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Designing, Fabrication and Control of Three Phase Digitalized Reciprocating Pump Test Rig with Automatic Control Drive Unit

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Abstract

Reciprocating pump is a positive displacement plunger pump. It is often used where relatively small quantity of water is to be handled and delivery pressure is quite large. Reciprocating pump is widely used in automobile service stations, chemical industries, or as metering and dosing pumps. Reciprocating pumps find vast applications in modern machineries and often works either in series or parallel. The apparatus consists of a KISAN WAVES-KW50 series, double acting reciprocating pump mounted over the sump tank. The pump is driven by 3-Phase mono block motor. An energy meter, voltage meter, ampere meter, frequency meter and r.p.m meter has been fixed on the electrical panel for finding out the different parameters. Measuring tank is provided to measure discharge of the pump. The pressure and vacuum gauges are fixed to measure the delivery pressure and suction vacuum respectively. R.P.M of motor is controlled with automatic control drive unit. Hand shut off valve/gate valve is provided at different stages of pipeline to control the pressure of water. In this experimental work, an attempt has been made to design and fabricate an experimental set-up that comprises of a reciprocating pump which is arranged in such a manner that the experimental set-up is able to work either individually or in series and in parallel combinations. The designed and fabricated test rig has efficiently served the purpose of providing a clear idea about the effectiveness of experimental set-up in transmitting fluid to distant work stations. It has been found that by using reciprocating pump of KISANWAVES-50, the overall efficiency of the pump is 88% with power consumption of 0.09 Kw at 800r.p.m.

1. Introduction

Reciprocating plunger pumps are robust, contamination tolerant and capable of efficiently pumping many types of fluids at high delivery pressures. As a consequence, they are widely used in a diverse range of industrial applications, including mining (for powered roof supports), chemical plant, reverse osmosis systems and food processing systems. The most common pump construction consists of a small number of cylinders, usually mounted in-line, each with a reciprocating piston driven by a rotating crank and connecting rod mechanism. [1] During the suction stroke, flow is drawn from the inlet manifold into a cylinder through a self-acting non-return valve; various valve designs are employed although spring-load poppet or disc valves are most frequently adopted. Fluid delivery also takes place through a self-acting non-return valve. It is well known that the pipeline pressure pulsations produced by these pumps are a source of noise and vibration and may have a significant influence on the reliability of a given installation. Consequently, it is highly desirable to be able to predict pressure pulsations at the design stage of an installation so that appropriate steps may be taken to minimize their levels and their influence. [2]

Considerable research effort has been devoted to the study of pressure pulsation behaviour in delivery lines of fluid power systems employing typically gear, vane or axial piston pumps and to a lesser extent to the suction lines of these systems [3-4]. However, fluid power pumps typically employ a large number of pumping elements (nine cylinders are commonly used in axial piston machines, for example). As a consequence they create relatively low amplitude flow pulsations and, in most instances, low-amplitude pressure pulsations with relatively high frequency content are generated. This allows a linearized analysis to be adopted and predictions can be conveniently conducted in the frequency domain.

In contrast, plunger pumps generally have a small number of cylinders (three or five are common) and are usually operated at lower speeds. This leads to very large flow pulsations, relative to the mean flow. It is possible that the consequent high-amplitude pressure pulsations, particularly in resonant delivery line systems, may invalidate the use of linear theory. Hence predictions of behaviour need to be performed either in the time domain or by means of an iterative scheme [5].A frequency domain approach to the prediction of suction line pulsation behaviour is likely to be invalid if cavitation is occurring as the effects are highly non-linear.

Some useful progress has already been made by a number of workers on the mathematical modelling of the pumping dynamics of reciprocating plunger pumps. Johnston [6] for example, has developed a detailed model which accounts for both valve dynamics and cavitation in the pump cylinders. However, inlet line pressure is taken to be constant and the delivery line is represented by a lumped parameter model. Vetter and Schweinfurter [7] address the

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problems of delivery pipeline wave propagation effects, but adopt a fairly rudimentary pump model. Most of their predictions of pulsation behaviour are presented in terms of peak-to-peak pulsation levels, rather than frequency spectra or time-domain waveforms. Thus the accuracy of the model is difficult to establish. Singh and Madavan [5] have presented a more detailed model of pumping dynamics which is linked to a frequency-domain model of the delivery pipeline. An iterative process is used to account for the interactions between the pipeline and the pump. Predicted pressure pulsation behavior is compared with experimental data in terms of amplitude spectra. Phase spectra are not included in the paper, so, again, it is difficult to establish the accuracy of the model in predicting behavior. Vetter and Schweinfurter do not attempt to predict suction line pulsations and although Singh and Madavan claim that their model will predict suction line behavior, no results are presented.

