Chris Betton, Team 7 CH. 13 * 34 a&e, 17, 19

34. a. $Q = 500 \frac{gal}{min}$ of water @ $h_a = 80ft$

From pump selection chart it is apparent that a **reciprocating pump** is most appropriate for these parameters.

e. $Q = 80 \frac{gal}{min}$ of water @ $h_a = 800ft$

high speed centrifugal pump

17. For a given centrifugal pump, if the speed of rotation of the impeller is cut in half, how does the total head capability change?

$$\frac{h_{a1}}{h_{a2}} = \left(\frac{N_1}{N_2}\right)^2, \quad N_2 = N_1 \cdot \frac{1}{2}$$

$$\therefore \frac{h_{a1}}{h_{a2}} = \left(\frac{N_1}{\left(\frac{N_1}{2}\right)}\right)^2 \rightarrow \frac{h_{a1}}{h_{a2}} = \left(\frac{2\cancel{N_1}}{\cancel{N_1}}\right)^2 = 4 \rightarrow \boxed{h_{a2} = \frac{1}{4} h_{a1}} \quad \boxed{75\% \text{ reduction}}$$

So, the speed reduction by a factor of 2 will result in a total head $\boxed{\text{reduction by a factor of 4.}}$

19. For a given size of centrifugal pump casing, if the diameter is reduced by 25%, how much does the capacity change?

Since volumetric flow rate (capacity) is directly proportional to the impeller diameter, a reduction of impeller diameter by 25% will result in a reduction of capacity by 25% i.e.

$$\boxed{Q_2 = \frac{3}{4} Q_1} \quad \boxed{25\% \text{ reduction}}$$

- Pumps are used to deliver liquids through piping systems. They must deliver the required volumetric flow rate while developing the required total dynamic head (h_a), created by ① elevation changes, ② differences in the pressure head & velocity heads, and all energy losses in a system. This relationship is characterized using Bernoulli's equation: $h_A = \frac{P_2 - P_1}{\gamma} + z_2 - z_1 + \frac{V_2^2 - V_1^2}{2g} + h_L$

- Understanding this relationship is vital to being able to correctly select a pump for a piping system.

- In chapter 13 lecture notes and class discussion I learned how to analyze the performance of pumps & how to select a pump for a given application. Understanding these concepts allows us to design systems that maximize pump efficiency thus minimizing energy expendetures.

Key concepts

- Energy added by a pump to the fluid (h_A)

