Small Engineering Project: Mel Cruz, Tai Booker, Chris Betton

Data and Variables

Tavg	42.5	F
viscosity (kinema	0.00002505	ft^2/sec
gamma	58.656	lb/ft^3
z1	16	ft
v1	0	
gravity	32.2	ft/sec^2
p2	0	
z2	36.42	ft
v2	0	
Lsuct	721	ft
Ldisch	402	ft
Relative Roughn	0.00015	ft
D/E(suct)	1148.666667	ft/ft
D/E(disch)	895.3333333	ft/ft
Re (suct)	27385.63594	ft/ft
Re (disch)	35134.36391	ft/ft
L suct	721	ft
L disch	402	ft
Volume Railcar	15000	gal
viscosity (dynami	0.00004845	lb-s/ft^2
hvp (water)	19.3	lb/ft^2

Step 1: Finding Diameter

Calculations

V-crit = 3 m/s	9.845	ft/sec
Q=15,000gal/6 hours	0.09283371269	ft^3/sec
d=sqrt(4Q/piV)	0.1095721186	ft
approx.	1.314865423	in

Therefore we decided that the discharge piping will be 1.5 in NPS schedule 40

The suction piping will be 2 in NPS schedule 40

Selected from Appendix F

Diameter (suction)	0.1723	ft
Diameter (discharge)	0.1343	ft
Velocity (suction)	3.981486828	ft/sec
Velocity (discharge)	6.553356783	ft/sec

Compute friction factor and fT

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

f suct	0.02622618111
f disch	0.02576299522

$$f_T = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)}\right)\right]^2}$$

fT suct	0.01898937676
fT disch	0.02017477352

Step 2: Compute pump head

$$h_A + \frac{p_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_{L\,12}$$

hA	104.3119198

hL=(3)h1+(4)h2+(6)h3+(2)h4+(2)h5+h6+(3)h7+h8+h9+h10

h1= entrance losses to tanks

h2 = gate valve losses (suction)

h3 = 90 degree elbows (suction)

h4 = check valve losses (suction)

h5 = exit losses from tanks (suction)

h6 = gate valve losses (discharge)

h7 = 90 degree elbow losses (discharge)

h8 = check valve losses (discharge)

h9 = major friction losses (suction)

h10 = major friction losses (discharge)

v^2/2g (suction)	0.246152754
v^2/2g (discharge)	0.666870887
k1*3	1.5
k2=8fT*4	0.6076600565
k3=30fT*6	3.418087818
k4=100fT*2	3.797875353
k5*2	2
k6=8fT	0.1613981881
k7=30fT*3	1.815729617
k8=100fT	2.017477352
k9=fL/D	109.7450759
k10=fL/D	77.11633714

$$hL = V^2/2g\,(suct) * (k1 + k2 + k3 + k4 + k5 + k9) + V^2/2g\,(disch) * (k6 + k7 + k8 + k10)$$

hL	83.89191975

Step 3: Select Pump

Required Data:

hA	104.3119198	
Q	0.09283371269	ft^3/sec
Q (gal/min)	41.66666239	

Based on the Sulzer Technical Data we selected the:

1 x 3 x 11.5 -1 OHH Centrifugal Pump

Impeller size: 290 mm

Step 4: Specify Electric Motor

$$P_A = \gamma Q h_A \qquad P_{\text{input}} = \frac{P_A}{\eta} = \frac{\gamma Q h_A}{\eta}$$

PA	568.0049245
efficiency	28%
Pinput (ft-lb/sec)	2028.589016
Pin (Hp)	3.651460229

