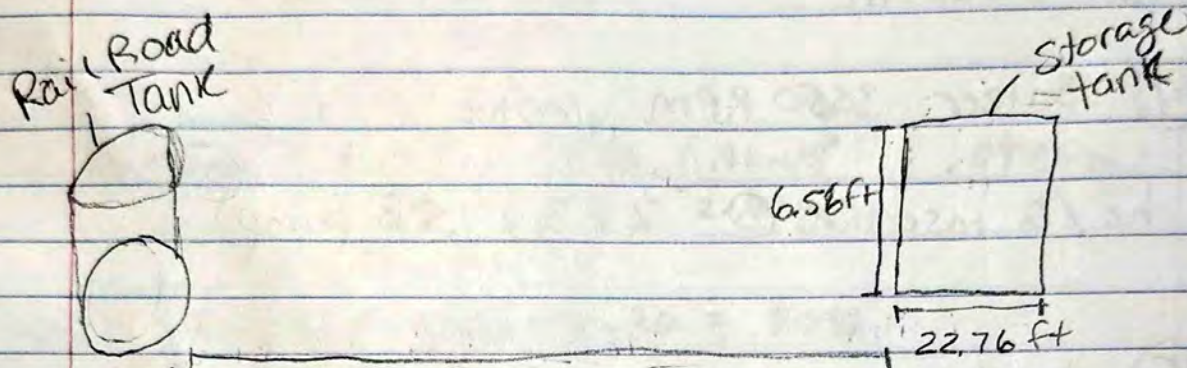
Test 3 MET 330 Joe Munoz

Design pipeline system from railroad car tank to storage tank for coolant



Lenght = 700ft − 22.76ft = 677.24

Specifications:

coolant viscosity & vapor pressure 1.5 time water

Choosing temperature @ 32°F where viscosity is high so system can handle worst case senario

SG = .94

$\nu_{water} @ 32°F = 1.89 \times 10^{-5}\ ft^2/s$

$\nu_{coolant} @ 32°F = 1.89 \times 10^{-5}\ ft^2/s \cdot 1.5 = 2.835 \times 10^{-5}$

Vapor pressure water @ 32°F = .08854 psia

Vapor pressure coolant @ 32°F = .08854 psia · 1.5 = .13281 psia

$\gamma = 62.42\ lb/ft^3 \cdot .94 = 58.5056\ lb/ft^3$

Flow rate $\frac{15000\ gal}{6\ hrs} = \frac{2500\ gal}{hr}$

$\frac{2500\ gal/hr}{26940\ \frac{gal/hr}{ft^3/s}} = .09279\ ft^3/s$

Pipe size: $Q = VA$ $\qquad V_{crit} = 9\ ft/s$

$Q = .09279\ ft^3/s$

$$A = \frac{Q}{V} = \frac{.09279\ \frac{ft^{3\cancel{2}}}{s}}{9\ \frac{\cancel{ft}}{\cancel{s}}} = .01031\ ft^2$$

$$D = \sqrt{\frac{A}{\frac{\pi}{4}}} = \sqrt{\frac{.01031\ ft^2}{\frac{\pi}{4}}} = .11458\ ft$$

$$D = .11458\ \cancel{ft} \cdot \frac{12\ in}{1\ \cancel{ft}} = 1.3749\ \text{inches}$$

Client requested minimum pipe diameter of 1.5 inches, which is greater than the calculated Diameter. Pipe size will be 1.5 inches to accomodate client request.

Pipe material + Dimensions:

Sched 40 steel Pipe DN 40

$D_{inside} = 1.610\ in$ or $.1342\ ft$

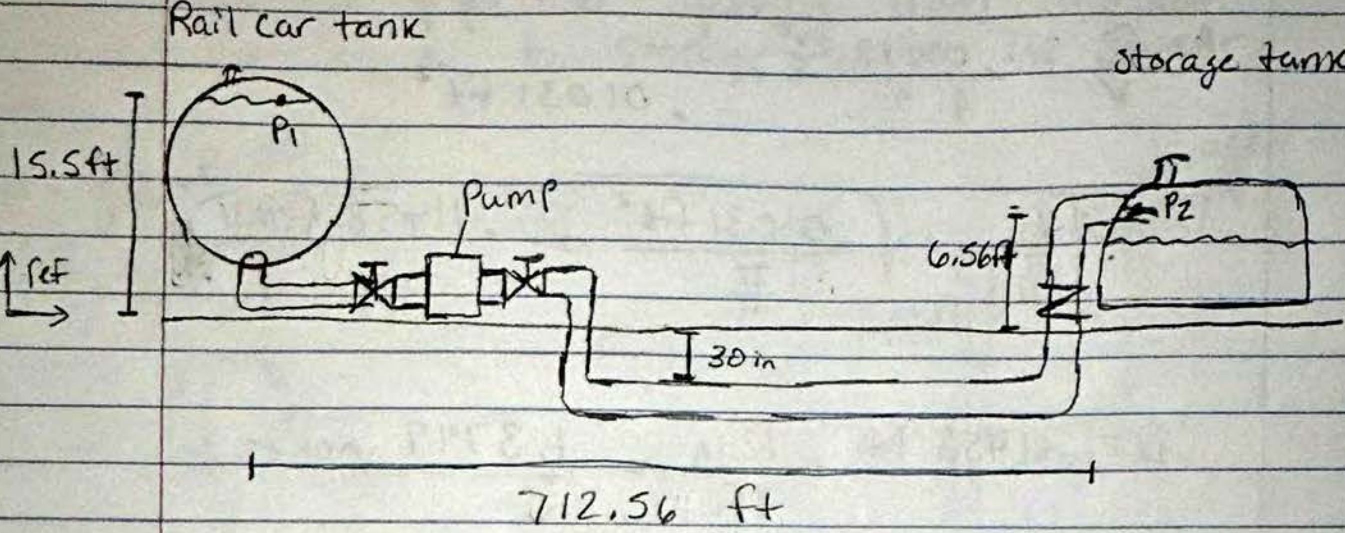
flow Area $= .01414\ ft^2$

$\varepsilon = 1.5 \times 10^{-4}\ ft$

Velocity Calculation with Choosen Pipe specs:

$$Q = VA \qquad V = \frac{Q}{A} = \frac{.09279\ ft^3/s}{.01414\ ft^2} = 6.56\ ft/s$$

Pipe layout:



Assume rail car hieght is industry standard of 15.5 ft

Total pipe lenght = 700ft + 6ft + 6.56 ft = 712.56 ft

Hydraulic Analysis:

$$\frac{\overset{0}{\cancel{P_1}}}{\gamma_L} + \frac{\overset{0}{\cancel{V_1^2}}}{2g} + z_1 + h_a = \frac{\overset{0}{P_2}}{\gamma_L} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$h_a = \frac{V_2^2}{2g} + (z_2 - z_1) + h_L$$

$$h_L = h_{L1\to 2} + 5h_{L,elbow} + 2h_{L,valve} + h_{L,ck\,valve} + h_{L,entry}$$

$$RE = \frac{VD}{\nu} = \frac{6.56\,ft/s \cdot .1342\,ft}{2.835\times10^{-5}\,ft^2/s} = 31066.5$$

$$F = \frac{.25}{\left(\log\left(\frac{1}{3.7 \cdot \frac{.1342ft}{1.5\times10^{-4}ft}} + \frac{5.74}{31066.5^{.9}}\right)\right)^2} = .02626$$

$$F_T = \frac{.25}{\left(\log\left(\frac{1}{3.7 \cdot \frac{.1342\,ft}{1.5\times10^{-4}\,ft}}\right)\right)^2} = .02017$$

$$h_{L,1\to2} = f \cdot \frac{L}{D} \cdot \frac{V_2^2}{2g} = .02626 \cdot \frac{712.56\,ft}{.1342\,ft} \cdot \frac{(6.56\,ft/s)^2}{2 \cdot 32.2\,ft/s^2}$$

$$h_{L,1\to2} = 93.19\ ft$$

$$h_{L,elbow} = K \cdot \frac{V_2^2}{2g} = .6054 \cdot \frac{(6.56\,ft/s)^2}{2 \cdot 32.2\,ft/s^2} = .4048\ ft$$

$$K = 30 \cdot f_T = 30 \cdot .02017 = .6054$$

$$h_{L,valve} = K \cdot \frac{V_2^2}{2g} = 6.86 \cdot \frac{(6.56\,ft/s)^2}{2 \cdot 32.2\,ft/s^2} = 4.588\ ft$$

globe valve

$$K = 340 \cdot f_T = 340 \cdot .02017 = 6.86$$

$$h_{L,ck\,valve} = K \cdot \frac{V_2^2}{2g} = 3.026 \cdot \frac{(6.56\,ft/s)^2}{2 \cdot 32.2\,ft/s^2} = 2.024\ ft$$

Ball check valve

$$K = 150 \cdot f_T = 150 \cdot .02017 = 3.026$$

$$h_{L,entry} = K \cdot \frac{V_2^2}{2g} = \frac{.5\,(6.56\,ft/s)^2}{2 \cdot 32.2\,ft/s^2} = .3344\ ft$$

$$K = .5$$

$$h_L = 93.19\ ft + (5 \cdot .4048\,ft) + (2 \cdot 4.588\,ft) + 2.024\,ft + .3344\,ft$$

$$h_L = 106.748\ ft$$

$$h_a = \frac{(6.56\ ft/s)^2}{2 \cdot 32.2\ ft/s^2} + (6.56\ ft - 15.5\ ft) + 106.748\ ft$$

$$h_a = 98.47\ ft$$

Preliminary pump requirements:

Pump head = 83.6 ft
flow rate = 2500 gal/hr or .09279 ft^3/s
41.667 gal/min

Kinetic Pump Arguement: Coolant is not multi-phase and flow rate does not need to vary, so a kinetic pump can be used in this case. A kinetic pump should be chosen since they are cheaper + smaller to reduce cost to client + save space.

additionally, calculating the specific speed and using the specif speed vs specific diameter shows a radial flow pump is best choice.

$$N_s = \frac{3000\ rem \cdot \sqrt{41.667\ gal/min}}{(83.6\ ft)^{3/4}} = 700$$

Pump selection:
Q + h requirements on Sulzer 1775 rpm 60 hz pump map land in 1x3x11.5

Must appy affinity laws to scale 3550 RPM graph x + y axiss

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$$

$$\frac{Q_2}{Q_1} = \frac{N_1}{N_2}$$

Y scaling Head (ft)

$$H_1 = \left(\frac{1775}{3550}\right)^2 \cdot H_2$$

X scaling of Flow (gal/

$$Q_2 = \frac{1775}{3550} \cdot Q_1$$

After rescaling for reduced RPM, flowrate and Head flow outside of impeller diameter curves. Must select overlapping pump 1.5x3x10.

rescaled 1.5x3x10 pump encompasses Q of 41 gal/min and 98 feet of head. Impeller size sits between 10.10 inches + 9.69 inches

Graph of System Curve:

$$h_a = (6.56 - 15.5) + \left(\left(\frac{.026 \cdot 712.56}{.1342} + 1\right) \cdot \frac{Q^2}{2 \cdot .01414^2 \cdot 32.2}\right)$$

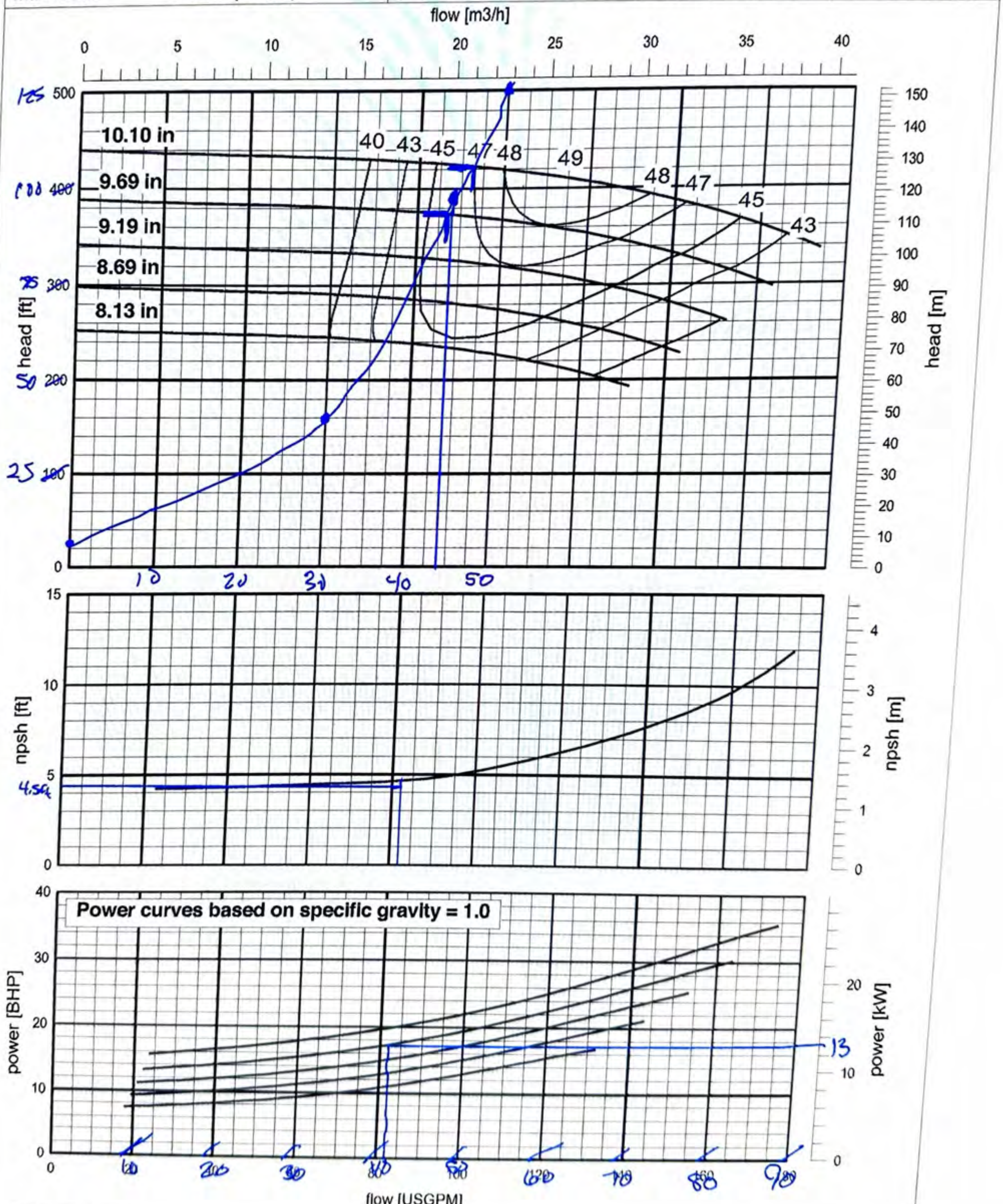
$Q = 50$ gal/min $= .1114\ ft^3/s$ $\quad h_a = 124.97$ ft

