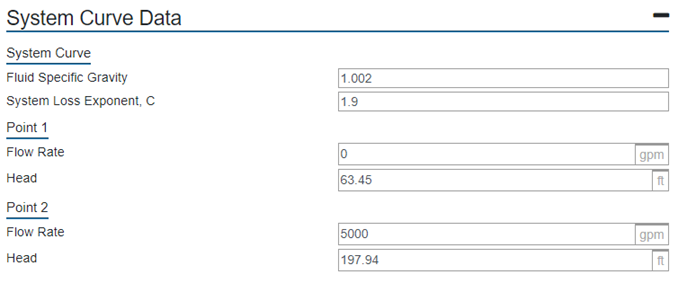
1. **Static Head = 75.0 + 2.31 x (5.0 – 10.0) = 63.45 feet**

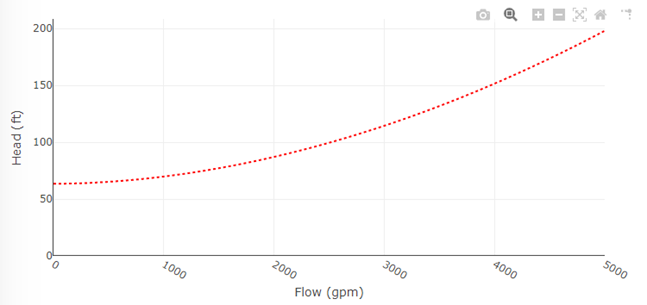


**Pump Head = 197.94 feet**

1. **Static Head = 63.45; k’ = (197.94 – 63.45)/50001.9 = 0.0000126**

**System Curve Equation = 63.45 + 0.0000126 x Q1.9**







1. Answer: kW with VFD = (100 hp x 0.746 kW/hp)/(0.95 x 0.97) = 80.95 kW

kW without VFD = (100 hp x 0.746 kW/hp)/0.95 = 78.53 kW

Extra Annual Cost for VFD Losses = (80.95 – 78.53) x 8760 hr/yr x $0.08/kWh = $1,696/yr

1. 6” diameter pipe from slide 47

A graph with lines and numbers

Description automatically generated

1. Pump Head: Straight pipe 1.8 feet loss/100 feet of pipe = 1.8 x 35 = 63 feet

Calculate velocity in the 6-inch diameter pipe. Cross sectional area = (Pi x (0.5)2)/4 = 0.19635 ft2. Flow velocity = (480 gal/min)/(7.48 gal/ft3 x 0.19635 ft2 x 60 sec/min) = 5.447 ft/s

V2/2g = (5.447 ft/s)2/(2 x 32.174 ft/s2) = 0.461 ft

90-degree elbows = 10 els x 0.3 x 0.461 ft = 1.383 ft

Gate valves = 2 valves x 0.2 x 0.461 ft = 0.184 ft

Check valve = 1 valve x 2.0 x 0.461 ft = 0.922 ft

Strainer = 1 strainer x 2.0 x 0.461 ft = 0.922 ft

Cooling coils = 5 coils x 12 ft/coil = 60 ft

Total head loss = 146.41 feet

Select pump for 480 gpm @ 150 feet of head

Bell & Gossett e1510 3AD 6.625 inch diameter impeller, 23.2 bhp, 30 hp motor, 3550 rpm

