PUMP STATION DESIGN

FLUIDS POWER AND ADVANCED FLUID MECHANICS

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Introduction

The aim of this project is to design a pump station for a machining unit to provide required coolant. The design includes deciding the position of the tanks, selecting pumps and the usage of appropriate fittings. Figure 1 shows the layout of the plant. Fresh coolant are carried by the trains and delivers to the unit and the dirty coolant after its use are carried away via road.

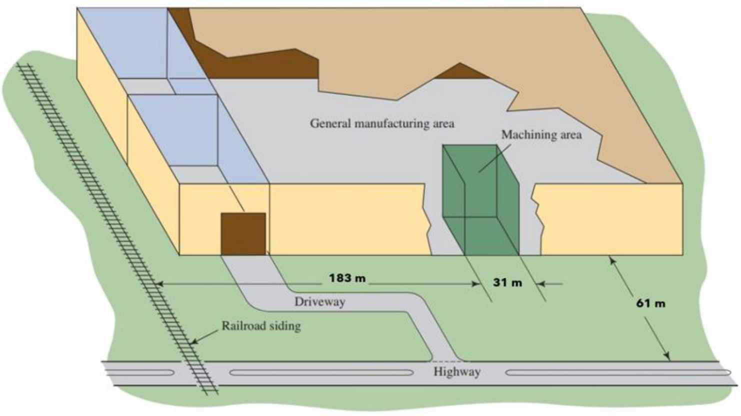

Figure 1 plot plan for the factory building

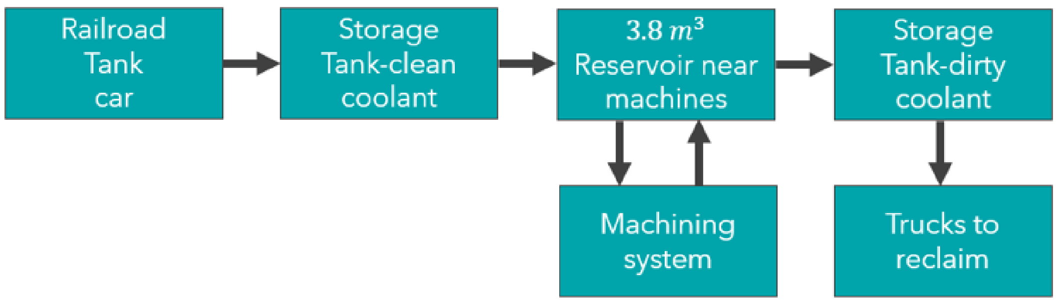

Figure 2 process flow diagram

Figure 2 shows the process flow diagram of the pumping unit, where the coolant comes through a railroad tank car to the machining area and this coolant is then transferred to a clean storage tank. From the storage tank the coolant needs to be transferred to a reservoir with a capacity of 3.8 m3.From the 3.8m3 reservoir tank the coolant has to go to machines and then recirculate back to the same reservoir. In every week the 3.8 reservoir is emptied and the dirty coolant in the reservoir is fed to a dirty storage tank and dirty coolant is carried out by trucks through roads in every month.

Assumptions

Before starting the calculations, we have to do some assumptions,

- viscosity and vapour pressure of the coolant are 1.5 times that of water at any given temperature
- The clean storage tank and the reservoir tank is place above the roof top as close as the railway path.
- The dirty coolant tank is paced on the ground level and the dirty coolant from the reservoir reaches the dirty coolant tank through gravity
- Pumping unit to the machining area from the reservoir tank for circulation is not considered
- The hight of the truck which carry away the dirty coolants is assumed to 4 meters.

Pumping unit 1 (railroad car to the clean coolant tank)

Clean storage tank dimensions = 10 X 6 X 1 m^3

Placed at the front left corner of the building (roof top)

Filling time = 75 minutes

Volume flow rate = 0.0134 m^3 /s

Elevation difference = 11 m

Suction line

Diameter of suction pipe = 4 inch = 0.1023 m

Length of suction pipe = 20 m

Material of the pipe = scheduled 40 steel

Fitting used = fully opened gate valve

Discharge line

Diameter of suction pipe = 3 inch = 0.0779m

Length of suction pipe = 28 m

Material of the pipe = scheduled 40 steel

Fitting used = 3/4 opened gate valve , one long radius elbow and 2 standard elbows

