e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:04/Issue:05/May-2022 Impact Factor- 6.752 www.irjmets.com

DESIGN OF HYDRAULIC RAM PUMP

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ABSTRACT

A hydraulic ram pump is a water pump driven by height differences present in the water level. The ram pump works without consume of any external power source. In areas where the natural flow of water exists like small creeks, streams of water over a small distance, hydraulic ram pumps can be used to transport this water without relying on electricity. The chances of introducing a hydraulic ram pump as a means of utilizing its energy to increase the head and range of a conventional pump is analyzed, for this, it is necessary to understand the performance parameters like head ratio H* or discharge head to drive head and flow-rate ratio Q* or discharge flow rate to drive flow rate, supply head, air chamber pressure, and waste valve beats per minute which vary for each pump. The increase in the supply head tends to increase the supply flow rate, delivery flow rate, delivery head, and therefore the overall efficiency of the pump. The increase in air chamber pressure tends to reduce the general efficiency of the pump. The increase in waste valve beats per minute tends to reduce the supply flow rate, delivery flow rate, and delivery head whereas it tends to increase the head ratio, the flow-rate ratio, and therefore increasing the overall efficiency of the pump.

Keywords: hydraulic ram pump, supply head, efficiency, irrigation, delivery height, discharge.

I. INTRODUCTION

A hydraulic ram pump (also called a hydram) is a pump that uses energy from water falling from the height (supply head) and pumps the water to increased level of height at outlet. No further power is required till there is a continuous flow of falling water, the pump will operate continuously and automatically. The provision of adequate domestic water to the dispersed rural population is a major problem in many developing countries. The cost of fuel and maintenance for the use of conventional pumping systems is increasing. Hydraulic ram pump (hydram) is a simple pumping device that uses renewable energy and lasts a long time. The hydraulic ram has only two moving parts; these are impulse valves and delivery valve that can be easily maintained. A hydraulic ram depends on the unbalanced flow of water in a pipe connected from a water source to a pump (called a "drive" pipe). This flow is generated by placing the hydraulic ram a certain distance under the water source and using a drive pipe from the water source to the pump. The hydraulic ram uses two check valves, which are the only moving parts of the pump. Figure 1.1 shows the schematic diagram of a ram pump.

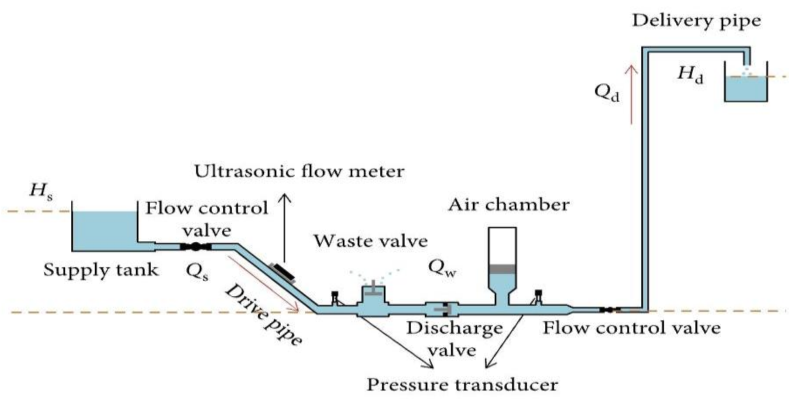

Figure 1.1: Schematic diagram of Hydraulic ram pump

1.1 Working of Hydraulic ram pump?

In order to understand more about hydraulic ram pump, we need to understand it's working.

Ram pump mainly works in a 5-step cycle as follows: -

Step 1: (Figure 1.2) Water (blue arrows) starts flowing through the drive pipe and out of the "waste" valve (#1 on the diagram), which is open initially. Water flows faster and faster through the pipe and out of the waste valve.