$$\Updownarrow$$

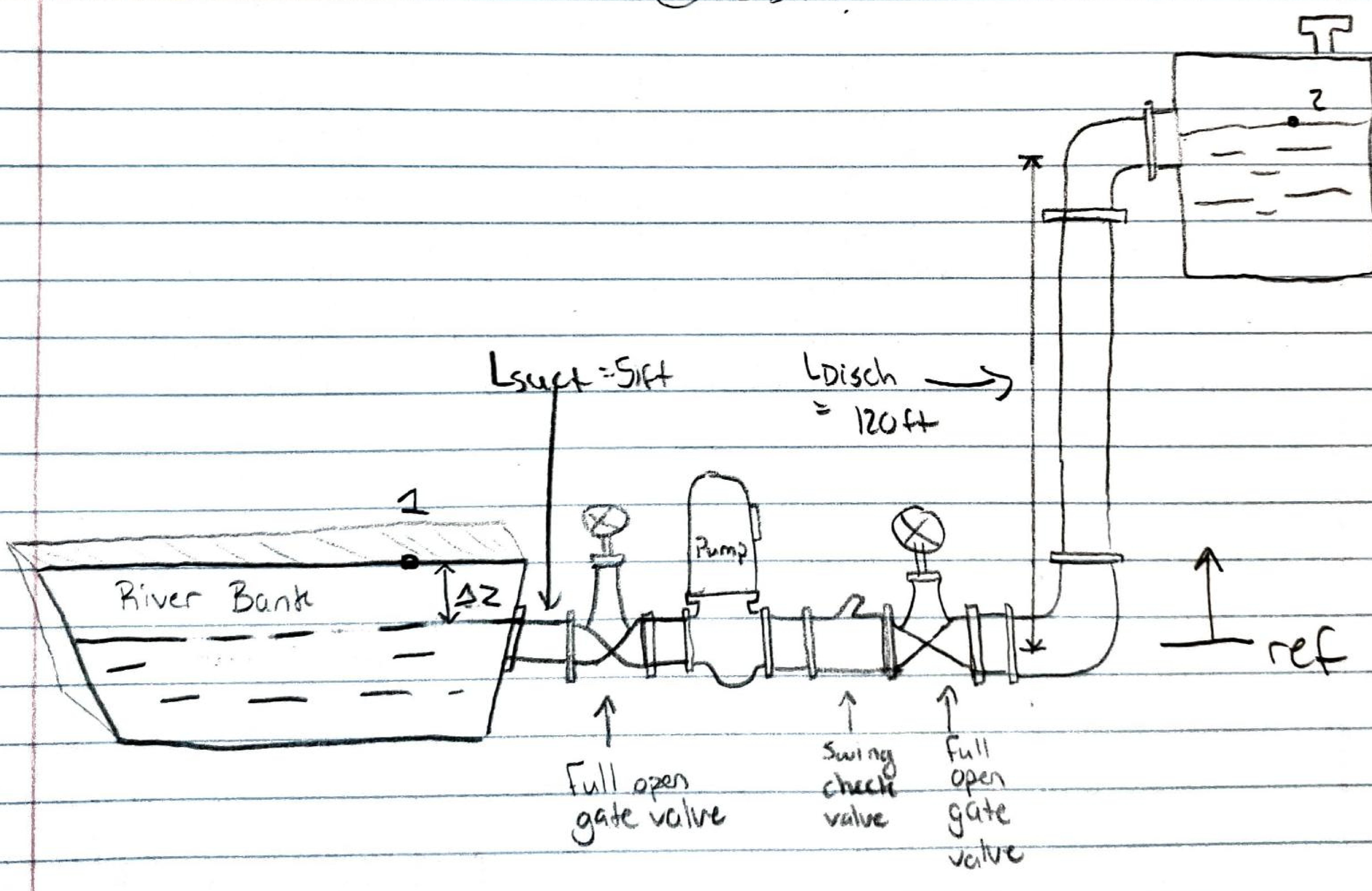
Total dynamic head (TDH)

- Pumps are prime movers of a fluid and are used to perform certain tasks:
  1) Increase the fluid pressure from the source, P_1, to the fluid pressure at P_2
  2) Raise the level of the fluid from $z_1 \rightarrow z_2$
  3) Increase velocity head from point 1 → point 2
  4) overcome energy losses that occur in the system due to friction in pipes, minor losses, or changes in flow area or direction.

Chris Betton

Design Problem 3

- $\varepsilon_{steel} = 1.5 \times 10^{-4}$ ft
- $T_w = 80°F$, $\gamma = 62.2 \frac{lb}{ft^3}$, $\nu = 9.15 \times 10^{-6} \frac{ft^2}{sec}$, $h_{vp} = 0.5069$ psia, $\eta = 1.77 \times 10^{-5} \frac{lb \cdot s}{ft^2}$
- Volume flow rate min. = $1500 \frac{gal}{min}$
- Tank elevation = 55 ft, distance = 125ft
- Ref 1 ≡ surface of riverbank Ref 2 ≡ surface of fluid in tank.
- Source : Riverbank ; 0 psig = P_1 in-line with pump suction
- Destination: Elevated tank @ 55ft.



