Modifying an existing fire water suction lift pump in to flooded Suction pump for better reliability of Fire water system

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Abstract - *The main objective of this design project is to modify a fire water lift pump in to flooded suction pump for better reliability of fire water system i.e relocating the pump from top of RCC tank into bottom of tank and redesigned the Suction line of the pump. In this design project the various head loss accounted for pipe line and fitting are calculated for the selected pipe size,there by Net positive suction head available in pump suction is calculated for both Flooded suction pump and Suction lift pump.Further,the power required to drive the pump is calculated for both type of pump and there by the Suction piping's for the flooded suction pump are designed. Finally concluded that modifying Suction lift pump into flooded suction pump has the advantage of increase in available NPSH though there is no impact on power required to drive the pump. Further it is worth in modifying by fore seeing various advantages.*

1. INTRODUCTION

The suction lift pump only can able to pump the water when priming is done. To perform this pump is provided with priming system and suction foot valve .The foot valves are the most prone to fail in a suction lift pump and hence it requires frequent maintenance. Further the Suction lift pump may not achieve the priming in case of Failure of foot valve, Suction pipe blockage due to sediments present in the water, In case of any leakages in the suction pipe through the fitting and other problems are Cavitation and wear in pump impeller when the NPSH available in the pump is less than the vapour pressure of water. (In this case sufficient margin of NPSH is available)The associated consequences with the above problem is, if the fire pump fail to pump the water during fire emergency, it is extremely difficult to put Off the fire results loss of life and asset

1.1 Fire water system

It consists of three basic parts:

- A large store of water in tanks, either underground or above ground, called fire water storage tanks,
- A large network of pipes ending in either hydrants or sprinklers also called Distribution system,
- A specialized pumping system.

1.2 Firefighting pumps

The most common types of Fire water pumps are Horizontal shaft centrifugal pump and vertical shaft Turbine pump.

Based on the Suction conditions the fire water pumps are further classified in to.

1.2.1 Flooded suction pump

A flooded suction in a centrifugal pump is where liquid originates.

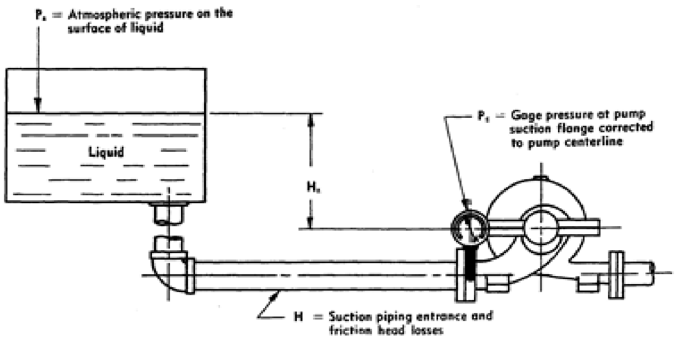

Fig 1.1 Open tank with liquid level above pump centerline.

The liquid is held at a level above the suction port of the pump, and allows liquid to arrive at the pump through gravity since the water level in the storage tank is above the center line of pump, there by a positive liquid head is available with the pump
For this application the NPSH:
Hsv = Ha + Hz –Hf –Hvp

1.2.2 Suction Lift Pump

In a suction lift Pump Suction is taken from an open to atmosphere tank where the liquid level is below the centerline of the pump suction. The weight of air in the earth's atmosphere is very frequently used to force liquid into the pump suction

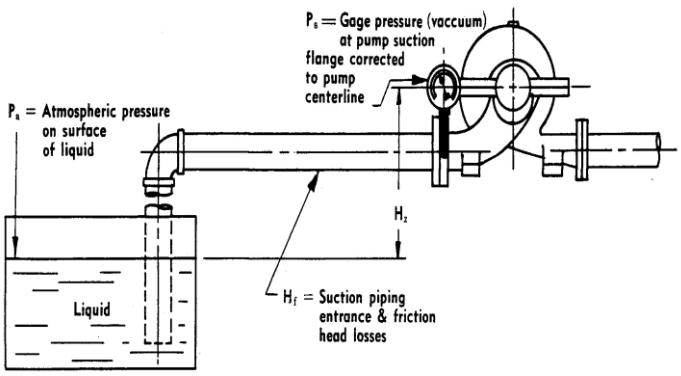

Fig.1.2 Open tank with liquid level below pump centerline

For this application the NPSH:

$$Hsv = Ha - Hz - Hf - Hvp$$

1.3. Net positive suction Head 2

A liquid will boil at any temperature if the pressure is reduced sufficiently and hence sufficient pressure shall be there on the fluid being fed to the pump so that the liquid does not boil in the suction system of the pump.