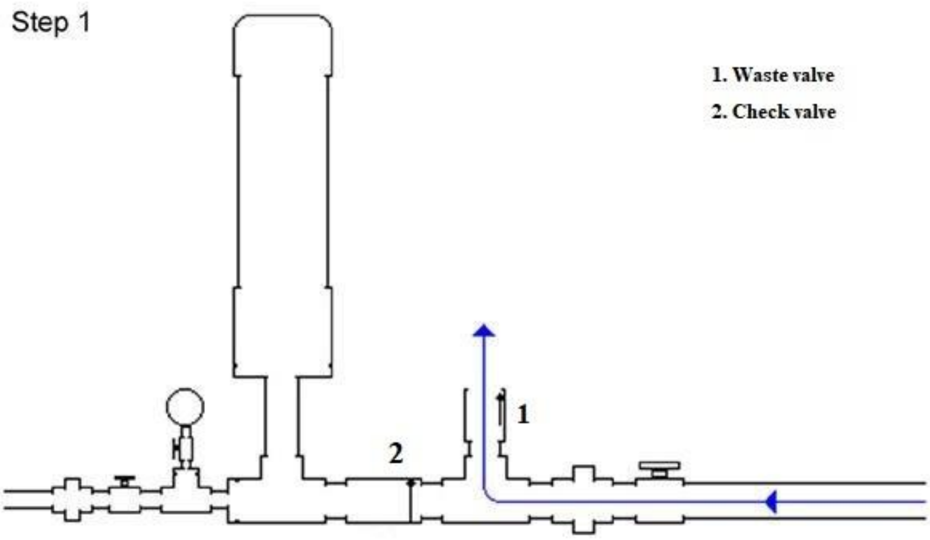

Figure 1.2: Water flow through waste valve

Step 2: (Figure 1.3) At some point water is moving so quickly through the waste valve (#1) that it pushes the valve's flapper up and slams it shut. The water in the pipe was moving quickly and had considerable momentum, but all the water weight and momentum is stopped by the valve's closure. That creates a high-pressure spike (red arrows) at the closed waste valve. The high-pressure spike forces some water (blue arrows) through the check valve (#2 on the diagram) and into the pressure chamber. This increases the pressure in that chamber slightly. The pressure "spike" in the pipe also begins moving away from the waste valve and up the drive pipe (red arrows) at the speed of sound and is released at the drive pipe inlet.

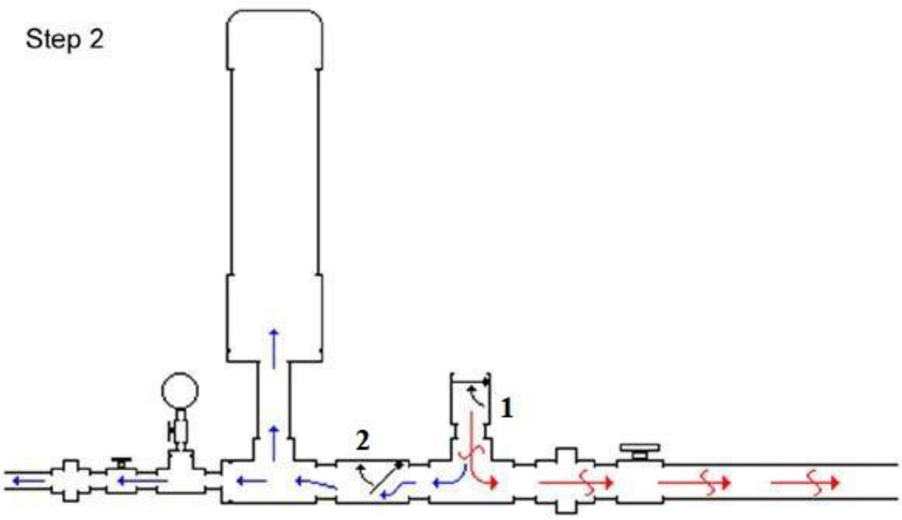

Figure. 1.3: Water flow though air chamber.

Step 3: (Figure 1.4) After the high-pressure wave reaches the drive pipe inlet, a "normal" pressure wave (green arrows) travels back down the pipe to the waste valve. The check valve (#2) may still be open slightly depending on backpressure, allowing water to enter the pressure chamber.