Find Diameter

$V_{crit} = 3\frac{m}{s} \approx 9.845\frac{ft}{s}$, $Q = 1500\frac{gal}{min} = 3.3420\frac{ft^3}{s}$

$\therefore A = 0.3472\ ft^2 \rightarrow D = 0.6651\ ft$, 8" sch. 40 steel pipe

Compute h_A

① $\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_L = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g} \Rightarrow h_A = z_2 - z_1 + h_L + \frac{V_2^2}{2g}$

2) $h_L = h_{entrance} + h_{friction\ suction} + h_{friction\ discharge} + 2 * h_{gate\ valve} + h_{check\ valve} + 2 \cdot h_{elbow} + h_{exit}$

$h_{entrance} = K\frac{V^2}{2g}$, $h_{suct} = \left(f\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$, $h_{disch} = \left(f\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$, $h_{gate} = \left(f_T\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)2$

$h_{check} = \left(f_T\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$, $h_{elbow} = \left(f_T\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)2$, $h_{exit} = 1.0\left(\frac{V^2}{2g}\right)$

From excel: $h_L = 9.86\ ft$

① $h_A = 55ft + 9.86ft + \left(\frac{9.619282^2}{2g}\right) = 66.296\ ft$

Select Pump

$h_A = 66.30ft$, $Q = 3.3420\frac{ft^3}{sec} = 1500GPM$

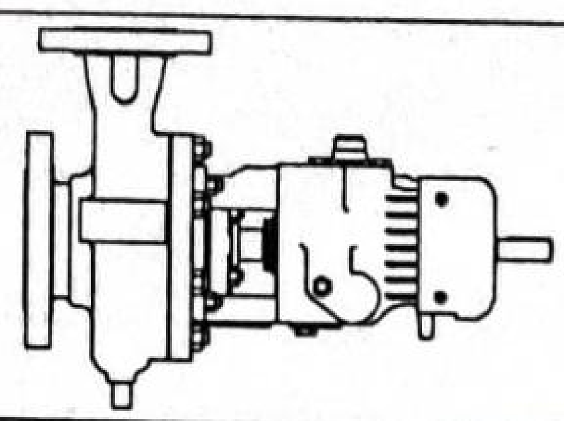
- Sulzer 60Hz, 1775 rpm chart $\Rightarrow$ 8×8×10 cent. pump.
- Use affinity laws to select correct pump:

$\left(\frac{N_2}{N_1}\right)Q_{rpm_1} = Q_{rpm_2}$ $\therefore$ $Q_{rpm_2} = Q_{rpm_1}(0.5956)$

$N_2 = 1775$ $\qquad h_{rpm_2} = h_{rpm_1}(0.2978)$

$N_1 = 2980$

From the above data, the 230mm pump was selected.