Step 5: Evaluate NPSH

NPSH = hsp+hshf-hvp

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + h_{L\,12}$$

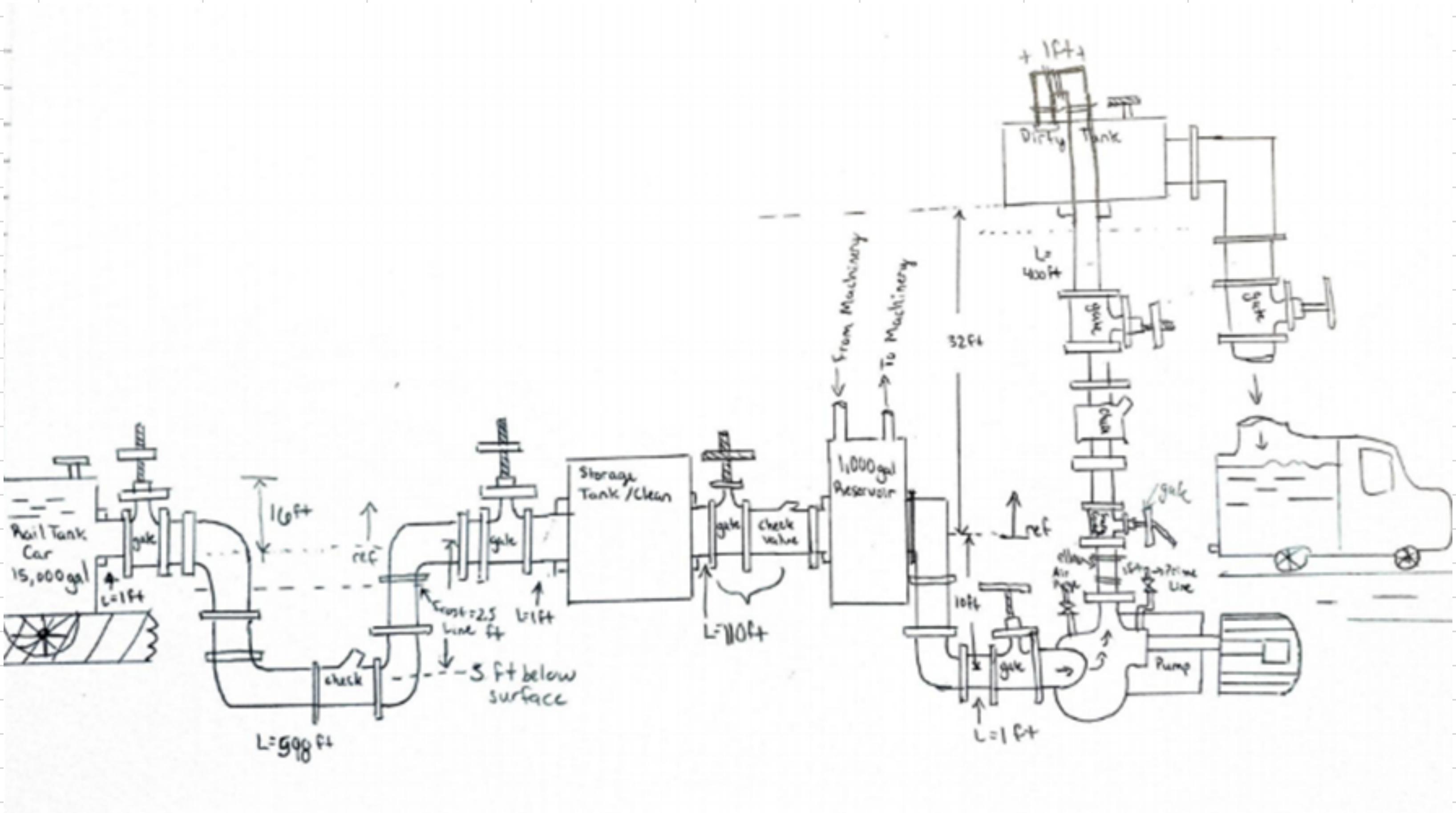
$$P2 = (V2^2/2g - z2 - hl1 - 2)^*\gamma$$

hL=h5+h3(2)+h2+fL/D*V^2/2g

hL=	0.8624207865	ft
k5	1	
k3*2	1.139362606	
k2	0.1519150141	
fL/D	1.21232237	
P2/gamma	-37.03626803	lb/ft^2
P2 (psi)	-0.2571963058	
NPSH=	-45.6802916	
hsp	-37.03626803	
hs	-10	
hf	0.8624207865	
hvp	0.4935556465	

Step 6: Cavitation Evaluation

NPSH req	4.5ft	from Sulzer
NPSH act	46 ft	
	Since NPSHact > 1.10 NPSHreq	
	No caviation	



Front View of System

Suction				
Quantity	**Nomenclature**			
6	90 degree elbows			
4	2 inch rising stem gate valves			
2	2 inch swing check valve			
3	entrance connections			
2	exit connections			
Discharge				
Quantity	**Nomenclature**			
1	1.5 inch gate valve			
3	90 degree elbows			
1	1.5 inch swing check valve			
1	exit connection			
Tanks				
Quantity	**Nomenclature**			
1	15,000 gal Rail Tank car			
1	Clean coolant storage tank			
1	1,000 gal Reservoir (input/output machining system)			
1	Dirty coolant tank			
Pipes				
Appendix F.1				
2 inch Schedule 40 Steel (suction)				
1 1/2 inch Schedule 40 Steel (discharge)				
Pump				
1 x 3 x 11.5-1 OHH Centrifugal Pump				
Impeller size:	290 mm			
Weight (kg)	237			