The net positive suction head (NPSH) is the total suction head in feet of liquid absolute determined at the suction nozzle and referred to datum, less the vapor pressure of the liquid in feet/meter absolute, in other words Net positive suction head is the absolute pressure, above the vapor pressure of the fluid pumped, available at the pump suction flange, to move and accelerate the fluid entering the impeller.

If the NPSH available in an installation is insufficient, the pump will cavitate and serious operational difficulties may develop

A centrifugal pump has a minimum required NPSH to prevent cavitation, which varies with capacity. In order for a pump to operate cavitation-free, the system NPSH available in an installation must exceed the required NPSH of the pump for that operating conditions.

The NPSH required of a pump can be supplied by the pump manufacturer. It is expressed in feet or meter of fluid pumped as is total head developed.

The system NPSH available in a proposed installation can be calculated by the formula:

$$Hsv = Ha + Hz - Hr - Hvp$$

Where:

Hsv = NPSH expressed in feet or meter of fluid
Ha = absolute pressure on the surface of the liquid where the pump takes suction expressed in feet or meter of fluid.
Hz =static elevation of the liquid above the centerline of the pump expressed in feet or meter. If the liquid level is blow the pump centerline, Hz is minus.
Hf =friction and entrance head losses in the suction piping expressed in feet or meter.
Hvp =absolute vapor pressure of fluid at the pumping temperature expressed in feet or meter of fluid.

1.4. Various Head loss in pipe and fittings

Energy losses occur in valves and fittings. Various types of fittings, such as bends, couplings, tees, elbows, filters, strainers, etc., are used in hydraulic systems

For many fluid power applications, the majority of the energy losses occur in valves and fittings in which there is a change in the cross-section of flow path and a change in the direction of the flow. Tests have shown that head losses in valves and fittings are proportional to the square of the velocity of the fluid:

$$Kv^2/2g$$

Where K is called the loss coefficient of valve or fittings.
K factors for commonly used valves and fitting are.

Table 1.1 K factors for commonly used valves and fittings

Valve or Fitting		K Factor
Globe valve	Wide open	10
	1/2 open	12.5
Gate valve	Wide open	0.20
	3/4 open	0.90
	1/2 open	4.5
	1/4 open	24
Return bend		2.2
Standard tee		1.8
Standard elbow		0.90
45° elbow		0.42
90° elbow		0.75
Ball check valve		4
Union socket		0.04

1.5 Head loss due to friction:

Darcy–Weisbach Equation

If a fluid flows through a length of pipe and pressure is measured at two stations along the pipe, one finds that the pressure decreases in the direction of flow. This pressure decrease is mainly due to the friction of the fluid against the pipe wall. Friction is the main cause of energy losses in fluid power systems

Frictional head loss can be find using Darcy- Weisbach equation as

$$\frac{4fLv^2}{2gD}$$

Where:

f is the Darcy friction factor,
L is the length of pipe (m),
D is the inside diameter of the pipe (m),
v is the average velocity (m/s) and g is the acceleration of gravity (m/s2).

To determine the values of the friction factor for use in Darcy's equation, we use the Moody diagram. If we know the relative roughness and Reynolds number, the friction factor can be determined easily.

The relative roughness of pipe is defined as the ratio of inside surface roughness ϵ to the diameter D

Relative roughness = ϵ/D

Table 1.2 Typical values of absolute roughness for various types of pipe

Type of Pipe	ε (mm)
Glass or plastic	Smooth
Drawn tube	0.0015
Wrought iron	0.046
Commercial steel	0.046
Asphalted cast iron	0.12
Galvanized iron	0.15
Cast iron	0.26
Riveted steel	1.8

2.Methodelogy:

Identify the new location to install the pump below the pump bottom line

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Finding the Piping route

⇩

Preparing PID/Piping Isometric diagram

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Calculating Total head loss

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Calculating net positive suction head available in the pump system

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Calculating Power required to drive the pump

⇩

Comparing all the above parameter against the existing suction lift pump

⇩

Conclusion

3. DRAWING PREPARATION

To perform the above modification i.e. to install the below the tank level, Identified the new location at grade level, Piping routings are identified, layout and PID/Isometric drawings are prepared.