Calculations for Pump 1 (Railroad car to the clean storage tank)

MG7024				System curves SI	
System Data: SI metric Units					
Volume flow rate Q(m^3/s)		0.0134		Elevation at point 1 =	0
Pressure at point 1(K.Pa)		101.325		Elevation at point 1 =	11
Pressure at point 2 (K.Pa)		101.325			
Velocity at point 1 (m/s)		0		Velocity head at point 1	0
Velocity at point 2(m/s)		0		Velocity head at point 2	0
Fluid Properties				Vapour Pressure	11.064
Specific Weight (kN/m3)		9.22E+03		kinematic viscosity(m^2/s)	9.84E-07
Pipe 1:				Pipe 2:	
Diameter D (m)		0.1023		Diameter(m)	0.0779
Wall Roughness (m)		0.0000015		Wall Roughness(m)	0.0000015
Length L (m)		20		Length L(m)	28
Area A (m^2)		0.008215253		Area(m^2)	0.004763702
E/D		1.46628E-05		E/D	1.92555E-05
L/D		195.5034213		L/D	359.4351733
Flow Velocity (m/s)		1.631112343		Flow Velocity (m/s)	2.812938429
Velocity Head(m)		0.135602828		Velocity Head (m)	0.403293711
Reynolds Number		169576.0089		Reynolds Number	222690.959
Friction factor		0.0178		Friction Factor	0.0168
Head Loss(m)		0.471892538		Head Loss	2.435293474
Energy Losses -pipe 1	K	Quantity	Total K		
Gate valve	0.128	1	0.128	Energy loss hl1	0.017357162
Entrance	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Total			0.128	Total (m)	0.017357162
Energy Losses -pipe 2	K	Quantity	Total K		
Gate Valve (3/4 open)	0.595	1	0.595	Energy Loss hl1	0.239959758
Standard Elbow	0.51	2	1.02	Energy Loss	0.411359585
Long radius elbow	0.34	1	0.34	Energy Loss	0.137119862
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy Loss	0
Total			1.955	Total (m)	0.788439205
Total energy loss(m)					0.805796367
Total head on pump Ha (m)					14.71298238
NPSHA (m)					9.298960334

Table 1 Calculations for Pump 1

Pumping unit 2 (clean coolant tank to the reservoir)

reservoir tank dimensions = 2 X 2 X 1 m^3

location- roof top, above the machining area, placed on the left side of the machining area(on the front), 146 m apart from the clean coolant tank.

Filling time = 20 minutes

Volume flow rate = 2.73 X 10^-3 m^3 /s
Elevation difference = 1 m

Suction line

Diameter of suction pipe = 3 inch = 0.0549 m

Length of suction pipe = 46 m

Material of the pipe = scheduled 40 steel

Fitting used = one Foot Valve (hinged disc type), one Elbow standard, one Check valve (swing type)

Discharge line

Diameter of suction pipe = 1.5 inch = 0.0368 m

Length of suction pipe = 100 m

Material of the pipe = scheduled 40 steel

Fitting used = 3/4 opened gate valve , 3 standard elbows and 3 check valves

Calculations for Pump 2 (clean coolant tank to the reservoir)