Kinetic vs Positive Displacement Pump
A Kinetic pump is being used because the facility is not moving a large flow of fluid very quickly.
We are given a timeframe of no less than 6 hours
Kinetic pumps work by tranferring kinetic energy from an impeller, to the fluid as it moves into and through the pump.
The Radial (centrifugal pump) is the type of kinetic pump being used due to its ease of serviceablity
and ease of disassembly without disturbing the suction and/or discharge piping.
A benefit from using the centrifugal pump is that flow rate can be manipulated whereas, positive displacement has a fixed flow rate.
Positive Displacement pumps are used for high-pressure applications requiring a relatively constant delivery in which this is not the case for the manufacturing facility design.
Positive displacement pumps tend to pulsate at its output and are suseptible to damage by solids.
There is also a need for a relief valve.
Positive displacement pumps work by ideally delivering a fixed quantity of fluid with each revolution of the pump rotor or drive shaft.

Team 7, Chris Betton, Tai Booker, Mel Cruz-Contee

→ Find Diameter

• $V_{crit} = 3\frac{m}{s} \approx 9.845\frac{ft}{sec}$, $Q = \frac{15{,}000\,gal}{6\,hours} \cdot \frac{1\,hour}{3600\,sec} \cdot \frac{1\,ft^3}{7.48052\,gal} = 0.09283\frac{ft^3}{sec}$

$A = \frac{Q}{V}$, $A = \frac{\pi}{4}d^2$

$\rightarrow d = \sqrt{\frac{4Q}{\pi V}} = \sqrt{\frac{4(0.09283)}{\pi \cdot 9.845}} = 0.1095\,ft \cdot \frac{12\,in}{1\,ft} = 1.3148\,in \approx 1.610\,in = 1\frac{1}{2}\,NPS$

$0.1342\,ft = D$

In preparation to use small pipe for pump discharge, we have decided to use:

Suction : 2" NPS, $D = 0.1723\,ft$, $A = 0.02333\,ft^2$, Disch: 1.5in =

Also in order to maintain >6 hour transfer time the pump rpm will be slowed.

→ Compute h_A

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} \quad \therefore \quad h_A = z_2 - z_1 + h_L$$

vent to atmosphere; 0 large tank; Atmosphere; 0 large tank

$$h_L = h_1(3) + h_2(4) + h_3(6) + h_4(2) + h_5(2) + h_6 + (3)h_7 + h_8 + h_9 + h_{10}$$

suct:
- h_1 = entrance losses = $k\left(\frac{v^2}{2g}\right)$, $K = 0.5$, $V = 0.68598\frac{ft}{sec}$
- h_2 = gate valve losses = $k\left(\frac{v^2}{2g}\right)$, $k = 8f_T$, "
- h_3 = 90° elbow losses = $k\left(\frac{v^2}{2g}\right)$, $k = 30f_T$.
- h_4 = check valve losses = $k\left(\frac{v^2}{2g}\right)$, $K = 100f_T$
- h_5 = exit losses = $h_1 = 1.0\left(\frac{v^2}{2g}\right)$

disch:
- h_6 = 1.5" gate valve losses (disch) = $k\frac{v^2}{2g}$, $k = 8ft$
- h_7 = 90° 1.5" losses (dischargee) = $k\frac{v^2}{2g}$, $k = 30ft$
- h_8 = check valve 1.5" (discharge) = $k\frac{v^2}{2g}$, 100ft

major: h_9 = suction pipe losses = $f\frac{L}{D}\cdot\frac{v^2}{2g}$ $\quad \frac{L}{D} = \frac{721\,ft}{0.1723\,ft}$