2. Description and Working

The main components are:
1. Cylinder with suitable valves at inlet and delivery.
2. Plunger or piston with piston rings.
3. Connecting rod and crank mechanism.
4. Suction pipe with one way valve.
5. Delivery pipe.
6. Supporting frame.
7. Air vessels to reduce flow fluctuation and reduction of acceleration head and friction head. A diagrammatic sketch is shown in Fig: 1.

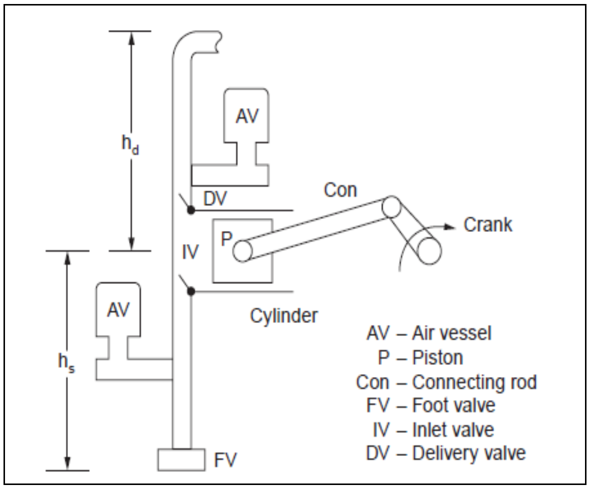

Fig: 1. Diagrammatic view of Single Acting Reciprocating Pump

The action is similar to that of reciprocating engines. As the crank moves outwards, the piston moves out creating suction in the cylinder. Due to the suction water/fluid is drawn into the cylinder through the inlet valve. The delivery valve will be closed during this outward stroke. During the return stroke as the fluid is incompressible pressure will developed immediately which opens the delivery valve and closes the inlet valve. During the return stroke fluid will be pushed out of the cylinder against the delivery side pressure. The functions of the air vessels will be discussed in a later section. The volume delivered per stroke will be the product of the piston area and the stroke length. In a single acting type of pump there will be only one delivery stroke per revolution. **[8]** Suction takes place during half revolution and delivery takes place during the other half. As the piston speed is not uniform (crank speed is uniform) the discharge will vary with the position of the crank. The discharge variation is shown in **Fig. 2.**In a single acting pump the flow will be fluctuating because of this operation.

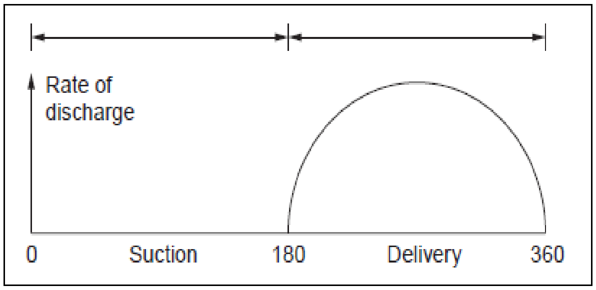

Fig: 2. Flow Variations during Crank Movement of Single Acting Pump

Fluctuation can be reduced to some extent by double acting pump or multicylinder pump. The diagramatic sketch of a double acting pump is shown in Fig: 3. In this case the piston cannot be connected directly with the connecting rod. A gland and packing and piston rod and cross-head and guide are additional components. There will be nearly double the discharge per revolution as compared to single acting pump. When one side of the piston is under suction the other side will be delivering the fluid under pressure. As can be noted, the construction is more complex. [9]