MG7024				System curves SI	
System Data: SI metric Units					
Volume flow rate Q (m3/s)	2.73E-03			Elevation at point 1(m)	0.3
Pressure at point 1(kPa)	101.325			Elevation at point 1 (m)	0.7
Pressure at point 2(kPa)	101.325				
Velocity at point 1(m/s)	0			Velocity head at point 1	0
Velocity at point 2(m/s)	0			Velocity head at point 2	0
Fluid Properties				Vapour Pressure	11.064
Specific Weight (kN/m3)	9.22E+03			kinematic viscosity (m^2/s)	9.84E-07
Pipe 1:				Pipe 2:	
Diameter D (m)	0.0779			Diameter (m)	0.04009
Wall Roughness(m)	0.0000015			Wall Roughness (m)	0.0000015
Length L(m)	46			Length L (m)	100
Area A(m^2)	0.004763702			Area (m^2)	0.001261658
E/D	1.92555E-05			E/D	3.74158E-05
L/D	590.5006418			L/D	2494.387628
Flow Velocity(m/s)	0.573083725			Flow Velocity (m/s)	2.16381874
Velocity Head(m)	0.016739294			Velocity Head (m)	0.238639732
Reynolds Number	45369.12821			Reynolds Number	88158.02165
Friction factor	0.016192			Friction Factor	0.015636
Head Loss Due to F(m)	0.160050861			Head Loss due to F(m)	9.30748528
Energy Losses -pipe 1	K	Quantity	Total K		
Foot Valve (hinged disc type)	1.35	1	1.35	Energy loss hl1	0.022598047
Elbow standard	0.54	1	0.54	Energy loss	0.009039219
Check valve (swing type)	1.8	1	1.8	Energy loss	0.03013073
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Total			3.69	Total (m)	0.061767996
Energy Losses -pipe 2	K	Quantity	Total K		
Gate Valve (3/4 open)	0.665	1	0.665	Energy Loss hl1	0.158695422
Elbow	0.57	3	1.71	Energy Loss	0.408073942
Check valve (swing type)	1.9	3	5.7	Energy Loss	1.360246472
Element	0	1	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy Loss	0
Total			8.075	Total	1.927015836
Total energy loss (m)					1.988783832
Total head on pump Ha (m)					11.85631997
NPSHA (m)					9.866391175

Table 2 Calculations for Pump 2

Pumping unit 3 (reservoir to the dirty coolant tank)

Dirty coolant tank dimensions = 5 X 3 X 2 m^3

Location – below the reservoir tank, on the ground, left side of the machining area

Filling time = 30 min

Volume flow rate = 0.01 m^3 /s
Elevation difference = 1 m

Suction line

Diameter of suction pipe = 4 inch = 0.1023 m

Length of suction pipe = 25 m

Material of the pipe = scheduled 40 steel

Fitting used = one fully opened gate valve, one Check valve (swing type)

Discharge line

Diameter of suction pipe = 3 inch = 0.0779 m

Length of suction pipe = 80 m

Material of the pipe = scheduled 40 steel

Fitting used = 3/4 opened gate valve , 2 standard elbows, one long radius elbow and 3 check valves

Calculations for Pump 3 (reservoir to the dirty coolant tank)

MG7024				System curves SI	
System Data: SI metric Units					
Volume flow rate Q (m3/s)		1.00E-02		Elevation at point 1 (m)	0.3
Pressure at point 1 (K.pa)		101.325		Elevation at point 1 (m)	2
Pressure at point 2 (K.pa)		101.325			
Velocity at point 1 (m/s)		0		Velocity head at point 1(m)	0
Velocity at point 2 (m/s)		0		Velocity head at point 2(m)	0
Fluid Properties				Vapour Pressure	11.064
Specific Weight (kN/m3)		9.22E+03		kinematic viscosity (m^2/s)	9.84E-07
Pipe 1:				Pipe 2:	
Diameter D (m)		0.1023		Diameter (m)	0.0779
Wall Roughness (m)		0.0000015		Wall Roughness (m)	0.0000015
Length L (m)		25		Length L (m)	80
Area A(m^2)		0.008215253		Area	0.004763702
E/D		1.46628E-05		E/D	1.92555E-05
L/D		244.3792766		L/D	1026.957638
Flow Velocity (m/s)		1.217248017		Flow Velocity (m/s)	2.099207783
Velocity Head (m)		0.075519507		Velocity Head (m)	0.224601086
Reynolds Number		126549.2603		Reynolds Number	166187.2828
Friction factor		0.017		Friction Factor	0.01619
Head Loss (m)		0.313741844		Head Loss (m)	3.734317422
Energy Losses -pipe 1	K	Quantity	Total K		
check valve (swing type)	1.6	1	1.6	Energy loss hl1	0.120831212
Gate Valve (Fully opened)	0.128	1	0.128	Energy loss	0.009666497
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy loss	0
Total			1.728	Total (m)	0.130497709
Energy Losses -pipe 2	K	Quantity	Total K		
Gate Valve (3/4 open)	0.595	1	0.595	Energy Loss hl1	0.133637646
long radius Elbow	0.34	1	0.34	Energy Loss	0.076364369
Check valve	1.7	3	5.1	Energy Loss	1.145465541
Standard elbow	0.51	2	1.02	Energy loss	0.229093108
Element	0	0	0	Energy loss	0
Element	0	0	0	Energy Loss	0
Total			7.055	Total (m)	1.584560665
Total energy loss(m)					1.715058374
Total head on pump Ha(m)					7.463117641
NPSHA(m)					9.64397048