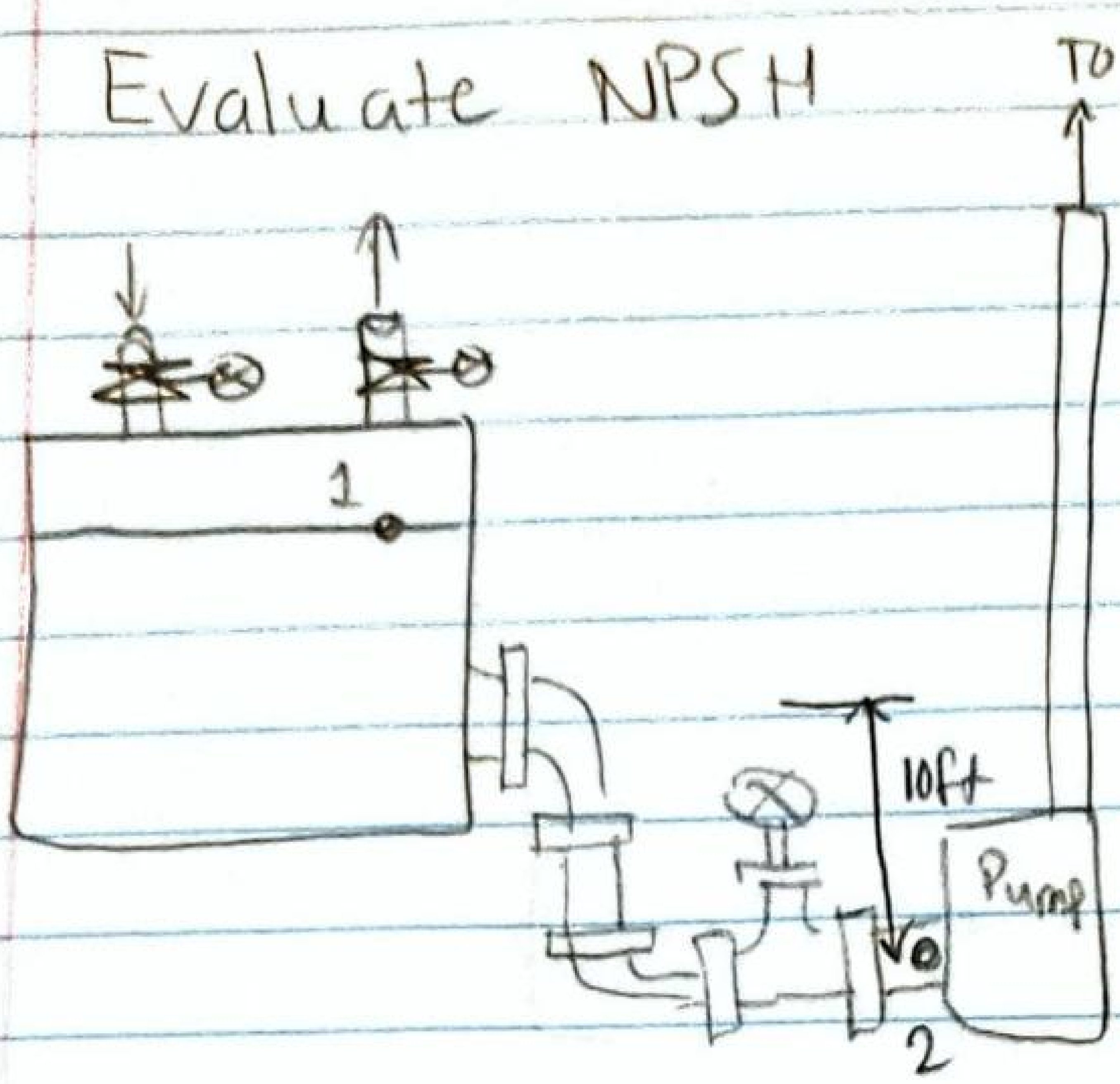
major: h_{10} = discharge pipe losses = $f\frac{L}{D}\cdot\frac{v^2}{2g}$ $\quad \frac{L}{D} = \frac{402\,ft}{0.125\,ft}$

→ Velocities

$V_{suct} = \frac{Q4}{\pi d^2} = 0.09283\frac{ft^3}{sec} \cdot \frac{4}{\pi} \cdot \frac{1}{0.1723\,ft^2} = 3.9815\frac{ft}{sec}$ $\quad \therefore \frac{v^2}{2g}suct = 0.24615$ f

$V_{disch} = \frac{4Q}{\pi d^2} = 0.09283\frac{ft^3}{sec} \cdot \frac{4}{\pi} \cdot \frac{1}{0.1342\,ft^2} = 6.556\frac{ft}{sec}$ $\quad \frac{v^2}{2g}disch = 0.667$

Evaluate NPSH



$P_1 = \emptyset$ because the tank is vented to atmosphere for maintenance (discharge pumping).

$$\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_3 + h_{L1-2}$$

0 0

$$h_{L1-2} = h_5 + h_3(2) + h_2 + f\frac{L}{D}\cdot\frac{V_2}{2g}$$

$$= 1.0\left(\frac{V_2}{2g}\right) + (2)(30\,\text{FT})\left(\frac{V_2}{2g}\right) + 8\,\text{FT}\left(\frac{V_2}{2g}\right) + f\frac{(11\,\text{Ft})}{.1723\,\text{Ft}}\cdot\left(\frac{V_2}{2g}\right)$$

$$= \frac{V_2}{2g}\left(1.0 + 2(30\,\text{FT}) + 8\,\text{FT} + f\frac{(11)}{.1723}\right)$$

$$= 0.86242\ \text{ft}$$

$$P_2 = \gamma\left(\frac{V_2^2}{2g} - z_2 - h_{L1-2}\right) = -2172.399\ \frac{\text{lb}}{\text{ft}^2}\cdot\frac{1\,\text{ft}^2}{144\,\text{in}} = h_{sp}$$

$$NPSH = h_{sp} + h_s - h_f - h_{vp} = -45.68\ \text{ft}$$

h_{sp} = static pressure $= \frac{P_2}{\gamma} = -37.0362$ ft

h_s = elevation difference $= -10$ ft

h_f = energy loss $= 0.86242$ ft

h_{vp} = vapor pressure $= 1.50\,(V_{p\,water}) = 1.50\left(19.3\ \frac{\text{lb}}{\text{ft}^2}\right) = \frac{28.95}{\gamma} = 0.4935\,\text{ft}$