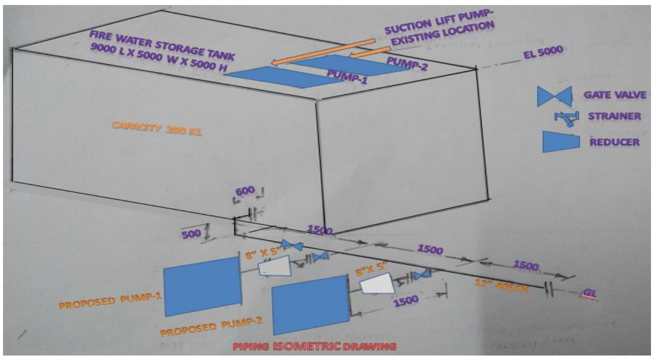

Fig.1.3 Piping Isometric diagram

4.Design Calculation

4.1 Design of header pipe for gravity filling

Size of selected header pipe is 12"NB

Inside Diameter of 12" NB pipe is D=305mm

Pump suction pipe size 8" NB (Recommended by pump manufacturer based on the pump suction nozzle size i.e. 5")

Inside Diameter of 8" NB pipe is d=203mm

Discharge of one fire water pump Q = 171 m^3/hr. = 171/3600 = 0.0475 m^3/s

Discharge when two pumps are in Operation during peak demand = 0.095 m^3/s

Velocity of water coming out from the tank due head pressure when tank level is 4.0 m

$V1= (2gH)^{0.5} =(2x\ 9.81x4)^{0.5} = 8.85$ m/s

Discharge of water @ 4.0 m Head for the pipe size of 12" (Id is 305 mm)

$=8.85 \text{ X } \pi/4 \text{ x } 0.305^2 = 0.646\ m^3/s = 2327\ m^3$/hr.

Velocity of water coming out from the tank due head pressure when tank level is 0.1 m

$V1= (2gH)^{0.5} =(2x\ 9.81x0.1)^{0.5} = 1.4$ m/s

Discharge of water @ 0.1 m Head for the pipe size of 12"(Id is 305 mm)

$Q = VxA = 1.4 \text{ X } \pi/4 \text{ x } 0.305^2 = 0.10\ m^3/s = 368\ m^3$/hr.

From the above calculation 12" header pipe is sufficient enough for gravity fill from the tank for all the water head to meet out the requirement of operating two pumps at a time (i.e. 171 m^3/hr. x 2)

Loss of head in different sections of pipe and fittings

Kinematic viscosity of water @ 20 Dec C, (v) $=1 \times 10^{-6}\ m^2/s$ (CST)

Velocity of water in 12" header (V) $= \dfrac{Q\ (m^3/s)}{A\ (m^2)}$

$$= \frac{0.095}{\pi/4 \times 0.305^2}$$

$$= 1.3 \text{ m/s}$$

Renaults number (Re) = *VD/v*

$$= \frac{1.3 \times 0.305}{1 \times 10^{-6}} \qquad Re = 396500$$

From the above it is under stood that the flow in the header pipe is turbulent

Co-Efficient of friction (f) $= \dfrac{\text{Relative Roughness of pipe}}{Re^{1/4}}$

Relative roughness of pipe=Pipe inside roughness(ϵ) / Inside diameter of pipe (D)

= 0.046 / 305 = 1.5×10^{-4}

= $1.5 \times 10^{-4}/396500^{¼}$ Co-Efficient of friction (f) = 6×10^{-6}

1. Loss of head at entrance of pipe header (m) =$0.5v^2 / 2g$

= $\frac{0.5 \times 1.3^2}{2\times 9.81}$ = 0.0258 m

2. Loss of head at Bend-1(m) = $Kv^2/2g$

K is the loss co efficient or K factor (0.9 for standard elbow)

= $\frac{0.9 \times 1.3^2}{2\times 9.81}$ = 0.077 m

3. Loss of head at Bend-2(m) = $\frac{0.9 \times 1.3^2}{2\times 9.81}$ = 0.077 m

4. Loss of head in Gate valve (m) = $Kv^2 / 2g$

K is the loss co efficient or K factor

(0.19 For full open gate valve)= $\frac{0.19 \times 1.3^2}{2\times 9.81}$ =0.016 m

5. Frictioal losses in pipe header for the length of 2 meters (hf) =$4fLv^2 / 2gD$

= $\frac{4\times6\times10^{-6} \times 2 \times 1.3^2}{2\times 9.81\times 0.305}$ = 1.32×10^{-5}m

Total losses in header pipe (1to5)

=0.0258+0.077+0.077+0.016+1.32×10^{-5} =0.19 m

Head loss in the pump-1 suction branch pipe from header:

Velocity of water in 8" branch suction pipe (V)= Q /A

= $\frac{0.0475}{\pi/4 \times 0.203^2}$ = 1.46 m/s

6. Loss of head at entrance of branch pipe (m) =$0.5v^2 / 2g$

= $\frac{0.5 \times 1.46^2}{2\times 9.81}$ = 0.054 m

7.Loss of head in pump suction Gate valve(m)=$Kv^2/2g$

K is the loss co efficient or K factor (0.19 for full open gate valve)

= $\frac{0.19 \times 1.46^2}{2\times 9.81}$ = 0.016 m

8.Loss of head in pump suction strainer (m)= 0.32 m (provided by strainer manufacturer)