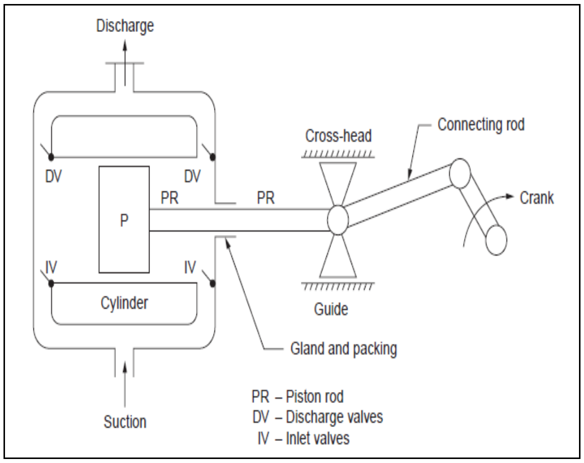

Fig: 3. Diagrammatic view of a Double Action Pump

3. Objective

The main objective of our project, as the name replicates **"Designing, Fabrication and Control of Three Phase Digitalized Reciprocating Pump Test Rig with Automatic Control Drive Unit"** is

A. To study in detail about fluid mechanics and machinery related articles.
B. To design and fabricate a **Digitalized Reciprocating Pump Test Rig.**
C. To design and fabricate **Electrical Panel**.
D. To control the speed of motor and compressor with **Automatic Control Drive unit**.
E. To make electrical connections and to feed **Current**

Transformer Coil (C.T) values in energy meter, ampere meter so as to get the output from the meter.

F. To feed numerical values in **Automatic Control Drive** unit for making it compactable with our test rig.

Based on the above given agendas we also have to calculate the following parameters.

1. Diameter of the cylinder (D)
2. Length of stroke (L)
3. Radius of crank (r)
4. Speed of crank (N)
5. Delivery height (hd)
6. Suction height (hs)
7. Cross section of cylinder (A)
8. Volume of water sucked in the suction stroke (Vs)
9. Discharge per second or theoretical discharge (Qtheo)
10. Weight of water delivered per second (W)
11. Power (P)
12. Co-efficient of discharge (Cd)
13. Slip (S)
14. % slip (S%)
15. Frictional losses (Fl)
16. Velocity of water in pipe (v)
17. Acceleration of water in pipe (aw)
18. Mass of water in pipe (Ww)
19. Force acting for acceleration of water in pipe. (Fa)
20. Intensity of pressure due to acceleration (Pa)
21. Pressure head due to acceleration in suction pipe (has)
22. Pressure head due to acceleration in delivery pipe (had)
23. Maximum pressure head due to acceleration (hamax)
24. Loss of head due to friction in suction pipe (hfs)
25. Loss of head due to friction in delivery pipe (hfs)
26. Maximum value of loss of head due to friction (hfmax)
27. Power expanded without air vessel (Pf1)
28. Power expanded with air vessel (Pf2)
29. % of power saved in (% sav)
30. Suction Head (Hs)
31. Delivery Head (Hd)
32. Total Head (Ht)
33. Output power of pump (Pw)
34. Input power to pump (Ip)
35. Overall efficiency of pump (Sp)

4. Materials and Methodology

4.1 MATERIALS: Material/Design Parameters of components used in Reciprocating Pump Test Rig

1. Reciprocating Pump and Motor

1. Model: KW-50 series **(Kisan waves make)**
2. Dimensions: 330 x 381 x 180 mm
3. Plunger diameter: 30 mm
4. Suction Volume:

a.	**(A) Spraying**	**(B) Irrigation**
b.	(i) R.P.M-1000	(i) R.P.M-800
c.	(ii) L/Min-57	(ii) L/Min-43

5. Pressure (kg/cm^2):

(A) Spraying
(i) High-4
(ii) Low-2
(B) **Irrigation**-10

6. **Motor:**
(i) Horse Power-3
(ii) R.P.M-2800
(iii) Phase-3

2. Digital Panel

For taking output data we have fixed some digital based meters, all of them are working on Three Phase electrical connections.