For a pump to operate without cavitation, an excess of pressure is required. Since there is plenty of NPSH, the pump will not cavitate

$NPSH_{req} = -3.8$ (from Sulzer)

$\boxed{NPSH_{act} > 1.10\ NPSH_{req}}$ ✓

Power

$P = \gamma Q h_A \quad = 568.0 \frac{lb\text{-}ft}{sec}$

$\gamma = 56.656 \frac{lb}{ft^3}$

$Q = 0.0928 \frac{ft^3}{sec}$

$h_A = 104.31 \ ft$

$P_{in} = \frac{P}{\eta} = 2028.6 \frac{ft\text{-}lb}{sec} \cdot .0018 HP = \boxed{3.65 \ HP}$

$\eta = 0.28$

Radial flow (Centrifugal) Kinetic pump.

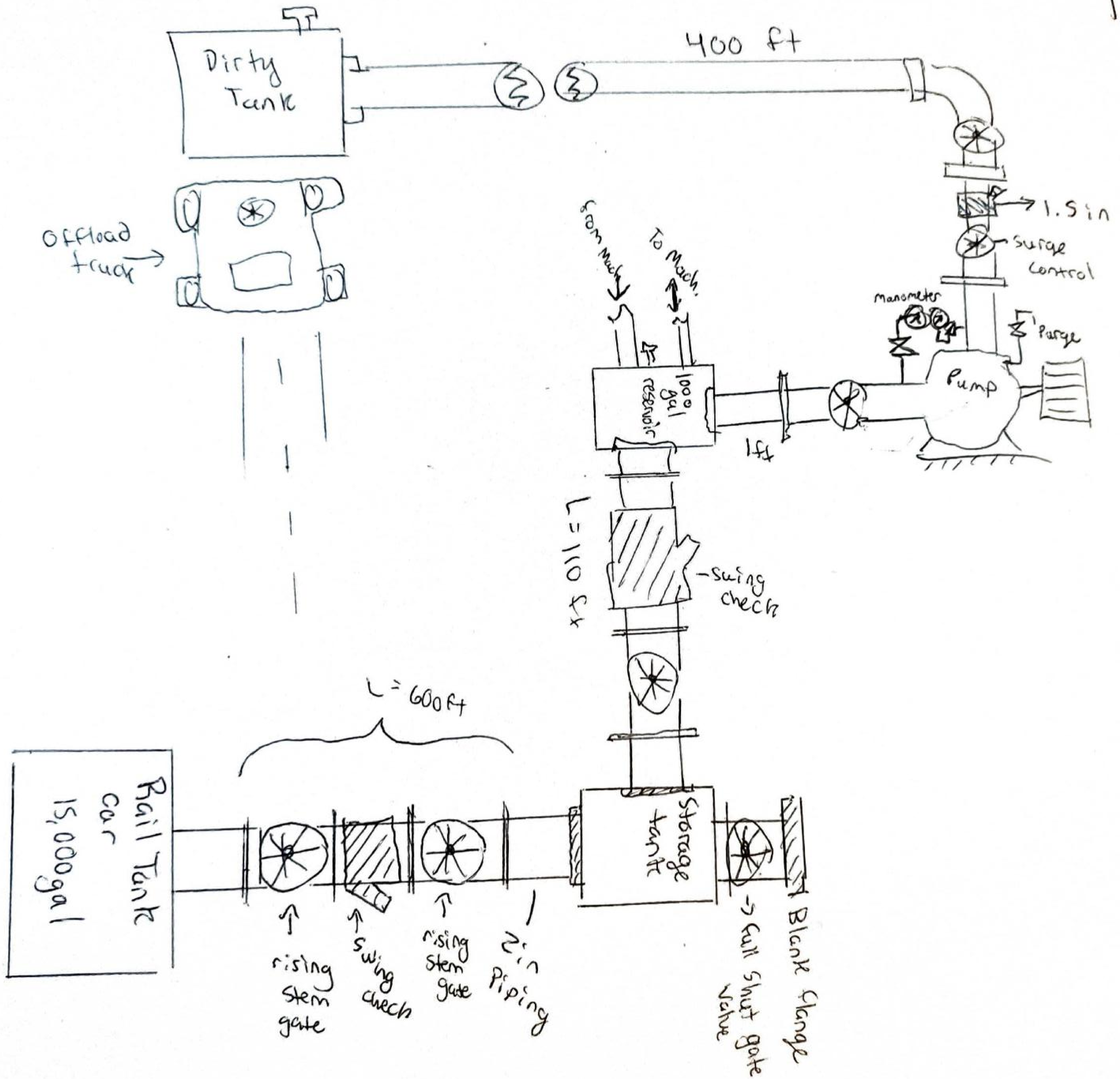
Kinetic pumps are less expensive than positive displacement pumps. Kinetic pumps are also smaller, making them easier to implement in systems where the pump is located underground or in hard to access areas.