Table 3 Calculations for Pump 3

Reservoir tank to the dirty coolant tank

The coolant from the reservoir reaches the dirty coolant tank through gravity. An 8-inch scheduled 40 steel pipes is used for this and a gate valve is placed between the pipe for regulating the flow. One elbow is paced at the inlet and one is on the exit and a wide opening is provided at the inlet. Pipe having large diameter is selected because dirty coolant may consist of large impurities. I t also enables high volume flow rate when moves by gravity.

Design layout of the pump station

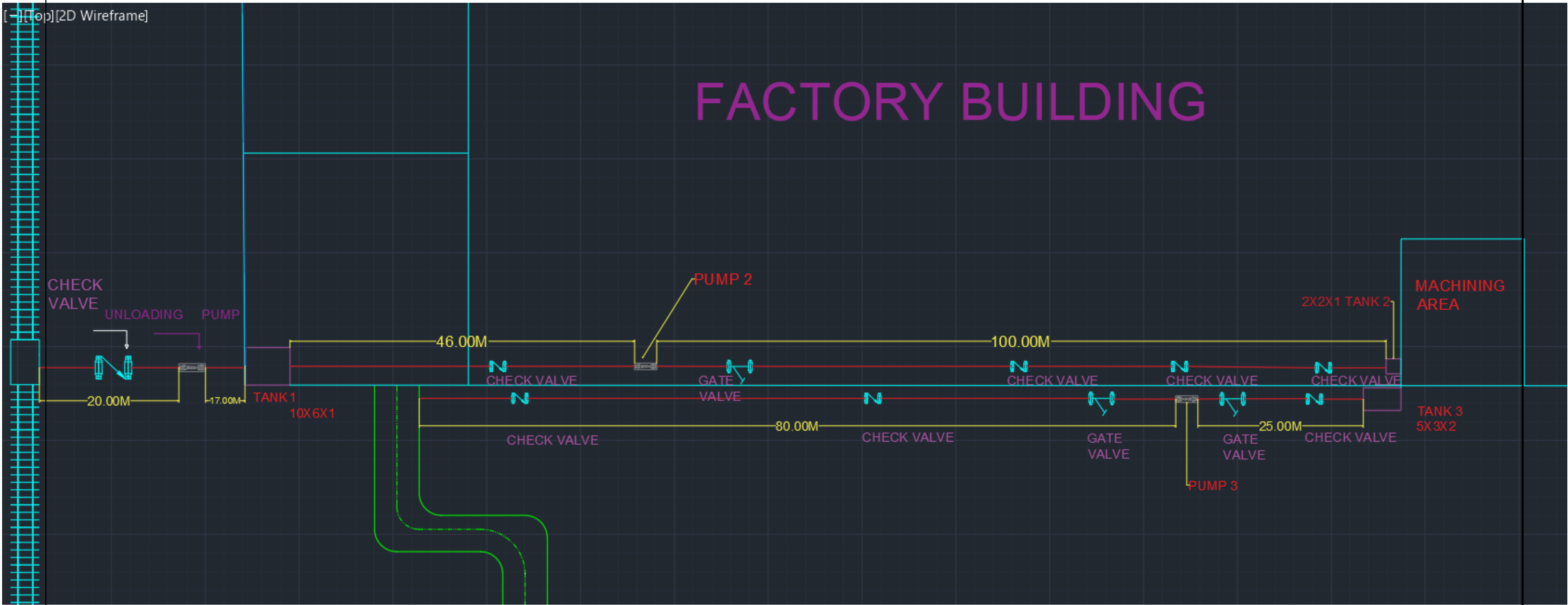

Figure 3 design layout (top view) (via AutoCAD)