9.Loss of head in 8"x 5"reducer fitting (m) = $0.5V_2^2 / 2g$

V_2 is the velocity in 5" cross section of pipe fitting= Q/A

= $\frac{0.0475}{\pi/4 \times 0.128^2}$ = 3.69 m/s

Loss of head in reducer fitting= $\frac{0.5 \times 3.69^2}{2\times 9.81}$ = 0.346 m

Loss of head in the branch pipe(6-9) =0.054+0.02+0.32+0.346 =0.74m

Total loss of head from Tank to pump suction nozzle=0.19+0.74=0.93m

Calculating Net positive suction head (NPSH) for Flooded suction pump

Available NPSH for the head of 4.0m(when the tank is full)
Hsv = Hp + Hz –Hf –Hvp

=10.19+4.0 – 0.93 -0.203

Available NPSH@ 4.0 m head of water in the tank=13.05m

Available NPSH@ 0.6 m head of water in the tank =10.19+0.6 – 0.93 -0.203

=9.65 m which is highly enough for the pump to run without cavitation

Power required to drive the pump = $\frac{\rho g \times Q \times Hm}{1000 \times \eta}$

Where,

Hm Is the Manometric head, and η is the pump efficiency

Relative roughness of pipe =Pipe inside roughness(ϵ) / Inside diameter of pipe(D)

=0.046 / 153(Disch pipe size is 6")=3×10^{-4}

Velocity of water in 6" discharge pipe header (V) =Q/A

= $\frac{0.0475}{\pi/4\times0.1532}$ = 2.58 m/s

Renaults number (Re) = VD / v

Kinematic viscosity(V) of water @ 20 dec C = 1×10^{-6} m2/s(CST)

= $\frac{2.58 \times 0.153}{1 \times 10^{-6}}$

(Re) =395286, f = $3 \times 10^{-4} / 395286^{¼}$ = 1.19×10^{-5}

Head loss due to friction in Discharge pipe (Hfd) 2g

= $\frac{4 \times 1.19\times10^{-5} \times 93.5 \times 2.58^2}{2\times 9.81\times 0.153}$ = 9.9×10^{-3}m

Hm is the manometric head= Hs+ Hd + Hfs+Hfd + $V^2d/2g$

= (-4.0 + 93.5 +0.93 +9.9 $\times10^{-3}$) + $2.58^2/2\times9.81$

= 90.43+ 0.33 = 90.76 m

$$\text{Power required to drive the pump} = \frac{\rho \times g \times Q \times Hm}{1000 \times \eta}$$

$$= \frac{1000 \times 9.81 \times 0.0475 \times 90.76}{1000 \times 0.68} = 62.1 \text{ KW}$$

Power required to drive the suction lift pump :

$$\text{Loss of head due to friction} = \frac{4fLv^2}{2gD}$$

$$= \frac{4 \times 1.19\text{x}10^{-5} \times 88 \times 2.58^2}{2 \times 9.81 \times 0.153} = 9.35\text{x}10^{-3}\text{m}$$

$$\text{Hm is the manometric head} = Hs + Hd + Hfs + Hfd + \frac{Vd^2}{2g}$$

$$= (1.5 + 88 + 0.86 + 9.35\text{x}10^{-3}) + \frac{2.58^2}{2 \times 9.81}$$

$= 90.36 + 0.33 = 90.69$ m

$$\text{Power required to drive the pump} = \frac{\rho \times g \times Q \times Hm}{1000 \times \eta}$$

$$= \frac{1000 \times 9.81 \times 0.0475 \times 90.69}{1000 \times 0.68} = 62.1 \text{ KW}$$

From the above calculation the power required to drive both the type of pumps are equal.

5. CONCLUSIONS

From the above Calculation modifying the existing Fire water lift pump into flooded suction will not have any impact over power required to drive the pump at the same time the available NPSH will increases. Considering the disadvantages of Suction lift pumps i.e.

The suction lift pump only can able to pump the water when priming is done. To perform this pump is provided with priming system and suction foot valve.

The usual problem associated with foot valve is it requires frequent maintenance.

Further the Suction lift pump may not achieve the priming in case of

- Failure of foot valve

- Suction pipe blockage due to sediments present in the water

- In case of any leakages in the suction pipe through the fitting

- The other problems are Cavitation and wear in pump impeller when the NPSH available in the pump is less than the vapor pressure of water. (In this case sufficient margin of NPSH is available)

- The associated consequences with the above problem is, if the fire pump fail to pump the water during fire emergency it is extremely difficult to put off the fire results loss of life and asset

- Other relevant issues are they require frequent preventive and breakdown maintenance

Further considering the criticality of fire water system to have a reliable Operation it is highly recommended to go for a flooded suction Fire water pump system in which the above problems are eliminated.

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