Dealing with fluid systems with small Q and low viscosity is better with kinetic pumps. Kinetic pumps allow you to work with a range of flow rates.

When getting water from underground, multiple impellers on a centrifugal pump aid in this effort. Furthermore, radial flow is used when moving fluid to an elevated tank. A small speed (N_s) is needed for radial pumps. We consider <4000 N_s to be a slow speed.

$$N_s = \frac{N\sqrt{Q}}{h^{3/4}} = \frac{3520 \cdot \sqrt{47}}{37^{3/4}} = 1520 \checkmark$$

Top View



Dirty Tank
400 ft
1.5 in
Surge control
Manometer
Purge
Pump
Offload truck
From Mach.
To Mach.
1000 gal reservoir
1 ft
L = 110 ft
swing check
L = 600 ft
Rail Tank car 15,000 gal
rising stem gate
swing check
rising stem gate
2 in Piping
Storage tank
Full Shut gate valve
Blank flange


Rail Tank Car
15,000 gal
L=1ft
gate
16ft
ref
check
L=998 ft
Frost Line = 2.5 ft
3 ft below surface
gate
L=1ft
Storage Tank/Clean
gate
check valve
L=110ft
1,000 gal Reservoir
From Machinery
To Machinery
32ft
10ft
ref
gate
L=1 ft
Pump
Dirty Tank
400 ft
L= 400ft total
gate
check
gate
elbow
Air Purge
1ft
Prime Line
gate

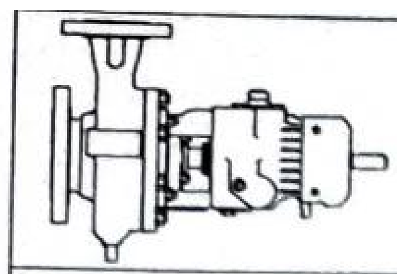
SULZER

TECHNICAL DATA - TYPE OHH

Mechanical Dimensions & Ratings – ISO Units

Series **2.00**	Page
TECHNICAL DATA	ISO
September - 02	**B21**

OHH TECHNICAL DATA	ISO	8x8x10-1	8x8x10-2	1x3x11.5-1	1.5x3x11.5-1	2x4x11.5-1	3x4x11.5-1	3x4x11.5-2
Max/Min Impeller Dia. (mm)		259/206	259/206	290/231	292/234	292/234	292/234	292/234
Volute Construction		Double	Double	Single	Single	Single	Single	Single
Max Operating Pressure (Barg)		51.0	51.0	51.0	51.0	51.0	51.0	51.0
Hydrostatic Test Pressure (Barg)	6	76.5	76.5	76.5	76.5	76.5	76.5	76.5
Max Operating Temperature (° C)		Refer to series B11-B16 for max pump operating temperatures for each material class						
Size of Casing Drain Construction NPT		0.75	0.75	0.75	0.75	0.75	0.75	0.75
Bearing Housing No.		4.1	4.1	4.1	4.1	4.1	4.1	4.1
Shaft Dia. between bearings (mm)		78	78	78	78	78	78	78
Span between bearings (mm)		212	212	212	212	212	212	212
Span CL Rad Brg to CL Imp (mm)		326	326	272	273	275	276	276
Shaft Dia. at Seal Chamber (mm)		58	58	58	58	58	58	58
Shaft Dia. at coupling (mm)		42	42	42	42	42	42	42
Typical API Baseplate #	7	4.0	4.0	3.5	3.5	3.5	3.5	3.5
Radial Bearing Number		6214	6214	6214	6214	6214	6214	6214
Thrust Bearing Number		7313	7313	7313	7313	7313	7313	7313
Pump Weight (kg)		362	362	233	237	245	249	249
Typical API Baseplate weight (kg)	7	541	541	500	500	500	500	500
Minimum Case Thickness (mm)		Refer to series B40-B41						
Max. Dia. Spherical Solids (mm)	3	12	12	3	6	10	13	13
Wear Ring Diameter - Eye (mm)		200	215	115	115	130	140	155
Wear Ring Diameter - Hub (mm)		165	165	115	115	130	140	155
Clearance Below 260°C - Eye (mm)	1	0.50	0.50	0.40	0.40	0.43	0.43	0.45
Clearance Below 260°C - Hub (mm)	1	0.45	0.45	0.40	0.40	0.43	0.43	0.45
Mass Moment of Inertia (kgm2) WR2	5	0.15	0.15	0.10	0.10	0.11	0.10	0.10
Shaft Stiffness Factor L3/D4	4	3.06	3.06	1.78	1.80	1.84	1.86	1.86
Critical Speed (Dry) (cpm)		5753	5753	11697	11163	10376	10605	10605
Temperature Limits (°C)		Refer to series B42 for recommended pump and bearing features required for elevated temperatures						