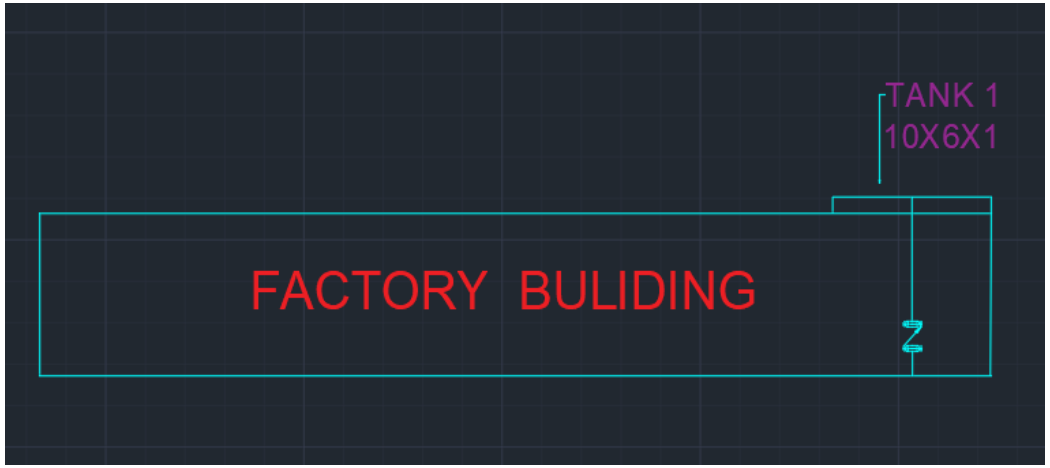

Figure 4 side view (left side of the building) (via AutoCAD)

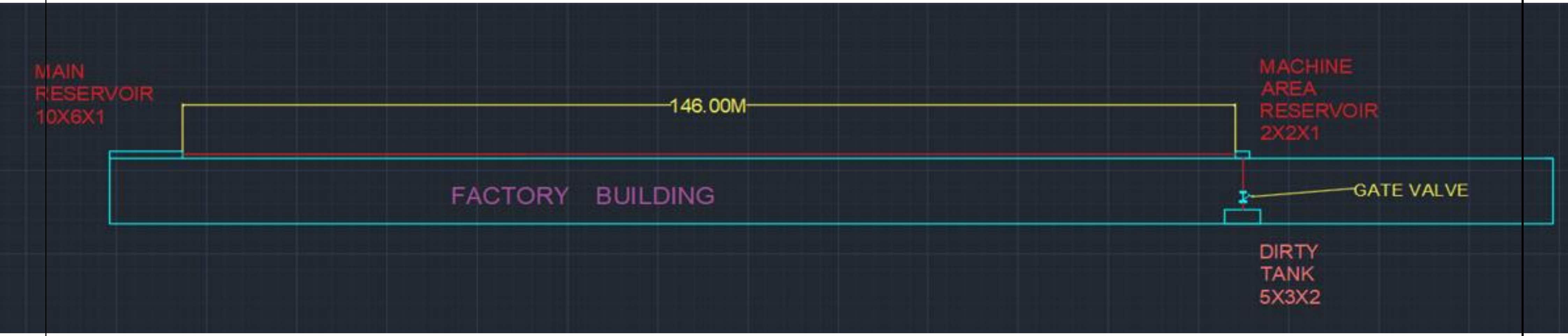

Figure 5 front view (via AutoCAD)