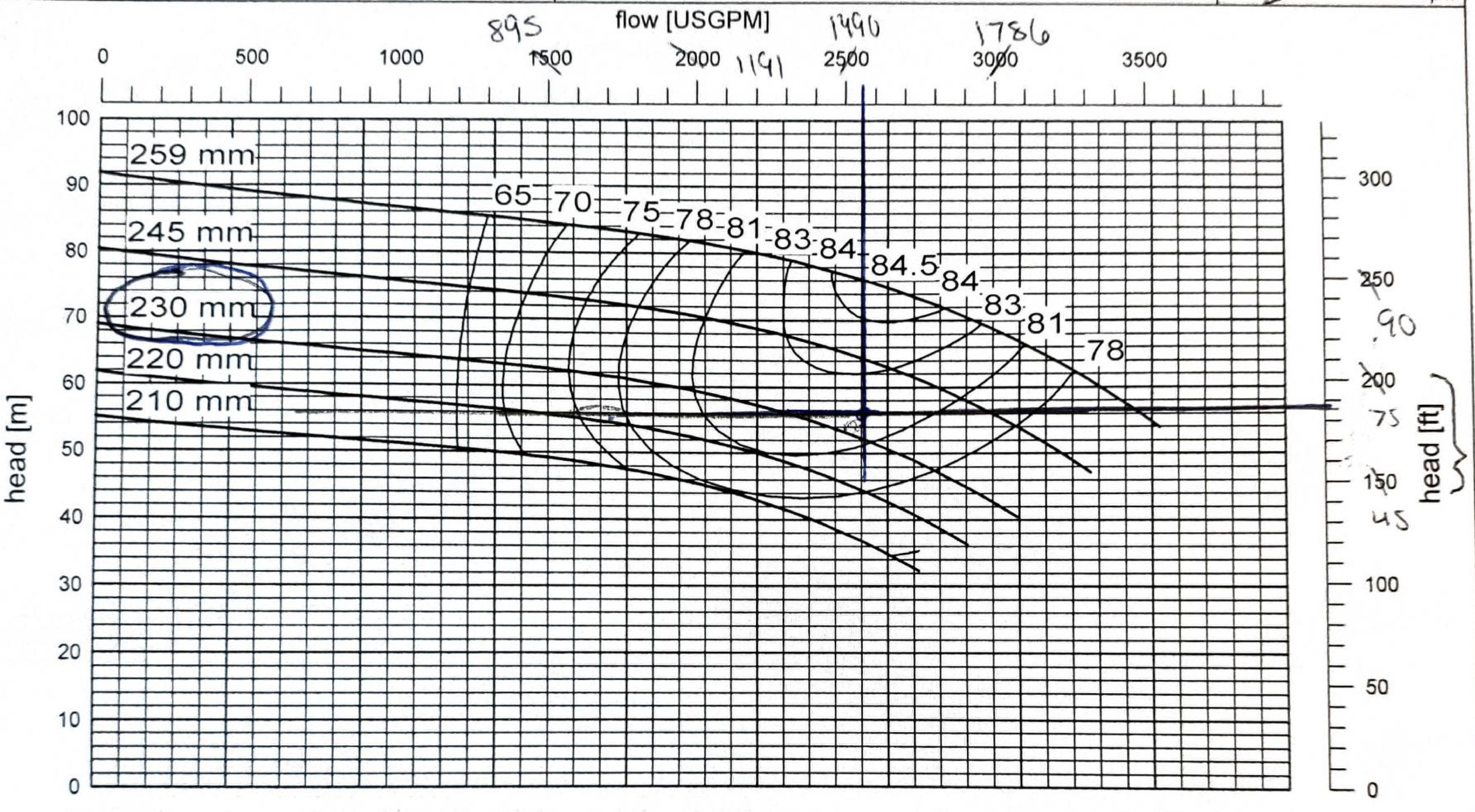
8 x 8 x 10 -1 OHH

SULZER

Series 2.00 / 50Hz E033

1775

Curve No	OHH 66-1-2-01	NSS	213 (11000)	Speed 2980 rpm
Efficiency Basis	API Std. clearances	nq	48 (2470)	
Max Solid	12 mm (.47 in)	Rotation	CCW viewed from coupling	



Class 3: Determine Pipe Diameter w/ valve in pipeline

Variable name	Data	Value		Units	Location
Pressure	pA	0		lb/ft^2	Given
Pressure	pB	0		lb/ft^2	Given
length suct	L1	5			
Length disch	L2	120		ft	Given
Height	zB	55		ft	Given
Specific Weight	γ	62.2		lb/ft^2	Table A
Kinematic Viscosity	ν	9.15E-06		ft^2/s	Table A
Wall roughness	ε	0.00015		ft^3/s	Table 8.2
Flow Rate	Q	3.342		ft^3/s	Given

Friction Coefficient	kvalve (gate) x2	2.25E-01		8*ft
	kvalve (check)	1.41E+00		100*fT
	k pipe	2.77E+00		fT=0.014
	k pipe suct	1.15E-01		
	k exit	1.00E+00		
	k entrance	5.00E-01		
	elbow x2	8.44E-01		30*fT