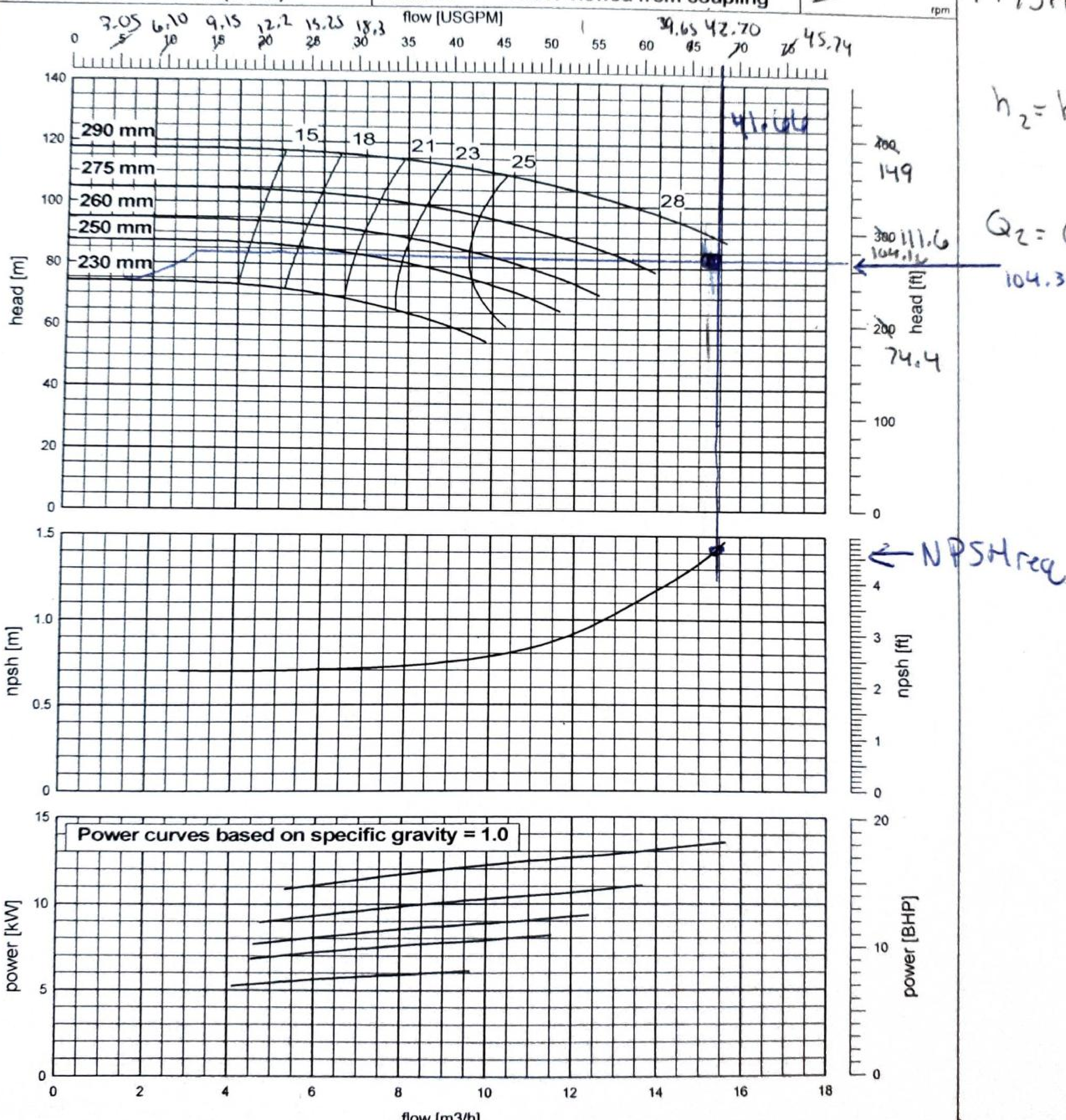


1 x 3 x 11.5 -1 OHH

SULZER
Series 2.00 / 50Hz E035

Curve No	OHH 35-1-2-02	**NSS**	159 (8210)	Speed ~~2910~~ rpm
Efficiency Basis	API Std. clearances	**nq**	6 (310)	
Max Solid	3 mm (.12 in)	**Rotation**	CCW viewed from coupling	