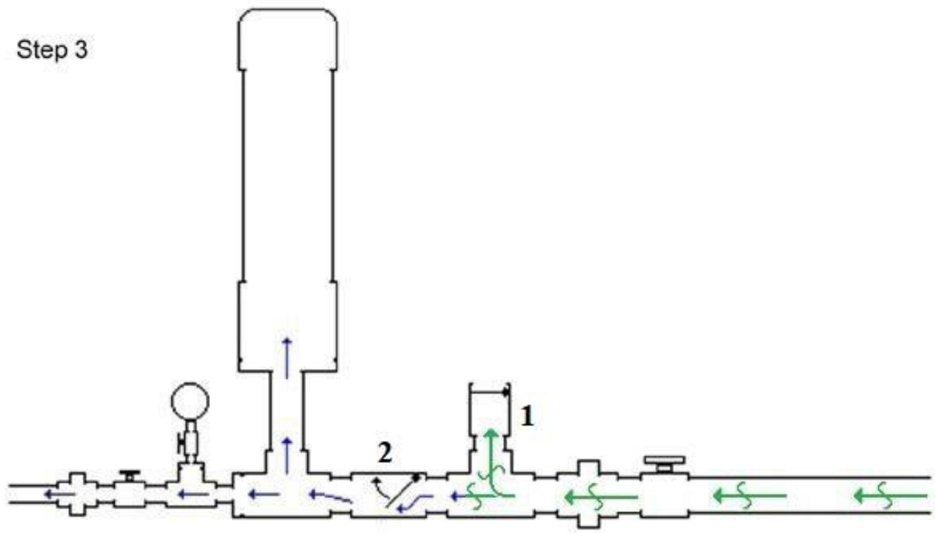

Figure. 1.4: Water Hammering Effect

Step 4: (Figure 1.5) As soon as the normal pressure wave reaches the waste valve, a low-pressure wave (brown arrows) travels up the drive pipe, which lowers the pressure at the valves and allows the waste valve to open and the check valve (#2) to close.

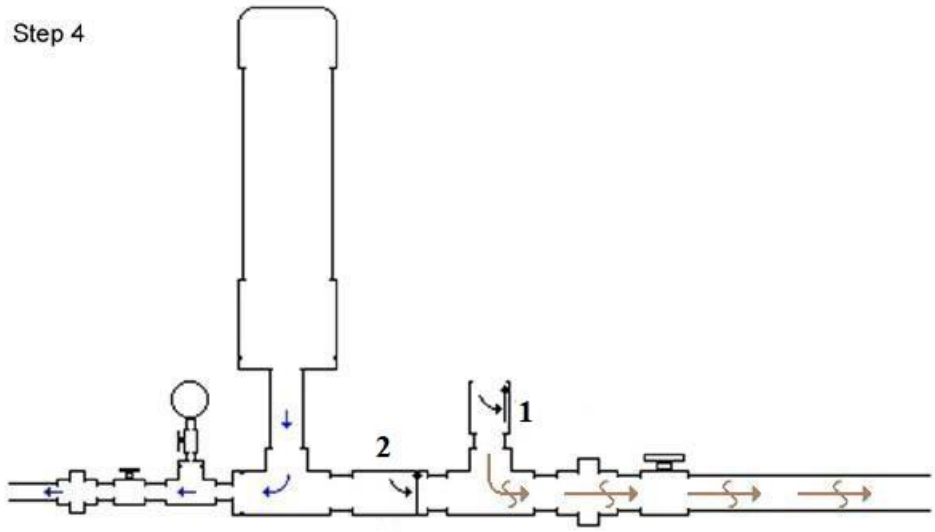

Figure. 1.5: Water flow at outlet

Step 5: (Figure 1.6) When the low-pressure wave reaches the drive pipe inlet, a normal pressure wave travels down the drive pipe to the valves. Normal water flow due to the elevation of the source water above the ram follows this pressure wave, and the next cycle begins.