Iterations	D (ft)	V (ft/s)	V^2/2g	Re	D/ε	f	fT	RHS	LHS	%diff	hL total
1	0.66510	9.619282	1.43681	6.99E+05	4434.00	1.54E-02	1.41E-02	4.31	-55.00	107.83%	9.86E+00

Ch 10 Sect 9
Ch 10 Sect 9
Ch 10 Sect 9
Ch 10 Sect 9
Ch 10 Sect 9
Ch 10 Sect 9

$$Re = \frac{VD}{\upsilon} \qquad \text{Relative roughness} = \frac{D}{\epsilon}$$

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right]^2} \qquad f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)}\right)\right]^2}$$

hL suct

1.05E+00

Tai Booker
MET 330
HW 3.3
Chapter 13

22,23,25

22. Describe each part of the centrifugal pump designation:
$1\frac{1}{2} \times 3 - 6$

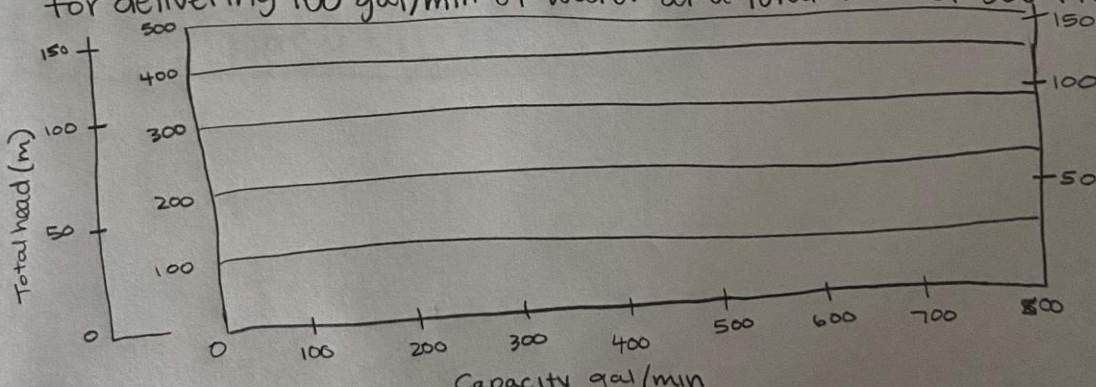
centrifugal pump $X \times Y - Z$

X - size of the discharge connection (nominal inch) = $1\frac{1}{2}$

Y - size of the suction connection (nominal inch) = 3

Z - casing size = 6

23. For the line of pumps shown in Fig. 13.22, specify a suitable size for delivering 100 gal/min of water at a total head of 300 ft.



Q = 100 gal/min
H = 300 ft

pump size found from the composite rating chart is $\boxed{1\frac{1}{2} \times 3 - 10}$

Tai Booker
MET 330
HW 3.3
Chapter 13

25. For the 2×3-10 centrifugal pump performance curve shown in Fig. 13.28, describe the performance that can be expected from a pump with an 8-in impeller operating against a system head of 200 ft. Give the expected capacity, the power required, the efficiency, & the required NPSH.

From figure 13.28 I found my answers needed

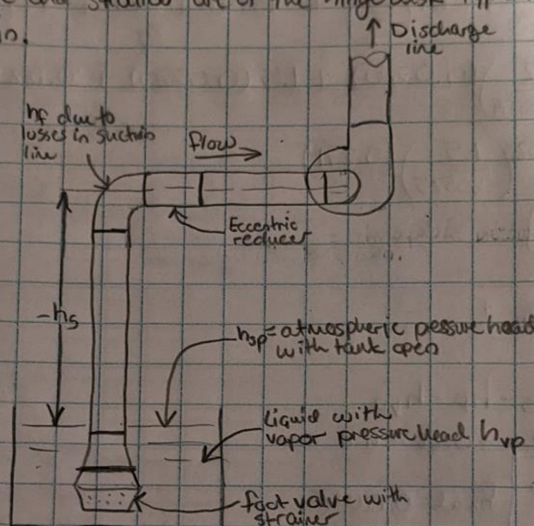
expected capacity $Q = 230$ gal/min
power required $p = 22$ hp
efficiency $e = 54\%$
$NPSH = 11$ ft