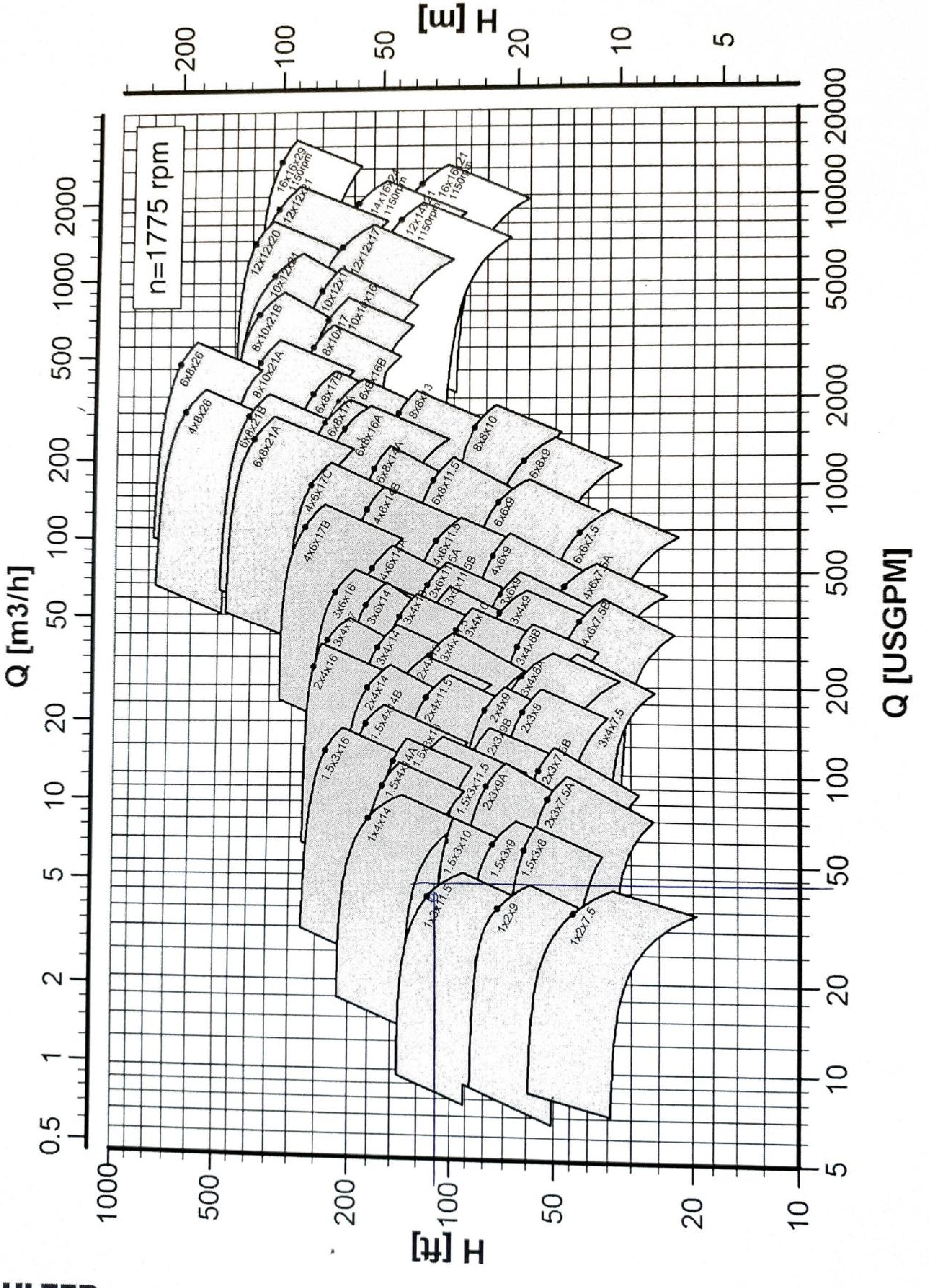
1775rpm



$$h_2 = h_1\left(\frac{N_2}{N_1}\right)^2 \therefore 400\left(\frac{1775}{2910}\right)^2 = 149$$

$$Q_2 = Q_1\left(\frac{N_2}{N_1}\right) \therefore 5\left(\frac{1775}{2910}\right) = 3.05$$

Rated Conditions



∴ Use 1x3x11.5 Pump