S. No	Part Name	Phase	Pieces
1	Energy meter	3-Phase	01 Piece
2	Voltage meter	3-Phase	01 Piece
3	Ampere meter	3-Phase	01 Piece
4	Frequency meter	3-Phase	01 Piece
5	Rotation per minute meter	1-Phase	01 Piece
6	Automatic control unit drive	3-Phase	01 Piece
7	Miniature circuit breaker-Triple pole triple throw type	3-Phase	01 Piece
8	Miniature circuit breaker-Single pole single throw type	1-Phase	06 Piece
9	Current transformer coils	1-Phase	03 Piece
10	Light emitting diode based indicators	1-Phase	01 Piece
11	Proximity Sensor	1-Phase	01 Piece

3. Measuring devices.

1. Pressure Gauges

For taking output data from the suction pipe and delivery pipe, we have fixed pressure measuring devices and they are

1. Vacuum Gauge 0-760 mm of Hg 01 Piece
2. Delivery pressure gauge-1 150 ps 01 Piece
3. Delivery pressure gauge-2 150 psi 01 Piece
4. Delivery pressure gauge-3 150 psi 01 Piece
5. Delivery pressure gauge-4 150 psi 01 Piece

2. Height Gauges (Borosil make)

For taking water level data from the suction tank and delivery tank, we have fixed height gauges upon Suction tank and upon delivery tank.

1. Suction tank Height gauge length = 458 mm
2. Delivery tank Height gauge length = 712 mm

3. Tank (Mild steel sheet)

1. Dimensions of Suction Tank
a. Length of suction tank = 1220 mm
b. Width of suction tank = 915 mm
c. Height of suction tank = 610 mm

2. Dimensions of Delivery Tank
a. Length of delivery tank = 610 mm
b. Width of delivery tank = 610 mm
c. Height of delivery tank = 915 mm

4. Piping (Galvanized iron pipes)
a. Length of suction pipe = 1219 mm
b. Diameter of suction pipe = 25.4 mm
c. Length of delivery pipe = 1753 mm (4No.)
d. Diameter of delivery pipe = 12.5 mm

5. Gate valve (Brass make)
a. Gate valve at delivery point-1= 12 mm Diameter
b. Gate valve at delivery point-2= 12 mm Diameter
c. Gate valve at delivery point-3= 12 mm Diameter
d. Gate valve at delivery point-4= 12 mm Diameter

e. Gate valve below the discharge tank = 50 mm Diameter
f. Gate valve at Suction point = 25 mm Diameter
g. Gate valve, below suction tank = 25 mm Diameter

6. Foot valve (Plastic make)

a. Diameter of foot valve = 25 mm

7. Final discharge pipe lines (Galvanized iron)

a. Discharge Pipe, below the discharge tank
(i) Length of discharge pipe = 406 mm
(ii) Diameter of discharge pipe = 50 mm

8. Length of scales behind the height gauge (Wooden scales)

a. Length of scale at Suction tank behind the height gauge = 395mm
b. Length of scale at Delivery tank behind the height gauge = 700 mm

4.2 Methodology

First of all, we all decided to fabricate a reciprocating pump test rig. Then part list was made and during that time we thought that to control the speed of the motor/pump we will not make use of old type of dynamometer, i.e. rope and brake type but we will make use of automatic control drive unit to control the speed of the pump/motor. After purchasing of all items, a rough drawing was made for given dimensions and then fabrication work had started for the same.

First off all we decided to make sump/reservoir tank, for that we took sheets of Mild steel of 14 gauge ,equals to 2 mm of size 2440 x 1220 mm. Then we cut it into different pieces having a size of 1220 x 610 mm (2 pieces), 915 x 610 mm (2 pieces), and 1220 x 915 mm (1 piece) so as to weld all the pieces all together and to give a specified dimension of 1220 x 915 x 610 mm. The capacity of the reservoir is 680 liter. Secondly we fabricated discharge tank of size 940 x 610 x 610 mm. For that 610 x 610 mm (1 piece) and 940 x 610 mm (4 pieces) were cut from mild steel sheet and were all welded altogether in right angle. The capacity of discharge tank is 349 liter. Grinding work was done to make the surface and edges smooth. M. seal was placed inside the tanks so as to make them water tight.

Below the suction tank a discharge valve of 25 mm is fixed to empty the reservoir after experimental work is completed.