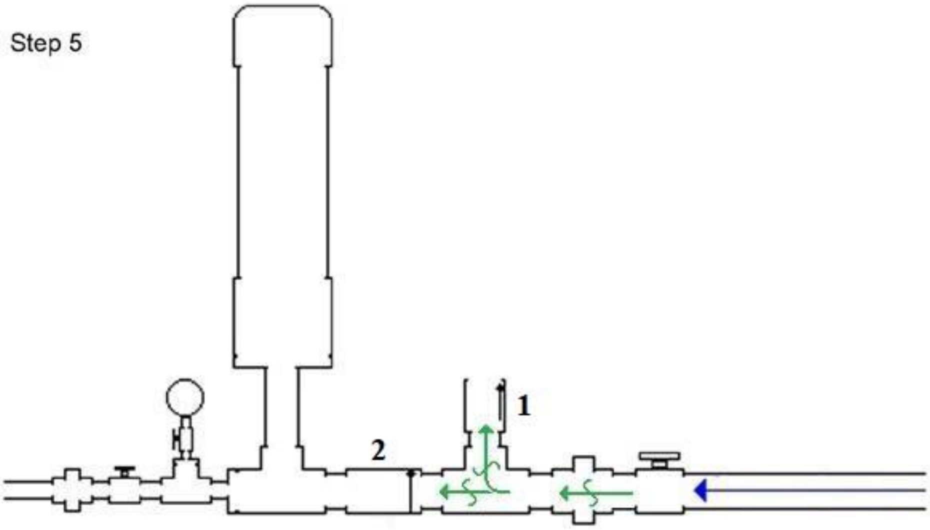

Figure. 1.6: Water flow though Waste valve and repeating of cycle

The hydraulic ram pump cycle described in Figures 1.2 to 1.6 may repeat from forty to ninety times per minute depending on elevation, drop of the hydraulic ram pump, drive pipe length from the water source to the ram pump, and drive pipe material used.

II. MODEL DESIGN

The below diagrams Figure 2.1 and Figure 2.2 give the 3d software view and actual model of the ram pump used for experimental calculation respectively. This 3d simulation of the model was created in the 3d simulation software called Solidworks. The above model was finalized for determination of readings required for the calculations. The merits of the above model are that there are no leaks in the air chamber, the complexity of the model is reduced due to the absence of the threading in the intermediate parts of the model, due to the inclusion of two waste valve the sufficient amount of pressure required for lifting of fluid as one waste valve is used as incline valve or non-return valve in the model.

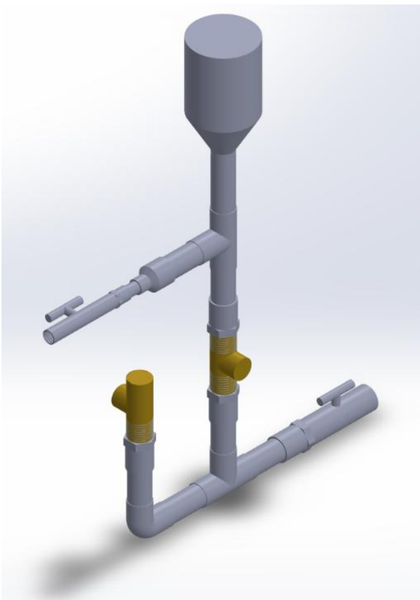

Figure 2.1: Concept design of model

Figure 2.2: Actual model of ram pump used

III. DETAILED DESIGN OF MODEL

Model The below figure (Figure 3) gives the dimensional representation of the ram pump model 2. The fluid flows from the input section to the T-section the center bottom at which the fluid flow is divided into two streams. One flow is towards the waste valve and other flow is towards the air chamber. In the flows towards the air chamber the fluid flows through the non-return valve and is pushed inside the air chamber, after passing through the non-return valve the fluid flows in one direction only. Here the air chamber adds extra pressure to the fluid which increase the discharge at outlet. The waste valve generates the water hammer effect.