Results

Pump 1

Major losses (losses due to friction) = 1.994 m

Minor losses (losses due to fittings) = 0.552 m

Total head loss = 2.223 m

Total head = 15.218 m

NPSHA = 10.51 m

NPSHR = 1.2 m

Pump selected = **3x4 – 8” impellor centrifugal pump at 1750 rpm**

Efficiency = 63%

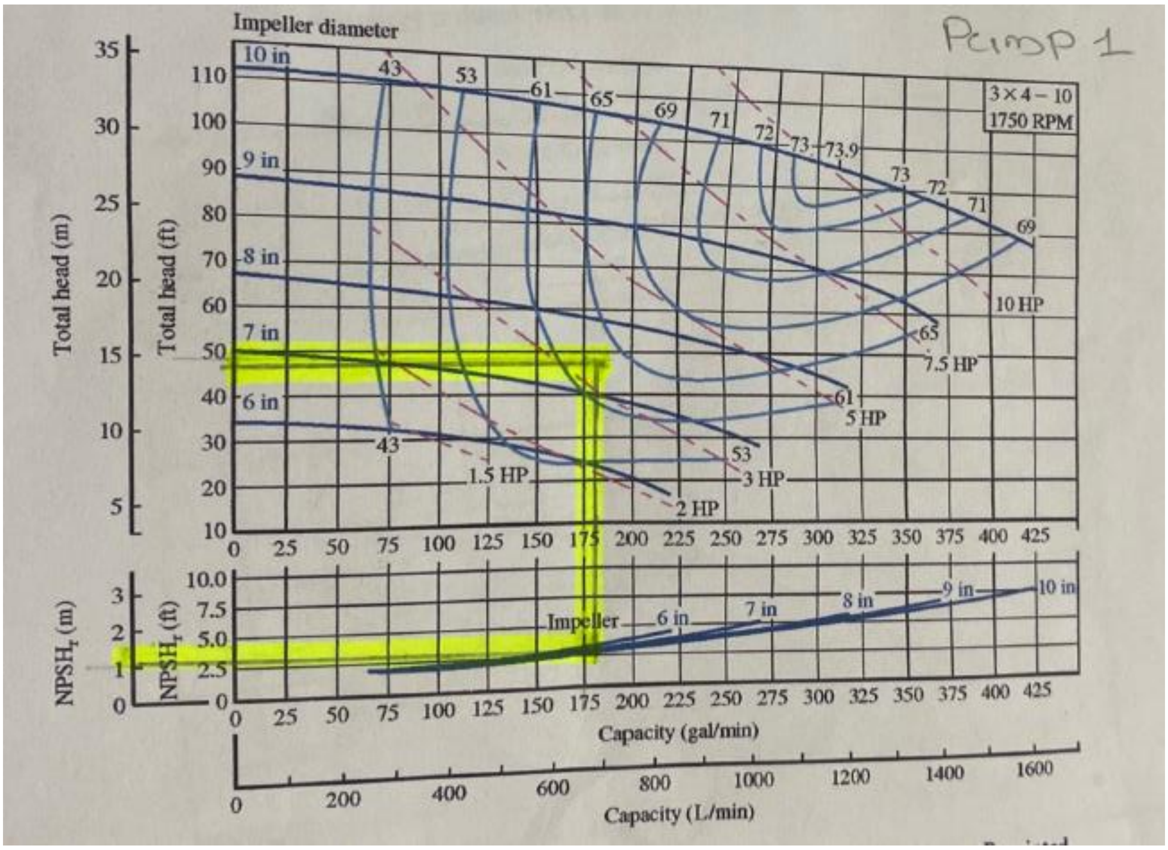

Figure 6 Pump selection graph of pump 1

Pump 2

Major losses (losses due to friction) = 5.085 m

Minor losses (losses due to fittings) = 1.068 m

Total head loss = 6.154 m

Total head = 11.941 m

NPSHA = 11.026 m

NPSHR = 0.4 m

Pump selected = **1½ X 3 – 6" impellor centrifugal pump at 1750 rpm**

Efficiency = 56%

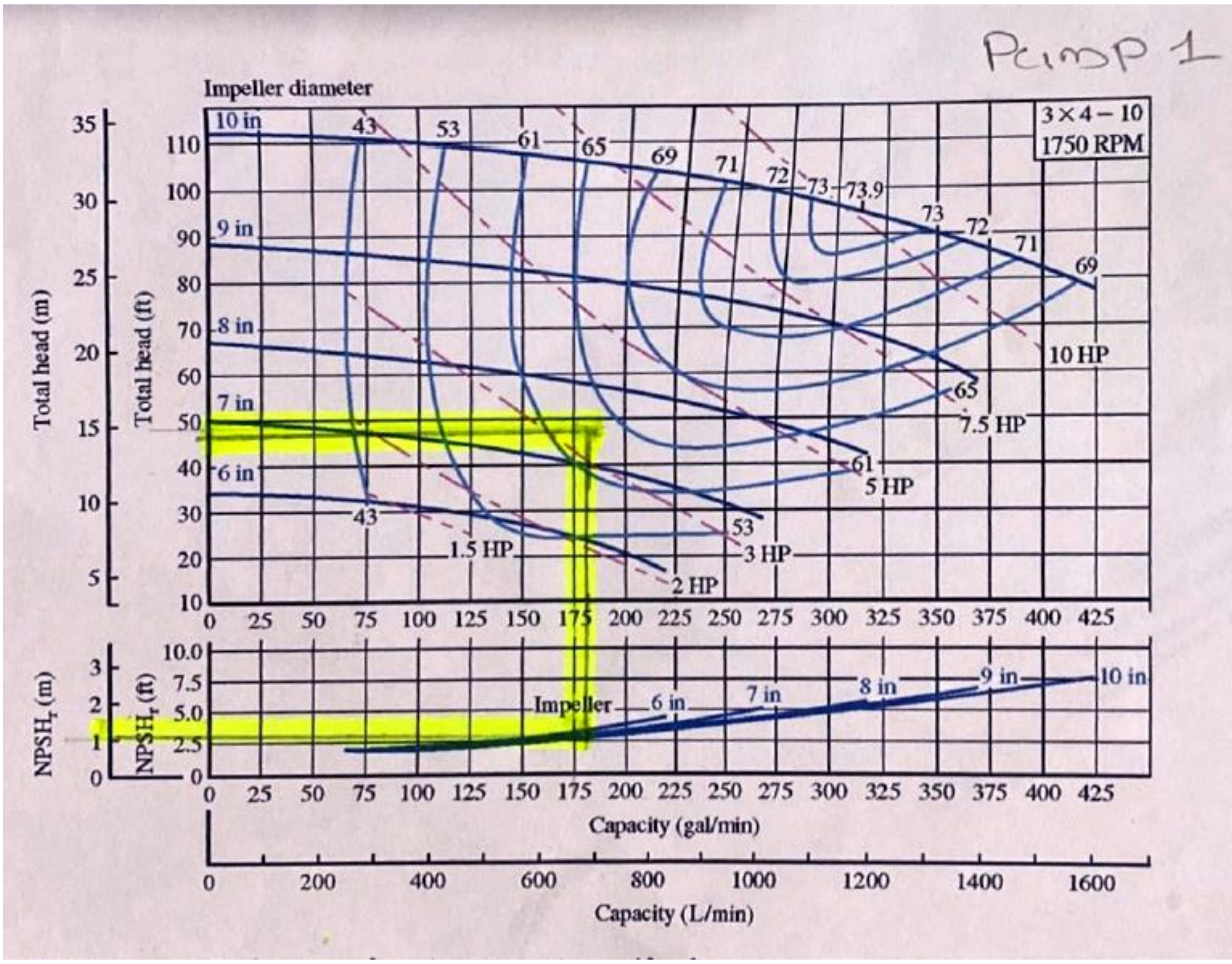

Figure 7 Pump selection graph of pump 2

Pump 3

Major losses (losses due to friction) =1.9496 m

Minor losses (losses due to fittings) =0.8618 m

Total head loss = 2.812 m

Total head = 7.462 m

NPSHA = 10.932 m

NPSHR = 1 m

Pump selected = **3x4 – 9" impellor centrifugal pump at 1750 rpm**

Efficiency = 57%

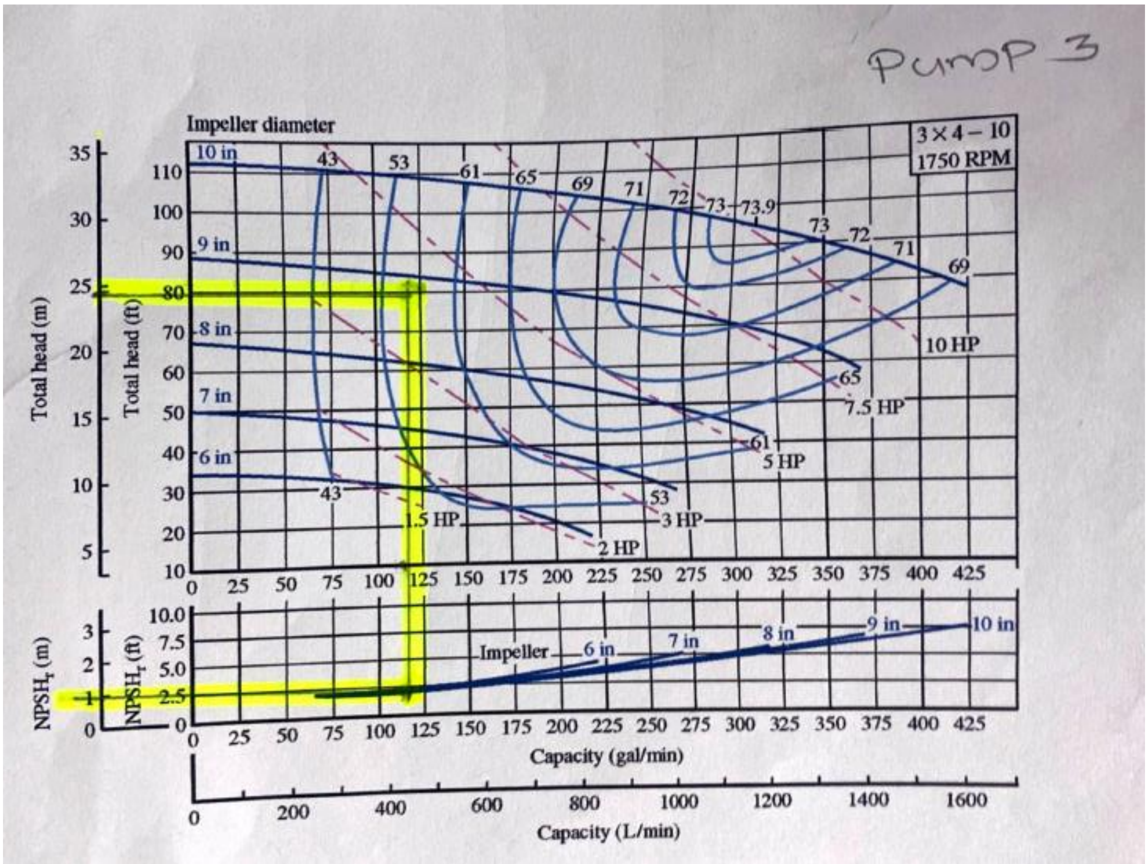

Figure 8 Pump selection graph of pump 3

Discussion

