การออกแบบปั๊มสูบน้ำ

โดย

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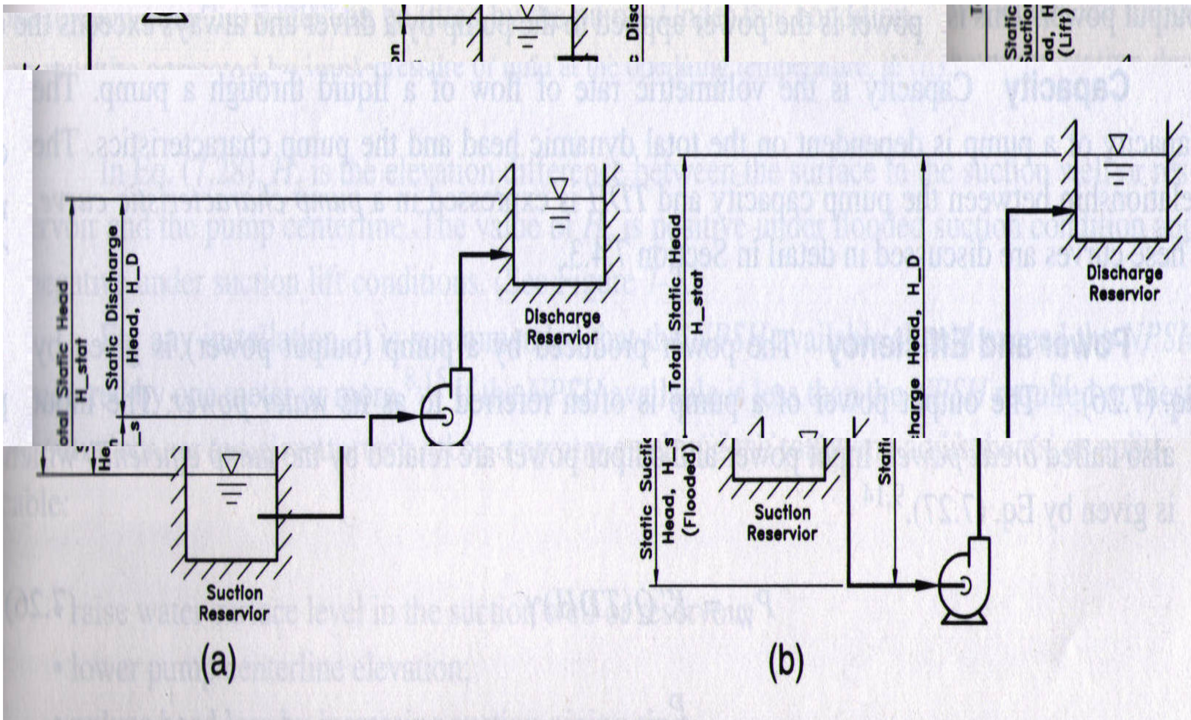
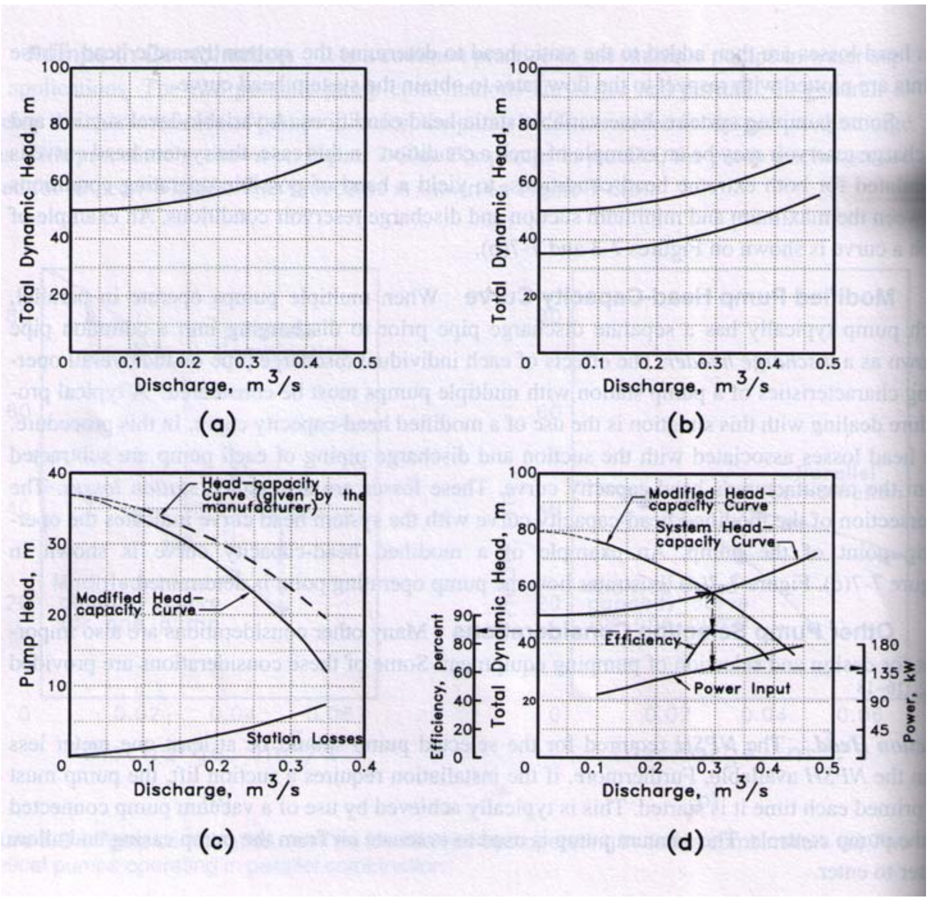