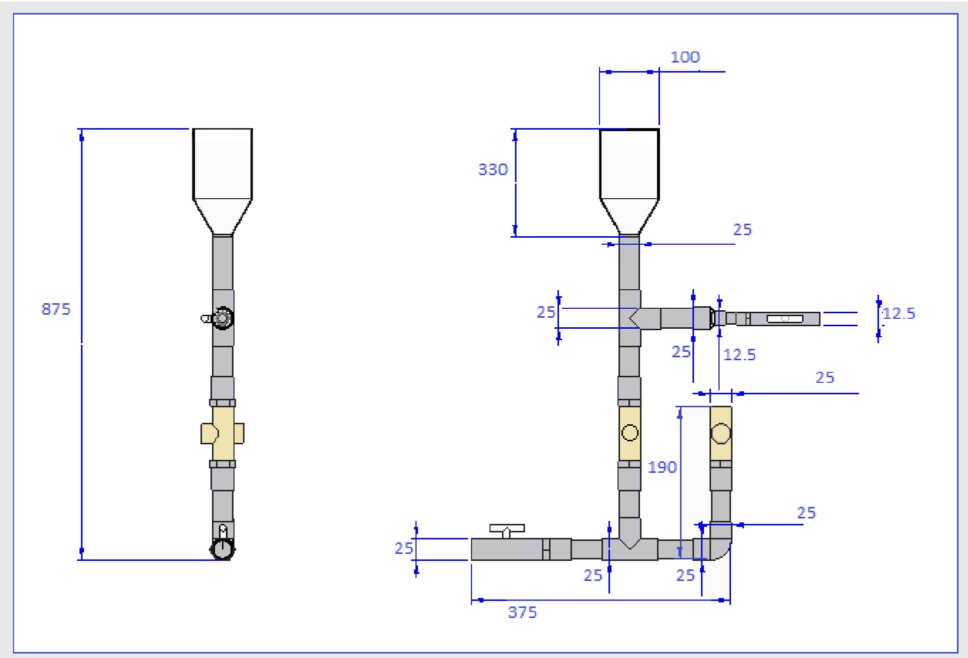

Figure 3: Detailed design of model

IV. EXPERIMENTAL SETUP

Schematic block diagram of the experimental setup has been portrayed in the figure (Figure 4.). The use of centrifugal pump as an inlet was discarded as the centrifugal pump provided a high pressure and high rate of discharge that creates unfavorable conditions and prevented the generation of back pressure and waste valve to remain close until the pump is turned off. The back pressure is the prime element necessary for the functioning of ram pump and provide water hammering effect necessary for delivery of the fluid.

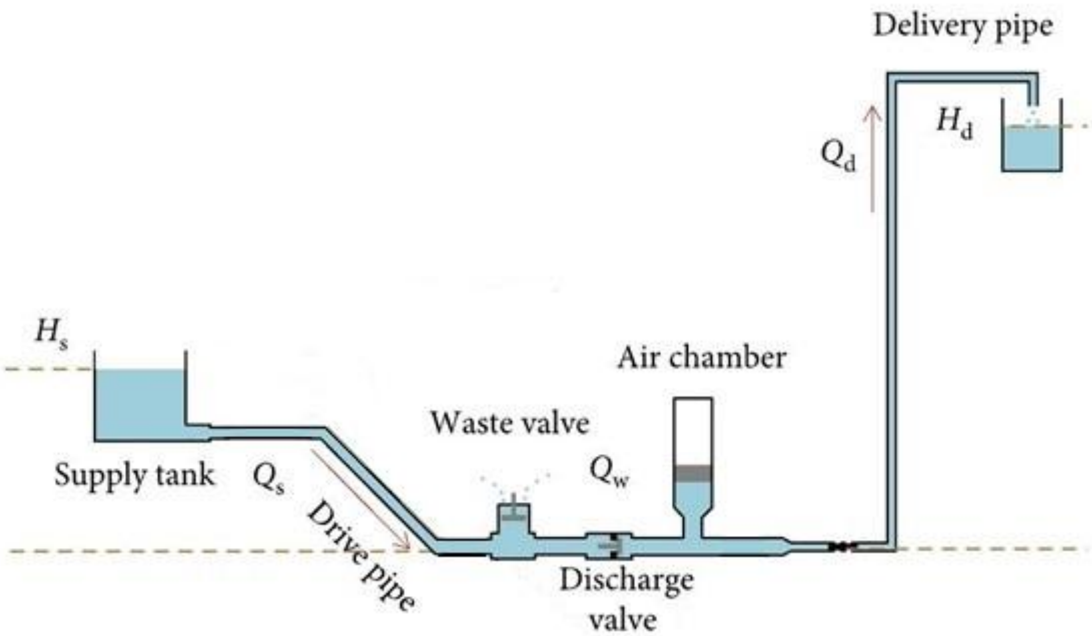

Figure 4: Experimental Setup

4.1 Requirement specification

There are many requirements to be complete in order to the combined system of hydraulic ram pump and centrifugal pump to function properly that are the input and output of the ram pump must be located at higher elevation from the ground level to obtain back pressure that is necessary for water hammering effect, the output must be at one-and-a-half-foot elevation from input, the input elevation must not exceed the distance of three feet.