Then a frame was made of size 2138 x 915 mm so as to place the reservoir tank upon it. To move the apparatus we used 6 wheels having dia. of 100 mm each. After that we placed the delivery tank upon the extended frame at a height of 915. Then motor and pump was made to align upon the frame.02 elbows were fixed on tanks having nipple diameter of 16 mm from where the water will enter through its lower portion and will left from its above portion inside the tanks through the glass pipes. In front of suction tank, a height gauge is fixed inside the nipples, which is made of glass having diameter of 16 mm and height 458 mm and for delivery tank, having height of 712 mm.

Suction pipe and delivery pipes were fixed upon the pump along with gate valves at different positions to get the output. The pump has a suction diameter of 50 mm and delivery diameter of 12 mm. After that we connected a suction pipe having length of 1219 mm to the suction end of the pump .Below the suction pipe we used a foot valve of dia. 50 mm. Now four delivery pipes of lengths 1753 mm and diameter of 12 mm are fitted upon the pump. Three delivery pipes are connected with each other for making series and parallel type of connections for creating flow conditions and between all the four pipes a TEE joint has been fixed so as to connect the pipes to the pressure gauges, after the TEE joint a gate valve of 12 mm is fitted to control the flow rate. In the end, final delivery pipe which is below the delivery tank having length of 406 mm and dia. 50 mm is also fitted so as to have recirculation of the water through the delivery tank to the suction tank. To remove the priming problem, a priming part is also used.

Now comes the work of electric panel. An electric panel was made with wooden board of size 2440 x 1220 x 10 mm .Pieces were cut from the board to make a panel of size 915 x 610 x254 mm. Digital meters like energy meter, voltage meter, ampere meter, frequency meter and r.p.m meter were fitted on the panel. Automatic control drive unit, miniature circuit breaker of triple pole triple throw and single pole single throw along with current transformer coils, light emitting diodes (Indicators), were attached with the meters. Electric supply is given to these meters via 3 phase motor. A Reciprocating pump of 2 H.P. and motor of 3 KW, having 2800 r.p.m is used. From voltmeter we can find out different voltages either by combining individual lines or by combination of the two phases. From ampere meter we can find out the current at line-1, line-2 and line-3. Similarly from the frequency meter we can find out the frequency. From the r.p.m meter we can find out the r.p.m of the pump. We use 7 indicators to know the supply status of all the meters. Automatic control drive is fitted from where we can change the r.p.m of the motor and can apply load on the pump.

Lastly paint work was done to give a good and charming finish to the apparatus.

5. Experimental Setup

6. Results and Discussion

Reciprocating pump is a positive displacement plunger pump. It is often used where relatively small quantity of water is to be handled and delivery pressure is quite large. Reciprocating pumps are widely used as Automobile Service Stations, Chemical Industries, or as metering and dosing pumps as well as for farming purposes. The apparatus consists of, double acting reciprocating pump mounted over the sump tank. The pump is driven by motor, which is controlled by automatic control drive unit. An energy meter measures electrical input to motor and other digital outputs are recorded by different types of meters fixed upon the panel. Measuring tank is provided to measure discharge of the pump. The pressure and vacuum gauges provided to measure the delivery pressure and suction vacuum respectively.

6.1 Experimental Procedure

1. Fill up sufficient water in sump tank/reservoir/suction tank.
2. Open the gate valve in the discharge pipe of the pump fully.
3. Check nut bolts & the driving belt for proper tightening.
4. Connect the electric supply and switch on the supply.
5. Slightly close the discharge valve. Note down pump speed, delivery
6. For measuring pressure, suction vacuum and time for energy meter & for flow other measurement close the measuring tanks drain valve, take time for one minute draw.
7. Repeat the procedure for different gate valve closing. Take care that discharge pressure does not rise above 8 Kg/cm^2.
8. Change the speed through automatic control unit and take readings for different gate valve openings at different speeds.
9. Put load upon the pump and motor by operating the A.C drive.