Figure 7-3 Definition sketches for determination of pump total static heads. (a) Lift suction head. (b) Flooded suction head.


Total Dynamic Head, m
Discharge, m^3/s
(a)
(b)
Pump Head, m
Head-capacity Curve (given by the manufacturer)
Modified Head-capacity Curve
Station Losses
(c)
Modified Head-capacity Curve
System Head-capacity Curve
Efficiency
Power Input
Efficiency, percent
Power, kW
(d)

Pumping Design

1.Flow rate	=	15	m^3/hr	
2. Static Suction Lift	=	2	m.	(pipe length)
3. Static Discharge Head	=	10	m.	(pipe length)
4. Suction Pipe Diameter	=	2	in	
	=	0.0508	m.	
5. Discharge Pipe Diameter	=	2	in	
	=	0.0508	m.	

$$\text{Equation} \quad Q = Av$$

$$A = \frac{\pi D^2}{4}$$

$$\therefore \quad v = \frac{Qx4}{\pi D^2}$$

$\therefore$ v = 7400.72 m/hr = 2.055755 m/sec

1. Calculate headloss in Suction Pipe

1.1 Minor losses due entrance

$$\text{Equation} \quad h_m = K\frac{v^2}{2g}$$

Entrance	K
Pipe Project into tank	0.83
End of pipe flushed with tank	0.5
Slightly rounded	0.23
Bell mouthed	0.04
Use	0.5

where

h_m = headloss inlet pipe (m)

v = water velocity in suction pipe (m/s)

g = Acceleration due to gravity 9.81 m/s^2

$\therefore$ h_m = 0.1077 m.

1.2 Minor Head losses in Pressure Conduits

$$h = k\frac{v^2}{2g}xnumber$$

Table 1 Minor Head losses in Pressure Conduits

Item	K factor	Number	Total Minor head loss
1. Gate Valve			
- Full open	0.19	1	0.040926
- One-fourth closed	1.15		0
- One - half closed	5.6		0
- Three - forths closed	24		0
- Typical value	1		0
2. Butterfly Valve			
- Full open	0.3		0
- 20^{o}	1.4		0
- Angle closed 40^{o}	10		0
- 60^{o}	94		0
- Typical value	1.2		0
3. Check valve			
- K = 1.5 - 2.5	1.5		0
4. Plug Valve	1		0
5. Elbow (45 -61 cm diameter)			
- 22.5^{o} (K = 0.1 - 0.2)	0.1		0
- 45^{o} (K = 0.2 - 0.3)	0.2		0
- 90^{o} (K = 0.25 - 0.6)	0.25		0
6. Tee			
- Run to run (K = 0.25 - 0.6)	0.25		0
- Branch to run(K= 0.6 - 1.8)	0.6		0
- Run to branch(K=0.6 - 1.8)	0.6		0