4.2 Experimental calculations

Calculations at various input heads in order to determine efficiency of the ram pump model manufactured.

1.] Input head- 0.5ft.

Output Head- 5ft. 1 inch

H_s = 0.1524 m

H_d = 1.54 m

Q_s = 2.5 L/min

Q_d = 0.21 L/min

n = 54

$Q_w = Q_s – Q_d$

= 2.5 – 0.21

<u>Q_w = 2.29 L/min</u>

$$\text{Efficiency } (\eta) = \frac{(Qd \times H)}{(Qd+Qw) \text{ X } Hs} \times 100$$

$$= \frac{.21 \times 1.3876}{(0.21+2.29) \times 0.1524} \text{ X } 100$$

= 76.48 %

2.] Input head- 1 ft.

Output Head- 6ft. 5 inches

H_s = 0.3048 m

H_d = 1.96 m

Q_s = 1.8 L/min

Q_d = 0.24 L/min

n = 47

$Q_w = Q_s - Q_d$

= 1.8 – 0.24

Q_w = 1.56 L/min

$$\text{Efficiency } (\eta) = \frac{(Qd \times H)}{(Qd+Qw) \times Hs} \times 100$$

$$= \frac{0.24 \times 1.6552}{(0.24+1.56) \times 0.3048} \times 100$$

= 72.41 %

3.] Input head- 1.5ft.

Output Head- 6ft. 10 inches

H_s = 0.4572 m

H_d = 2.08 m

Q_s = 1.9 L/min

Q_d = 0.28 L/min

n = 49

$Q_w = Q_s - Q_d$

= 1.9 – 0.28

Q_w = 1.62 L/min

$$\text{Efficiency } (\eta) = \frac{(Qd \times H)}{(Qd+Qw) \times Hs} \times 100$$

$$= \frac{0.28 \times 1.6228}{(0.28+1.62) \times 0.4572} \times 100$$

= 52.31%

V. RESULTS AND DISCUSSION

Number of experiments were performed on the pump models and various reading and data were recorded. The obtained readings indicate that the output discharge and velocity are less then input discharge and velocity. It also indicates that major amount of water is wasted in the waste valve where the water hammering effect is obtained.

5.1 Result Table of Hydraulic Ram Pump calculations

In table (Table 5.1.), we considered a ram pump with a constant supply head. The inlet of the ram pump was provided some input with vertical elevation. There is increase in velocity at the outlet of the ram pump as compared to the inlet of the ram pump. The increase in the discharge at outlet in compensated by the loss of water at the waste valve. The efficiency will decrease linearly with the decrease in delivery head.

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Table 5.1: Result table for Hydraulic ram pump model system

Sr. no.	Input Head (Hs)	Hs in meters	Output head (Hd)	Hd in meters	Qs (L/min)	Qd (L/min)	Qw	Beats per min	Efficiency η
1	0.5ft	0.1524	5ft 1 inch	1.54	2.5	0.21	2.29	54	76.48
2	1ft	0.3048	6ft 5 inch	1.96	1.8	0.24	1.56	47	72.41
3	1.5ft	0.4572	6ft 10 inch	2.08	1.9	0.28	1.62	49	52.31

5.2 Result Graphs: -

1.) Output Head Vs Discharge

In graph (Figure. 5.1), we can see that discharge increases as the output head increases. The discharge is directly proportional to the output head.