6.2 Observations

1. Diameter of the cylinder (D) = **0.0381 (m)**
2. Length of Stroke (L)=**0.127 (m)**
3. Radius of crank (r)=$\frac{L}{2}$

   = **0.06 (m)**
4. Speed of crank(N) =**800 r.p.m (standard)**
5. Delivery height (h_d) = **1.753 m**
6. Suction height (h_s) = **1.219 m**
7. Cross section of cylinder(A) = $\frac{\pi (D)2}{4}$ m^2

   =**0.0007 m^2**
8. Volume of water sucked (Vs) =A x L in the suction stroke= **0.000089 m^3**
9. Discharge per second or(Q_{theo})=3 x A x L x $\frac{N}{60}$

Theoretical discharge =**0.0033** $\frac{m3}{s}$

10. Weight of water delivered(W)=ρ x g x Q

Per second = ρ x g x A x L x $\frac{N}{60}$

= **34 N**

11. Work input per second

= weight of water lifted per second x total or work input /s height water is lifted

= W x (h_s + h_d)

= ρ x g x A x L x $\frac{N}{60}$ (h_s + h_d) $\frac{Nm}{s}$

= **99** $\frac{Nm}{s}$

12. Power (P)

= ρ x g x A x L x $\frac{N}{60 x 1000}$ (h_s + h_d) kw

= **0.09 kw**

13. Co-efficient of discharge (C_d)

= Actual discharge/Theoretical discharge

Where, Q_{act} = 43 L.P.M

= $\frac{Qact}{Qtheo}$

= **13030**

14. Slip(S) = Q_{theo} -Q_{act}

=**- 42.9**

15. % slip($S_{\%}$)=$\frac{Qtheo - Qact}{Qtheo}$ x 100

= **78 %**

16. Frictional Losses (F_l) = 3 (m)
17. Velocity of water in pipe(v = $\frac{A}{a}$ [ω r sin ωt] ,

When, θ= 45^0

Where, (ω) = $\frac{2\pi N}{60}$ = **5 m/s^2**

18. Acceleration of water in pipe (a_w)

= $\frac{A}{a}$ [ω^2 r cos ωt]

= **15 m/s^2**

19. Mass of water in pipe (W_w)

= ρ x a x l

Where, l=length of pipe

= **17 Kg**

20. Force acting for acceleration (F_a) of water in pipe.

= ρ x A x l [ω^2 r cos ωt]

= **260 N**

21. Intensity of pressure due to (P_a)

= $\frac{\rho \text{ x } A \text{ x } l \text{ [ω2 r cos ωt]}}{a}$

Acceleration = **26.197 KPa.**

22. Pressure head due to

$(h_{as}) = \frac{ls}{g} \times \frac{A}{as} \times [\omega^2 r \cos \omega t]$

Acceleration in suction pipe

When, θ= 0^0 = **1.01 m**
When, θ= 90^0 = **0 m**
When, θ= 180^0 = **- 0.50 m**

23. Pressure head due to

$(h_{ad}) = \frac{ld}{g} \times \frac{A}{ad} \times [\omega^2 r \cos \omega t]$

Acceleration in delivery pipe
When, θ= 45^0 = **2.61 m**

24. Maximum Pressure head

$(ha_{max}) = \frac{l}{g} \times \frac{A}{a} \times [\omega^2 r]$

due to acceleration. = **5.03 m**

25. Loss of head due to friction (h_{fs})

$= \frac{4 \times f \times ls}{ds \times 2g}[\frac{A}{as} \omega r \sin \theta]^2$

In suction pipe

When, θ= 0^0 = **0 m**
When, θ= 90^0 = **290 m**
When, θ= 180^0 = **0 m**

26. Loss of head due to friction $(h_{fs}) = \frac{4 \times f \times ld}{dd \times 2g}[\frac{A}{ad} \omega r \sin \theta]^2$

In delivery pipe
When, θ= 0^0 =**0 m**
When, θ= 90^0 =**180 m**
When, θ= 180^0 =**0 m**

27. Maximum value of loss $(h_{fmax}) = \frac{4 \times f \times l}{d \times 2g}[\frac{A}{a} \omega r]^2$

of head due to friction = **180 m**

28. Power expanded *without* $(P_{f1}) = \frac{\rho \times g \times AL \times N}{60} \times \frac{4 \times f \times l}{3 \times d \times g}[\frac{A}{a} \omega r]^2$

air vessel = **236 watt**

29. Power expanded *with* $(P_{f2}) = \frac{\rho \times g \times AL \times N}{60} \times \frac{4 \times f \times l}{d \times 2 g}[\frac{A}{a} \times \frac{\omega r}{\pi}]^2$

air vessel = **34 watt**

30. % of power saved in(% $_{sav}$)= $\frac{(Pf1) - (Pf2)}{(Pf1)}$

overcoming friction in pipes = **6 %**

31. Suction Head $(H_s) = \frac{Ps}{1000} \times 13.6$

Where
S_p=specific gravity of mercury=13.6
Ps= Vacuum/suction Pressure in mm of Hg. **= 0.06 m**