Table 1 Minor Head losses in Pressure Conduits (contrinues)

Item	K factor	Number	Total Minor head loss
7. Reduer (with angle of divergence 10^{o} - 20^{o}) K = 0.15 - 0.2	0.15		0
8. Increaser (with angle of divergence 10^{o} - 20^{o}) K = 0.05 - 0.3	0.05		0
		Total	0.040926

1.3 Friction losses in the pipe are typically calculated from Dracy-Weisbach

$$Equation \quad h_f = f \frac{L}{D} \frac{v^2}{2g}$$

where

h_f = total friction head loss in suction or discharge pipes,(m)

L = length of pipe,(m) (suction or discharge pipes)

D = diameter of the pipe,(m)

v = velocity in the pipe,(m/s)

f = coefficient of friction (Dracy - Weisbach) page 636(integrated design of water treatment facilities)

g = acceleration due to gravity, 9.81 m/s^2

Table 2 Approximate Minor Head Losses in Fittings and Valves (page 98, water and wastewater technology)

Fitting and Valve	Equivalent Length (Diameters of pipe)	Loss Coefficient k
1. Tee (run)	20	0.6
2. Tee (branch)	60	1.8
3.90° bend-		
Short radius	32	0.9
Medium radius	27	0.75
Long radius	20	0.6
4. 45° bend	15	0.42
5. Gate Valve (full open)	17	0.48
(open 1:4)	1000	
6. Swing check valve(open)	135	3.7
7. Butterfly valve (open)	40	1.2
8. Glove valve (open)	200	
9. Check valve(full open)	150	
10. Check valve with strainer	400	

Table 3 Approximate Minor Head Losses in Fittings and Valves in term Equavalent Pipe Length(L_e)

Fitting and Valve	Equivalent Length (Diameters of pipe)	Pieces	Diameter suction pipe (m.)	Equivalent Pipe(L_e) (m.)
1. Tee (run)	20		0.0508	0
2. Tee (branch)	60		0.0508	0
3.90^o bend-				0
Short radius	32		0.0508	0
Medium radius	27		0.0508	0
Long radius	20		0.0508	0
4. 90^o Standard	30	1	0.0508	1.524
4. 45^o bend	15		0.0508	0
5. Gate Valve (full open)	17		0.0508	0
(open 1:4)	1000		0.0508	0
6. Swing check valve(open)	135		0.0508	0
7. Butterfly valve (open)	40	1	0.0508	2.032
8. Glove valve (open)	200		0.0508	0
9. Check valve(full open)	150		0.0508	0
10. Check valve with strainer	400		0.0508	0
			Total (L_e)	3.556

∴ Equivalent length in Suction pipe (L_{suc}) = suction pipe length + L_e

= 2 + 3.556

L_{suc} = 5.556

Table 4 Relation between surface conditions and friction coefficien

Condition	Friction Coefficient			
	n (Manning's)	C (Hazen's)	f (Darcy's)	Notes
Very smooth surface	0.01	140	0.0002	PVC Pipe clean cement lined pipe
Fair condition surface	0.013	120	0.0012	Unlined pipe
Rough surface	0.016	100	0.0025	Rusted pipe

Pipe Material : PVC ∴ f = 0.0002

Theory

$$Equation \quad h_f = f \frac{L}{D} \frac{v^2}{2g}$$

∴ h_f = 0.004712 m.