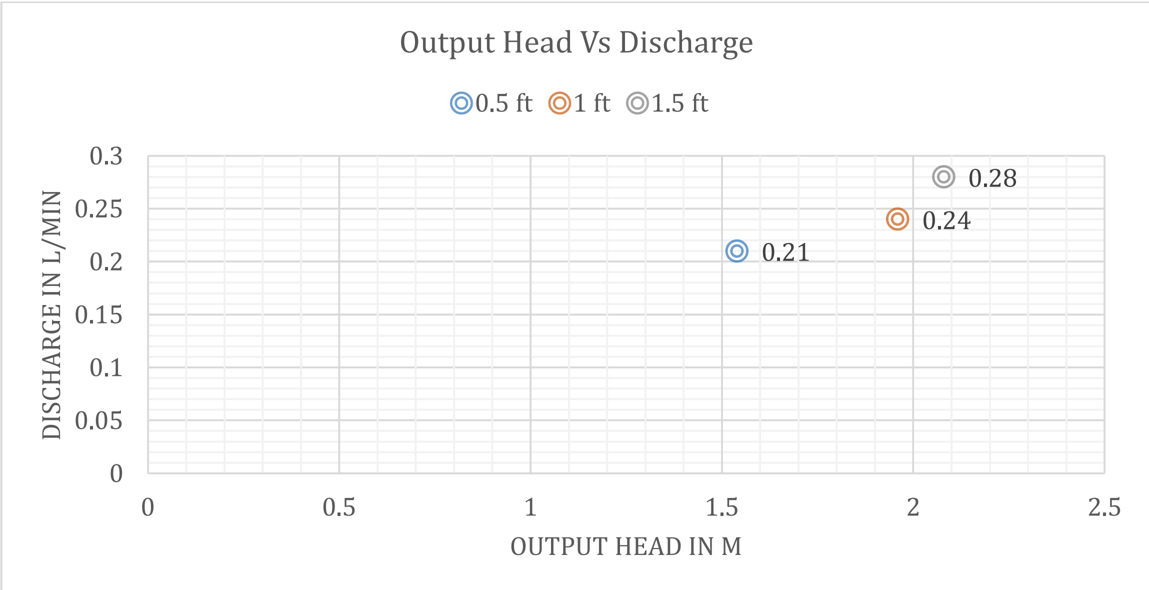

Figure 5.1: Output Head Vs Discharge Graph of Ram Pump

2.) Input Supply Vs Beats

In graph (Figure 5.2), we can see that the beats per min of the waste valve increases linearly as the discharge increases. The discharge is directly proportional to the velocity of water.

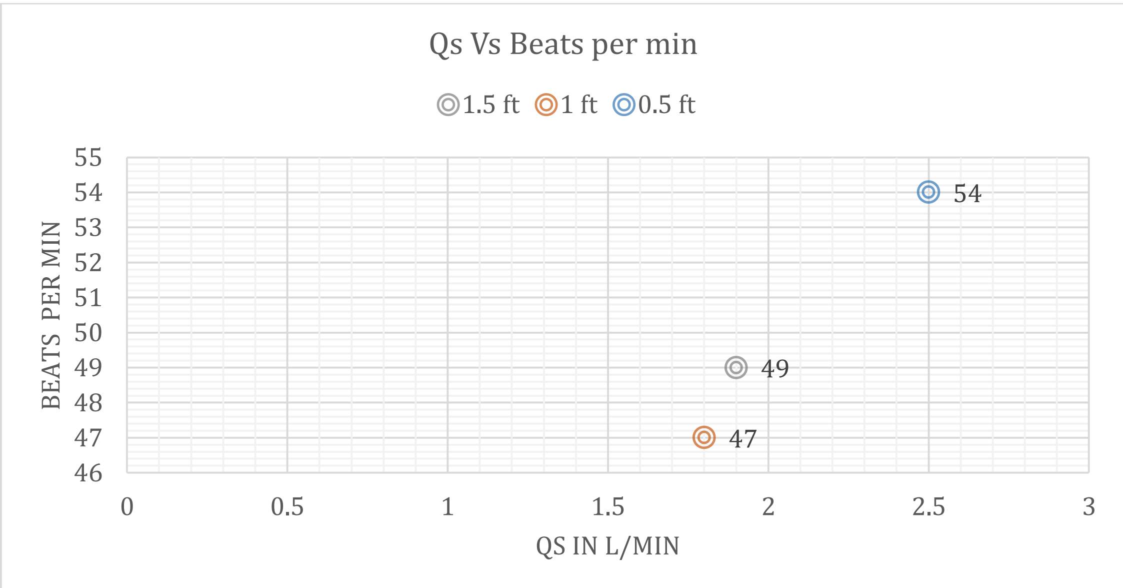

Figure 5.2: Input Supply Vs Beats Graph of Combine system

3.) Head Vs Discharge

In graph (Figure. 5.3), we can see that the beats per min of the waste valve increases linearly as the discharge increases. The discharge is directly proportional to the velocity of water.