$Q = 30$ gal/min $= .0668403\ ft^3/s$ $\quad h_a = 39.27$ ft

1.5 x 3 x 10 -1 OHH

SULZER
series 2.00 / 60Hz E030

Curve No	OHH 60-1-1-01	**NSS**	9890 (192)	Speed
Efficiency Basis	API Std. clearances	**NS**	420 (8)	**3520**
Max Solid	.25 in (6 mm)	**Rotation**	CCW viewed from coupling	rpm



Rated Conditions

Project	Item	
H =	Q =	P =
Calculated Efficiency =		NPSH

Impeller diameter selected is 9.69in

$Q_{act} = 41.3$ gal/min $= 2478$ gal/hr $= .09201\ ft^3/s$
$h_{act} = 94$ ft

Time to fully empty rail car tank

$$\frac{15000\ gal}{2478\ \frac{gal}{hr}} = 6.05\ hrs$$

6.05 hrs > 6 hrs per client request

Pump power:

$$P_A = \gamma_c h_a Q = 58.5056\ lb/ft^3 \cdot 94ft \cdot .09201\ ft^3/s$$

$$506.04\ \frac{lb \cdot ft}{s} \cdot \frac{1.356W}{\frac{lb\text{-}ft}{s}} = 686.20\ W$$

$$P = \frac{P_A}{\eta_{mech}} = \frac{586.20\ W}{.83} = 826.75\ W$$

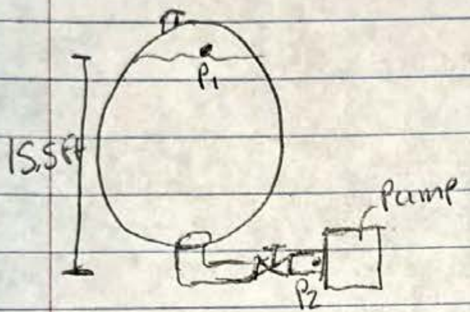
$$P_{act} = 826.75W \cdot 1.10 = 909.42\ W$$

Electrical Power require is 909.42 W

NPSH Eval: $NPSH_{available} > NPSH_{req'd}$

$$NPSH_{available} = \frac{\overset{0}{P_1} - P_v}{\gamma} + (Z_1 - Z_{suct}) - H_{L suct}$$

$$P_v = .13281 \frac{lb}{in^2} \cdot \frac{144\ lb/ft^2}{lb/in^2} = 19.12\ lb/ft^2$$



$$H_{L,suct} = H_{L,entry} + H_{L,valve} + H_{L,elbow}$$

$$H_{L,suct} = .3344 ft + 4.588 ft + .4048 ft = 5.3272 ft$$

$$NPSH_{avaible} = \frac{-19.12\ lb/ft^2}{58.5056\ lb/ft^3} + (15.5 ft - 0) - 5.3272 ft$$

$$NPSH_{available} = 9.84\ ft$$

$NPSH_r$ @ 3550 rpm = 4.5 ft

$$NPSH_{r,2}^{@1775\,RPM} = \left(\frac{1775.}{3550}\right)^2 4.5 ft = 1.125 ft$$

9.84 ft NPSH available is greater than 1.125 ft required, so NO cavitation will occur.

Materials + Equipment List:

Rail road tank } Both already provided
Storage tank

1.5 in nominal sched 40 steel pipe, 720 ft
1.5 in nominal 90° standard Elbow, 5 total
1.5 in nominal Global valve, 2 each
1.5 in nominal ball valve, 1 each
one Sulzer pump model 1.5x 3x 10 (60hz) with 9.69 in impellor