∴ Total Head Loss in Suction Pipe : h_m + Mior head losses in Pressure Conduits + h_f

Total Head Loss in Suction Pipe : 0.153337

Pumping Design

1.Flow rate	=	15	m^3/hr	=	0.004167	m^3/s
2. Static Suction Lift	=	2	m.	(pipe length)		
3. Static Discharge Head	=	10	m.	(pipe length)		
4. Suction Pipe Diameter	=	2	in			
	=	0.0508	m.			
5. Discharge Pipe Diameter	=	2	in			
	=	0.0508	m.			

$$Equation \quad Q = Av$$

$$A = \frac{\pi D^2}{4}$$

$$\therefore \quad v = \frac{Qx4}{\pi D^2}$$

$\therefore \quad v = 7400.72$ m/hr $= 2.055755$ m/sec

2. Calculate headloss in Discharge Pipe

2.1 Minor losses due exit

Exit	K
conduit to still water	1

$$Equation \quad h_m = K\frac{v^2}{2g}$$

where

h_m = headloss inlet pipe (m)

v = water velocity in discharge pipe (m/s)

g = Acceleration due to gravity 9.81 m/s^2

$\therefore \quad h_m = 0.215399$ m.

2.2 Minor Head losses in Pressure Conduits $h = k\frac{v^2}{2g}xnumber$

Table 5 Minor Head losses in Pressure Conduits

Item	K factor	Number	Total Minor head loss
1. Gate Valve			
- Full open	0.19	1	0.040926
- One-fourth closed	1.15		0
- One - half closed	5.6		0
- Three - forths closed	24		0
- Typical value	1		0
2. Butterfly Valve			
- Full open	0.3		0
- 20^o	1.4		0
- Angle closed 40^o	10		0
- 60^o	94		0
- Typical value	1.2		0
3. Check valve			
- K = 1.5 - 2.5	1.5		0
4. Plug Valve	1		0
5. Elbow (45 -61 cm diameter)			
- 22.5^o (K = 0.1 - 0.2)	0.1		0
- 45^o (K = 0.2 - 0.3)	0.2		0
- 90^o (K = 0.25 - 0.6)	0.25		0
6. Tee			
- Run to run (K = 0.25 - 0.6)	0.25		0
- Branch to run(K= 0.6 - 1.8)	0.6		0
- Run to branch(K=0.6 - 1.8)	0.6		0

Table 5 Minor Head losses in Pressure Conduits (contrinues)

Item	K factor	Number	Total Minor head loss
7. Reduer (with angle of divergence 10^{o} - 20^{o}) K = 0.15 - 0.2	0.15		0
8. Increaser (with angle of divergence 10^{o} - 20^{o}) K = 0.05 - 0.3	0.05		0
		Total	0.040926

2.3 Friction losses in the pipe are typically calculated from Dracy-Weisbach

$$Equation \quad h_f = f \frac{L}{D} \frac{v^2}{2g}$$

where

h_f = total friction head loss in suction or discharge pipes,(m)

L = length of pipe,(m) (suction or discharge pipes)

D = diameter of the pipe,(m)

v = velocity in the pipe,(m/s)

f = coefficient of friction (Dracy - Weisbach) page 636(integrated design of water treatment facilities)

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Table 6 Approximate Minor Head Losses in Fittings and Valves (page 98, water and wastewater technology)

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Short radius	32	0.9
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Long radius	20	0.6
4. 45° bend	15	0.42
5. Gate Valve (full open)	17	0.48
(open 1:4)	1000	
6. Swing check valve(open)	135	3.7
7. Butterfly valve (open)	40	1.2
8. Glove valve (open)	200	
9. Check valve(full open)	150	
10. Check valve with strainer	400	

Table 7 Approximate Minor Head Losses in Fittings and Valves in term Equavalent Pipe Length(L_e)

