DESIGN AND PERFORMANCE EVALUATION OF A LOCAL DOWNDRAFT HYDRAULIC RAM PUMP

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Abstract

Imported hydraulic ram pump are expensive, need accurate fabrication like machining, grinding, and casting which are costly and are rarely present in the locality specifically near farms for irrigation and domestic uses. Thus, there was a need to design a locally made downdraft hydraulic ram pump.

The designed downdraft type of ram pump is farmers friendly because parts were locally available. There was no need for machining, grinding, and casting. The design needed only the following useful parts the breather pipe, gate valve, pipes, swing valves, union joints, couplings, nipple pipes, pressure gauge, and anti-leak materials.

In the design process of the downdraft type hydraulic ram pump, parts were specified based on the following factors: minimum stream flow, vertical fall of the water from the source, vertical lift from the pump to the point of water utilization. These factors dictated the proper design of the downdraft type hydraulic ram pump. The drive and breather pipes were calculated based on its ratio of the length and the diameter which revealed a length of 75ft with 3 inchesdiameter and 50 ft for the 2 inches. Dimensionsof the pressure chamber weretheresults of the relationship between the pressure chamber size and the drive pipe size which was 4 inches diameter with a length of 62inches for the 2 inches drive pipe; and for the 3 inches diameter drive pipe the pressure chamber size of 4 inches diameter and a length of 140 inches. The design of the delivery pipes were$1\frac{1}{2}$ inchesdiameter and 1 inch, for the 3 inches and 2 inches ram pumps, respectively.

The minimum inflow were 2.4 and 20.4 gal/min, for the 2-inch and 3-inch ram pumps respectively. Both ram pumps used in 1 foot vertical fall and 8 feet vertical lift. However, the minimum discharge flow of the 2-inch pump was 0.2 gallon per minute and 1.53 for the 3-inch pump. Lowering further the vertical fall or the inflow will stop the operations of the pumps.

Keywords: Ram pump, water fall, water lift

I. Introduction

Hydraulic ram pump is one of renewable energy technologies that is used to provide energy from water needed for irrigation and domestic purposes. It is a way to pump water from stream, creek, and other water sources with flowing water. The device which uses the kinetic energy of falling water to lift a lesser amount of water to higher elevation than the source. It can operate anytime as long as there is water flowing from a source. It does not need wind or sunshine or other sources of energy to operate.

It was designed to improve crop production, extensive landscaping and gardening. But with the advent of electrical pumps and fossil fuel operated engines, interest in using the hydraulic ram became dormant. The use ram pumps faded and just left on the. Stream in the stream until expensive parts, fossil fuel shortages, and environmental concerns brought back to the public's mind the need for a pump that requires almost no repairs or maintenance, inexpensive, self-acting, and environmentally friendly. Cost was a major factor in the growth of ram use. Not only was the machine inexpensive to buy, but it also was simple to install and they were almost maintenance free.

Existing old hydraulic ram pumps are very bulky, expensive for they require precise machining processes and casting of some of its parts. Their operation is relatively complex (i.e. complex valve system such that various adjustments must be done before it normally starts for operation). Thus, some of the end-users, stakeholder like farmers could not comprehend and had difficulty to install the pump efficiently. With these, there is a need to design a downdraft hydraulic ram pump using locally available materials which makes it simple to be understood and operate nice the end-users.

Fig 2. *Valve Regulated Hydraulic Ram Pump.*

II. Review of Literature

In 1772, John Whitehurst invented a non-self-acting ram pump in England. While, in 1796 Golfier of France added a valve which made the device self-acting.

The first US patent was issued to Joseph Curneau and Stephen Hallet in 1809.

While in 1840, most ram pumps of American farms were imported from Europe.

By the end of the twentieth century, interest in hydraulic rams has revived due to the needs of sustainable technology in developing countries.

III. Materials and Methods

The design study made used a 2 inches and 3 inches diameter pipes, since these are available in the locality.

The following requirements were considered in designing the downdraft type hydraulic ram pumps:

1. Principle of operation

General operation principles of the downdraft hydraulic ram pump.

As the inflow water from the source enters the dive pipe, it passes through the swing valve; it creates a momentum, which abruptly closes the valve. The sudden closure produces high pressure in the body of the pump. This pressure pushes the spring valves inlet and enters the pressure chamber intermittently. Little by little the pressure increases until it reaches the operating pressure to deliver the water to the point of utilization. As the water enters the pressure chamber the pressure in the body of the pump where the swing valve is located, the pressure due to the water momentum decreases tending the swing valve to open. Again the flowing water into the drive pipe creates another momentum for the next cycle. One cycle approximately completed in 1 second and the operation continue as long as there is an inflow of water. The water must be free from debris to avoid interruption of the pump operation.