32. Delivery Head (H_d)
=Discharge Pressure,kg/cm^2 *10 m
As (10 m of water=1 kg/cm^2) **= 45 m**

33. Total Head (H_t) =H_s+H_d + 3 mtr,
Where, Frictional losses = 3 mtr
= 49 m

34. Output power of pump $(P_w) = \frac{W * Qa * Ht}{1000}$kw

Where,
W=Specific weight of water =9810 N/m^3
Q_a=Discharge m^3/sec
H_t=Total Head
= **1.58 kw at 800 r.p.m**

35. Input power to pump $(I_p) = \frac{10 * 3600}{te * 1600}$ kW

Let time required for one minute of meter/time, (t_e) is 10 seconds, then, Where energy meter constant is 1600
= **2.25 kWh**

36. Taking motor efficiency (S_p) =I_p * 0.80
=80%, we have input shaft power
= **1.8 kW**

37. Overall efficiency of pump

$(\eta) = \frac{Pw}{Sp} * 100\ \%$ = **88 %**

Condition-1: Valve # 1, 2 and 4 fully closed and valve # 3 open.

1. R.P.M = 800
2. Suction pressure = 5 In Hg
3. Delivery pressure gauge # 1 =1.4 kg/cm2
4. Delivery pressure gauge # 2 =1.6 kg/cm2
5. Delivery pressure gauge # 3 =1.6 kg/cm2
6. Delivery pressure gauge # 4 =1.3 kg/cm2
7. Voltmeter reading (V) =

S.No	ϕ- 1	ϕ -2	ϕ - 3	ϕ - 1+2	ϕ - 2+3	ϕ - 3+1
1.	231.3	245.2	229	407.7	408	406.4

8. Ampere meter Reading (A) =

S.No	ϕ- 1	ϕ - 2	ϕ - 3
1.	23.4	21	25.05

9. Energy meter reading (E) =

S.No	KWh	W-1	W-2	W-3	PF-1	PF-2	PF-3
1.	308.3	190	169	212	0.31	0.10	0.42

10. Frequency meter reading (F) = 50 Hz
11. Time for discharge reading(T) = 20 sec
12. Discharge at full throttle = 1 cm

13. Discharge at 3/4 throttle = 0.5 cm

Condition-2: **Valve # 2, 3 and 4 fully closed and valve #1 open.**

1. R.P.M = 800
2. Suction pressure = 5 In Hg
3. Delivery pressure gauge # 1 =1.5 kg/cm^2
4. Delivery pressure gauge # 2 =1.6 kg/cm^2
5. Delivery pressure gauge # 3 =1.7 kg/cm^2
6. Delivery pressure gauge # 4 =1.5 kg/cm^2
7. Voltmeter reading (V) =

S.No	ϕ- 1	ϕ -2	Φ- 3	ϕ - 1+2	ϕ - 2+3	ϕ - 3+1
1.	230.8	245.6	229.3	407.4	410.5	405.9

8. Ampere meter Reading (A) =

S.No	ϕ- 1	ϕ - 2	ϕ - 3
1.	3.4	31.86	15.23

9. Energy meter reading (E) =

S.No	KWh	W-1	W-2	W-3	PF-1	PF-2	PF-3
1.	308.4	199	182	241	0.35	0.13	0.48

10. Frequency meter reading (F) = 48.40 Hz
11. Time for discharge reading(T) = 20 sec
12. Discharge at full throttle = 1 cm
13. Discharge at 3/4 throttle = 0.5 cm

Condition-3: **Valve # 1, 3 and 4 fully closed and valve #2 open.**

1. R.P.M = 800
2. Suction pressure = 5 In Hg
3. Delivery pressure gauge # 1 =1.5 kg/cm^2
4. Delivery pressure gauge # 2 =1.7 kg/cm^2
5. Delivery pressure gauge # 3 =1.6 kg/cm^2
6. Delivery pressure gauge # 4 =1.5 kg/cm^2
7. Voltmeter reading (V) =