Fitting and Valve	Equivalent Length (Diameters of pipe)	Pieces	Diameter suction pipe (m.)	Equivalent Pipe(L_e) (m.)
1. Tee (run)	20		0.0508	0
2. Tee (branch)	60		0.0508	0
3.90° bend-				0
Short radius	32		0.0508	0
Medium radius	27		0.0508	0
Long radius	20		0.0508	0
4. 90° Standard	30	1	0.0508	1.524
4. 45° bend	15		0.0508	0
5. Gate Valve (full open)	17		0.0508	0
(open 1:4)	1000		0.0508	0
6. Swing check valve(open)	135		0.0508	0
7. Butterfly valve (open)	40	1	0.0508	2.032
8. Glove valve (open)	200		0.0508	0
9. Check valve(full open)	150		0.0508	0
10. Check valve with strainer	400		0.0508	0
			Total (L_e)	3.556

∴ Equivalent length in Suction pipe (L_{suc}) = suction pipe length + L_e

= 2 + 3.556

L_{suc} = 5.556

Table 8 Relation between surface conditions and friction coefficien

Condition	Friction Coefficient			
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Rough surface	0.016	100	0.0025	Rusted pipe

Pipe Material : PVC ∴ f = 0.0002

Theory

$$\text{Equation} \quad h_f = f \frac{L}{D} \frac{v^2}{2g}$$

∴ h_f = 0.004712 m.

∴ Total Head Loss in Discharge Pipe = h_m + Mior head losses in Pressure Conduits + h_f

Total Head Loss in Discharge Pipe = 0.261037

3. Total Dynamic Head(TDH)

1. Head Loss in Suction Pipe = 0.153337

2. Head Loss in Discharge Pipe = 0.261037

3. Total Static Head = Static Suction Lift + Static Discharge Head

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$$Equation \quad Total\ Dynamic\ Head = Total\ Static\ Head + Headloss(pipe + media)$$

∴ Total Dynamic Head = 12.41437 m.

4. Power Requirement (Theory) or power output of the pump (water power)

$$Equation \quad P_w = Q(m^3/s)xTDH\ (m)x\gamma(KN/m^3) \quad KW$$

$$Equation \quad P_w = Q(m^3/s)xTDH\ (m)x9.81(KN/m^3)$$

$$Equation \quad P_w = \frac{Q(ft^3/s)xTDH(ft)x62.4lb/ft^3}{550} \quad HP$$

P_w = 0.507438 $KN.m/s$ $\quad Watt = N.m/s = kg.m/s^2.m/s$

∴ P_w = 0.507438 KW

5. Pump Power Requirement or power input to the pump (break power)

$$Equation \quad P_p = \frac{P_w}{\eta}$$

where

P_p = Pump Power Requirement,(KW)

Efficiency of pump and motor (60% - 70%) Choose η = 60%

(Usually 70 - 90%)

∴ P_p = 0.845729 KW

From 0.7457 KW = 1 HP

∴ 0.845729 KW = 1.134141 HP

$Equation:$ $$\boxed{\rho = \frac{\gamma(N/m^3)}{g(m/s^2)}}$$

$Equation:$ $$\boxed{F = m(kg)xa(m/s^2)}$$

$$\therefore \quad \boxed{F = ma \quad (kg.m/s^2 = N)}$$

$$\therefore \quad \boxed{\rho = \frac{\gamma(kg.m/s^2)/m^3}{g(m/s^2)} \quad (kg/m^3)}$$

$Equation:$

$$\therefore \quad \boxed{\gamma = \rho g \quad (N/m^3)}$$

where

$$\rho H_2O = 1000 \quad kg/m^3$$

$$g = 9.81 \quad m/s^2$$

$$\therefore \quad \boxed{\gamma = 1000(kg/m^3)x9.81(m/s^2)}$$

$$\therefore \quad \boxed{\gamma = 9.81 \quad K(kg.m/s^2)/m^3}$$

$$\therefore \quad \boxed{\gamma = 9.81 \quad KN/m^3}$$

Table 7-8 Typical Electrical Motor Efficiencies

Motor Power Rating, kW	Typical Efficiency, percent
1–5	70–80
5–7.5	80–85
7.5–20	85–88
20 and above	88–92

Source: Reference 26.