The amount of water supplied depends on its size of the ram pump. The size of the ram pump is based on the size of pipe used I the body of the pump as shown in Table 1.

Table 1Estimated Amount of Water to be supplied by Ram Pump

Output Range	Ram Size
700 to 4,000 gal./day up to 16,000 gal./day	2-inch ram 3-inch ram

2. The minimum source stream flow, Qs

On site, flow of the water from the source can be measured by weir (notch board) method for large flow or by bucket method when the water flow is low (Figure 1.)

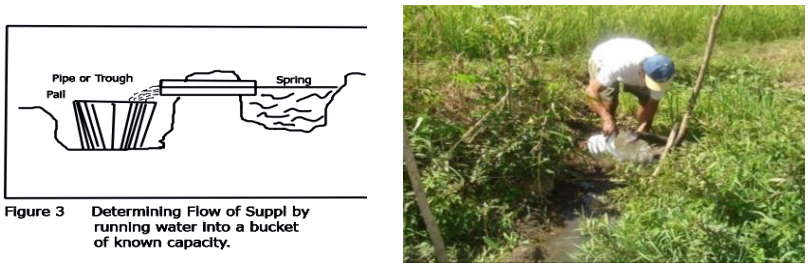
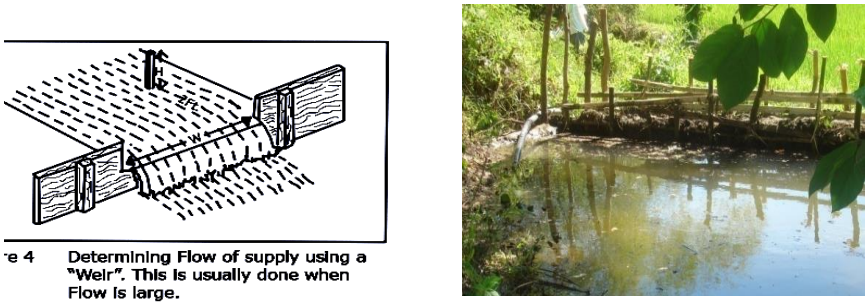


Figure 3 Determining Flow of Suppl by running water into a bucket of known capacity.

Fig 1 *Determining flow of supply by running water into a bucket of known volume.*



e 4 Determining Flow of supply using a "Weir". This is usually done when Flow is large.

Fig 2 *Determining flow of supply using a weir when flow is large.*

3. The Vertical Fall, F

The difference in vertical elevation between level of the water source and planned location of the ram is known as the fall (Figure 3). Two methods of measuring the vertical fall were;

By using an ordinary carpenter's level and a meter stick, and Run the water from the water source to the planned location using PVC pipe. The PVC pipe was slowly lifted up, when its water stop to flow, the end of the pipe from the location of the pump is the vertical flow.

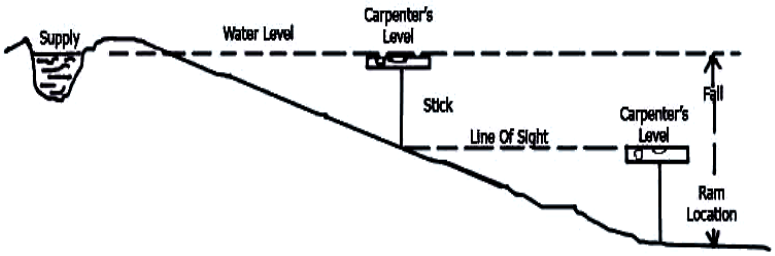


Fig 3 *Determining Vertical Fall and Elevation using a Carpenter's Level and the PVC Method*

4. The vertical Lift, E

Vertical lift is the total height to which water must be delivering from the ram site to the point of utilization. It was determined by the same method used to calculate vertical fall.