HW 3.3 Team 7 Melanie Cra Cortez

#55, 65

55. Determine the available NPSH for the system shown in Fig 13.36 (b). The fluid is water at 80°C and the atmospheric pressure is 101.8 kPa. The water level in the tank is 2.0 m below the pump inlet. The vertical leg of the suction line is DN 80 Schedule 40 steel pipe, whereas the horizontal leg is DN 50 Schedule 40 pipe, 1.5 m long. The elbow is of the long radius type. Neglect the loss of the reducer. The foot valve and strainer are of the hinge disk type. The flow rate is 300 L/min.

Diagram:



Purpose:

Determine the $NPSH_A$ for the system.

Data + Variables:

$P_{ATM} = 101.8$ kPa $\quad T_w = 80°C \quad$ elbow = long radius

$Q = 300$ L/min $\quad$ vert leg DN 80 sch 40 $\quad h_s = 2.0$ m

$L = 1.5$ m $\quad$ horiz leg DN 50 sch 40 $\quad h_{vp} = 4.8$

$\varepsilon = 4.6\times10^{-5}$

Calculations:

① $NPSH_A = h_{sp} \pm h_s - h_f - h_{vp}$

② $h_{sp} = \frac{P_{ATM}}{\gamma} = \frac{101.8\,kN}{m^2} \cdot \frac{m^3}{9.53\,kN} = 10.682\,m$

③ $h_f = f_3\left(\frac{L}{D}\right)\left(\frac{V_3^2}{2g}\right) + k_1\left(\frac{V_3^2}{2g}\right) + f_{3T}(20)\frac{V_3^2}{2g} + f_2\left(\frac{L}{D}\right)\left(\frac{V_2^2}{2g}\right)$

$f_{3T} = 0.018$

$k_1 = 75 f_{3T} = 75(0.018) = 1.5$

$V_3 = \frac{Q}{A_3} = \frac{300\ L/min}{4.268\times10^{-3}\,m^2} \cdot \frac{1\,m^3/s}{60000\ L/min} = 1.05\ m/s$

④ $\frac{V_3^2}{2g} = \frac{(1.05)^2}{2(9.8)} = 0.0560\,m$; $N_{R3} = \frac{V_3 D_3}{\upsilon} = \frac{(1.05)(0.0779)}{3.6\times10^{-7}}$

$N_{R3} = 2.3\times10^5$

$\frac{D_3}{\varepsilon} = \frac{0.0779}{4.6\times10^{-5}} = 1694$

$f_3 = 0.0195$

⑤ $V_2 = \frac{Q}{A_2} = \frac{300/60000}{2.168\times10^{-3}} = 2.31\ m/s$

⑥ $\frac{V_2^2}{2g} = \frac{(2.31)^2}{2(9.8)} = 0.271\ m$

$N_{R_2} = \frac{V_2 D_2}{\nu} = \frac{(2.31)(0.0525)}{3.6\times10^{-7}} = 3.4\times10^5$

$\frac{D_2}{\varepsilon} = \frac{0.0525}{4.6\times10^{-5}} = 1141$

$f_2 = 0.0202$

* Plug in to Eqn 3

$$h_f = f_3\left(\frac{L}{D}\right)\left(\frac{V_3^2}{2g}\right) + k_1\left(\frac{V_3^2}{2g}\right) + f_{3T}(20)\frac{V_3^2}{2g} + f_2\left(\frac{L}{D}\right)\left(\frac{V_2^2}{2g}\right)$$

$$= 0.0195\left(\frac{2}{0.079}\right)(0.0560) + 1.5(0.0560) + 0.018(20)(0.0560)$$