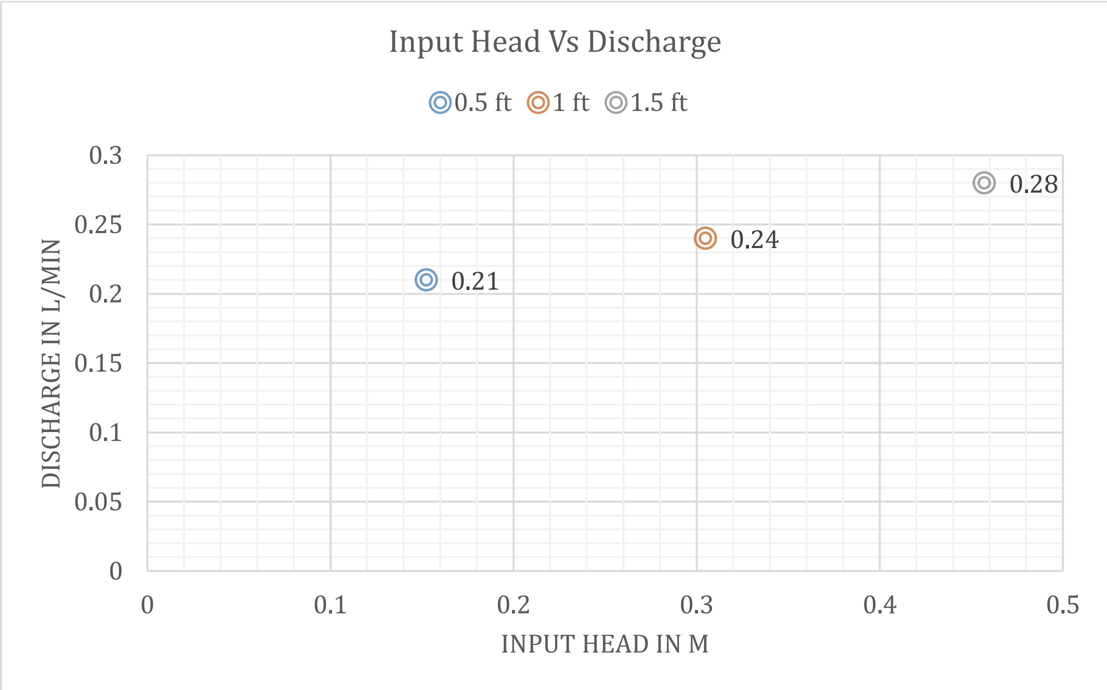

Figure 9.3: Input Head Vs Discharge Graph of Combine system

VI. CONCLUSION

In the present paper the construction and working of hydraulic ram pump were studied. We have analyzed, manufacture, and explore practical working of ram pump. The ram pump gives 0.21L/min output discharge when 2.5L/min supply is provided that is 8.4% discharge at input head of 0.5 feet. For 2 feet ram pump gives 0.24L/min output discharge when 1.L/min supply is provided, that is 13.33% discharge and for 2.5 feet it gives 0.28L/min output discharge when 1.9L/min supply is provided, that is 14.73% discharge. We can conclude from the above experimental result that the discharge at the output of the ram pump is relatively very less as compared to the discharge present at the inlet of pump, it is due to the presence of waste valve where significant amount of water is wasted.

VII. FUTURE SCOPE

Improvements can be made in the lifting capacity of pump by adjusting the positioning of the waste valve and non-return valve by performing various experiments and obtaining various iterations. We can also increase the pressure in the pump by using various shapes and sizes of the air chamber. We can also increase the output head of the pump by changing the elevation of the input head

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