For a fully efficient pump system appropriate use of pumps and appropriate positioning of the tanks are prerequisite. In our design, the clean coolant tank having a capacity of 60 m^3 (10x6x1) is placed on the extreme front left of the roof top of the building. Since the pump have to pump a large volume, the tank is placed as close as the railways but if the tank is placed on the ground level the power and time required to pump coolant to the reservoir tank increases. Since machine area is working 24/7, we have to pump coolant from the clean coolant tank to the reservoir frequently. So, to reduce the head on the pump from clean coolant tank and the reservoir tank the clean coolant tank is placed above the roof top. The total head and the total energy loss of the pump 1 is found to be 15.218 m and 2.223 m respectively. An 8-inch impeller, 1750 rpm pump is selected for this and the tank fillies in 75 minutes.

The reservoir tank having a capacity of 4 m^3 (2x2x1) is placed as close as the left side of the machining area. Since the machining unit is working 24x7 it requires continuous supply of coolant the clean coolant tank and the reservoir tank are placed on the roof top on the same elevation, the potential head was low which will reduce the total head on pump (Ha) and so we can achieve high volume flow rate using low power pump and a 6 inch impeller, 1750 rpm pump is selected. Since the discharge line in the pump 3 is long 3 checks valves are provided between this line and helpful periodic maintenance. The reservoir tank is assumed to be fills in 20 minutes high volume flow rate because the machine area is running 24x7 and thereby it reduces the filling and emptying time of the reservoir tank. The total losses of the pump 3 was found to be 11.941 m and the total head on the pump is 6.154 m.

The dirty coolant tank of dimension 30 m^3 (15x3x2) is placed straight down to the reservoir tank at the ground level for easy movement of the coolant by gravity drain to the dirty coolant tank, this would enables the emptying of the reservoir tank very quickly. The dirty coolant is pumped from the dirty tank to the truck in the driveway which is 105 m apart. For the pump from the dirty coolant tank to the trucks, the total head is found to be 7.462 m and the total losses due to friction and fittings is 2.812 m. since the height of the truck is assumed to be 4 meters, pumps having 9-inch impeller and 1750 rpm is selected and it can empty the tank in 30 minutes. Checks valves are provided within the suction and delivery pipe for maintenance and a gate valve is used at the discharge line for regulating the valve.

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