S. No	ϕ- 1	ϕ -2	ϕ - 3	ϕ - 1+2	ϕ - 2+3	ϕ - 3+1
1.	231.2	243.9	228.6	406.2	407.7	405.7

8. Ampere meter Reading (A) =

S. No	ϕ- 1	ϕ - 2	ϕ - 3
1.	3.12	20.54	16.04

9. Energy meter reading (E) =

S. No	KWh	W-1	W-2	W-3	PF-1	PF-2	PF-3
1.	308.5	204	180	214	.35	.13	.48

10. Frequency meter reading (F) = 48.66 Hz
11. Time for discharge reading (T) = 20 sec
12. Discharge at full throttle = 1 cm
13. Discharge at 3/4 throttle = 0.5 cm

Condition-4: **Valve # 1, 2 and 3 fully closed and valve # 4 open.**

Now open the adjusting screw (RED colored screw on left side of pump before taking below given readings)

1. R.P.M = 800
2. Suction pressure = 5 In Hg
3. Delivery pressure gauge # 1 =0 kg/cm^2
4. Delivery pressure gauge # 2 =0 kg/cm^2
5. Delivery pressure gauge # 3 = 0 kg/cm^2
6. Delivery pressure gauge # 4 =2 kg/cm^2
7. Voltmeter reading (V) =

S. No	ϕ- 1	ϕ -2	ϕ - 3	ϕ - 1+2	ϕ - 2+3	ϕ - 3+1
1.	231.2	241.3	228.6	405.7	408.2	405.6

8. Ampere meter Reading (A) =

S. No	ϕ- 1	ϕ - 2	ϕ – 3
1.	3.6	32.2	25.6

9. Energy meter reading (E) =

S. No	KWh	W-1	W-2	W-3	PF-1	PF-2	PF-3
1.	308.6	317	310	344	.37	.15	.53

10. Frequency meter reading (F) = 48.60 Hz
11. Time for discharge reading (T) = 20 sec
12. Discharge at full throttle = 1.5 cm
13. Discharge at 3/4 throttle = 1cm

7. Conclusion

This project is focused on the construction & operation of the reciprocating pump test rig. Our achievement is something we term a moderate success. While many factors have limited the reciprocating pump to a level than what it could actually have been, still we have been successful to demonstrate the worth of a reciprocating pump. Our reciprocating pump test rig is a simple homemade type, built on easily available materials and technology. This device serves its purpose to some extent, but with proper course of actions, it can perform still better. From what we have derived from this project all the way from concept building, inception to final operation, we believe that he usefulness and effectiveness of a reciprocating pump against its simplicity and economics makes it a very powerful and practical machine, If carried out in proper ways in a large scale, reciprocating pump can be a handy tool of great importance in the hilly regions like Himachal and Nepal. Thus we would like to put forth some recommendations regarding its use.

1. Reciprocating pump can be a very useful tool to provide water easily at higher elevations. Thus, their construction and use must be executed with great priority.
2. The pump is itself an economic device; however it must be made further affordable by procuring and producing in large quantities. This pump delivers sufficient pressure which makes it useful for irrigation and for servicing stations.
3. Similarly, some local people must be trained to operate and maintain a reciprocating pump, since the pump is quite simple, this task can be easily accomplished.

8. Summary

Last but not the least to say, our apparatus is

1. Simple in construction, easy to installation, reliable in operation & maintenance.
2. Easy to procure components & assemble to build.
3. Can work continuously for 24 hrs a day.
4. Moving parts such as valves, bearings etc may be subjected to damage & need regular inspection.

Our work is intended to fabricate a reciprocating pump test rig and to build an apparatus which is beneficial for the students and more over it is beneficial to get the parameters checked by any of the company who is involved in making of reciprocating pumps, just what has to be done is to fix a pump of any specification and get the details of the pump parameters. By making use of pump of Kisan waves, KW-50 series we have found that the efficiency of this pump is 88 % at 800rpm with a power consumption of 0.09 Kw.

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