$$+ 0.0202\left(\frac{1.5}{0.0525}\right)(0.271)$$

$\boxed{h_f = 0.28\ m}$

* Lastly, plug in Eqn 1

$NPSH_A = h_{sp} - h_s - h_f - h_{vp}$

$= 10.68 - 2.0 - 0.28 - 4.8$

$\boxed{NPSH_A = 3.43\ m}$ final answer

65. A pump draw propane at 45°C ($sg = 0.48$) from a tank whose level is 1.84m below the pump inlet. The energy losses in the suction line total 0.92m and the atmospheric pressure is 98.4 kPa absolute. Determine the required pressure above the propane in the tank to ensure that the $NPSH_A$ is at least 1.50m.

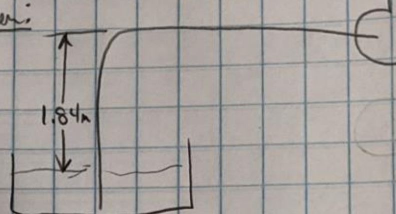
Purpose:
To determine the required pressure above the propane in the tank to ensure the $NPSH_A$ is at least 1.50m.

Data + Variables:

$sg_{prop} = 0.48$
$T_{prop} = 45°C$
(elevation diff) $h_s = 1.84m$
(loss) $h_f = 0.92m$
$P_{ATM} = 98.4$ kPa
(net positive suction head available) $NPSH_A = 1.50m$

$\gamma = sg(\gamma_w)$
$= (0.48)(9.81 \text{ kN/m}^3)$
$\gamma = 4.7088 \text{ kN/m}^3$
or 4.86 kN/m^3 from App B

Diagram:



Calculation:

① $NPSH_A = h_{sp} \pm h_s - h_f - h_{vp}$

h_{sp} = static pressure head above fluid
h_s = elevation diff between fluid + centerline of pump
h_f = energy loss in the suction line
h_{vp} = vapor pressure head of the liquid at the pump temp.

② $h_{sp} = \frac{P_{abs}}{\gamma}$ substitute $P_{ABS} = P_{ATM} + P_{tank}$

$h_{sp} = \frac{P_{ATM} + P_{tank}}{\gamma}$

* substitute eqn 2 in place of h_{sp} in eqn 1

is negative since below pump inlet

$NPSH_A = \left(\frac{P_{ATM} + P_{tank}}{\gamma}\right) \pm h_s - h_f - h_{vp}$

* Solve for TGP

$\frac{P_{ATM} + P_{tank}}{\gamma} = NPSH_A + h_s + h_f + h_{vp}$

$P_{ATM} + P_{tank} = \gamma(NPSH_A + h_s + h_f + h_{vp})$

$P_{tank} = [\gamma(NPSH_A + h_s + h_f + h_{vp})] - P_{ATM}$

From Vapor vs. temp for propane graph:
h_{vp} at 45°C is 340m

$P_{TANK} = [\gamma(NPSH_A \pm h_s + h_f + h_{vp})] - P_{ATM}$

$= 4.7088(1.5 + 1.84 + 0.92 + 340)] - 98.4$

$= 1621.051 - 98.4$

$P_{TANK} = 1522.651 \text{ kN/m}^2$
Required pressure above propane in the tank

I learned that pumps are used to deliver liquids through piping systems. They must deliver the desired volume flow rate of fluid while developing the required total dynamic head h_A created by elevation changes, differences in the pressure heads and velocity heads, and all energy losses in the system. The inlet to the pump is called the suction line and the outlet of the discharge line. The pressure at the inlet to the pump and its outlet must be measured to enable analysis that ensures proper operation of the pump.

Pumps serve as prime movers in most fluid systems. It must increase the velocity head from that at point 1 to that at point 2. It must overcome any energy losses that occur in the system due to friction in the pipes or energy losses in valves, fittings, process components, or changes in the flow area or direction of the flow. There is more power required to drive the pump than the amount that eventually gets delivered to the fluid.