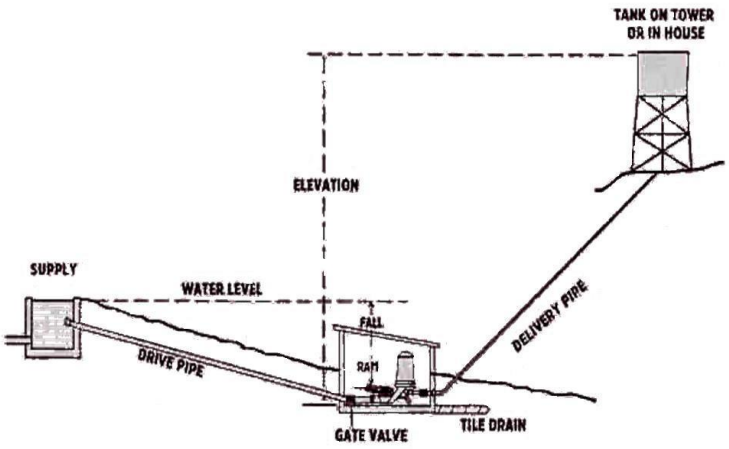


Fig 4*. Determining the Vertical Lift*

5. The size of the Drive Pipe.

The length and size of the drive pipe were based on the ratio of the drive pipe length (l) to the drive pipe diameter (d) for stability of ram pump installation. The best range is an l/d ratio of between 150 and 1000 (l/d = 150 to l/d = 1000).

6. Design the size of pressure chamber

The size of the pressure chamber was determined of the relationship of expected pressure chamber sizes to the drive pipe size, flow per cycle and volume required. The data was based from a ram pump operating at 60 cycles per minute.

Table2. Relationships pressure chamber sizes to drive pipe sizes, flow per cycle, and volume
required.

Drive Pipe Diameter (in)	Expected Flow Per Cycle (gallons)	Pressure Chamber Volume Required (gallons)	Length of Pipe Required for Pressure Chamber (For indicated pipe diameter (inches)	
			3	4
2	0.067	3.40	110	62
3	0.150	7.50	245	140

7. The discharge flow however can be estimated by the given relationship.

D = 0.6 x Q x F/E

Where:

D = discharge flow rate delivery (gallons/min)

Q = minimum pump inflow (gallons/min);

F = fall from water source (ft);

E = lift from pump to water delivery (ft); and

0.6 = efficiency factor.

8. Delivery pipe

The diameter of the delivery pipe of the ram pump was determined based on the drive pipe diameter, pump minimum and maximum inflow in liter per minute as well as the expected minimum and maximum output flow in liter per minute (Table 3).

Table 3. Hydraulic Ram specifications

Drive Pipe Diameter (in)	Delivery Pipe Diameter (in)	At Minimum Inflow		At Maximum Inflow	
		Pump Inflow (liter per minute)	Expected Output (liter per minute)	Pump Inflow (liter per minute)	Expected Output (liter per minute)
2	1	50.47	60.33	189.25	22.71
3	$1\frac{1}{2}$	75.7	90.5	283.875	34.065

9. Specifying the different parts of the ram pump

The configuration of the hydraulic ram was designed to specify the arrangement of the parts. The ram pump was designed as a downdraft type based on the sequence of the swing valve with the source pressure chamber and the source of water. Part list was developed to systematically assemble the ram pump. These parts were specified and available within the locality.

The specified salient parts of the pump are presented in Table 4. The arrangement of parts are presented in Figure 5. The specifications were based on the calculated values from principles of design relationships and equations as well as principles of hydraulics for proper mechanical operation of the pump.

IV. Results and Discussion

1. Parts of the Downdraft Hydraulic Ram Pump (DHRP).

Figure 5 shows the results of the design process for the specified parts of the downdraft hydraulic ram pump. The synchronization and locations of these parts are also shown in this figure.

Table 4 further shows the parts with the nomenclatures for easier acquisition of these parts. These parts are available in the locality for immediate installation. The parts are galvanize Iron pipes, joints, brass valves namely: ball valve, spring check valve and swing valve

Fig 5. Salient parts of the downdraft hydraulic ram pump

Table 4. Design parts list of the hydraulic ram

Part	Specification	
	2-inches pump	3 inches pump
Drive pipe	2 pcs 2”φ x 25’ G.I. pipe	3 pcs 3”φ x 25 G.I. pipe
Inlet Ball valve	2”φ G.I. pipe	3”φ G.I. pipe
swing valve	2”φ brass	3”φ brass
Spring valve	2”φ brass	3”φ brass
Pressure chamber	4”φ x 4’ G.I. pipe	4”φ x 4’ G.I. pipe10 G.I. pipe

Pressure gauge	¼" φ, 100 psi capacity	¼" φ, 100 psi capacity
Discharge ball valve	3/4 " φ	
Discharge pipe	¾"φ x 12" G.I. pipe	1 ¼ "φ x 12" G.I. pipe
Delivery pipe	1"Φ x 200 ' polyvinyl pipe	1 ½ "Φ x 200 ' polyvinyl pipe

2. Drive pipe length

The length of the drive pipes were based on the relationship L/d = 150, hence, the length of the drive with diameters of 2" and 3" are 50 feet and 75 feet, respectively.

3. The Size of the Pressure Chamber

Pressure chamber sizes based on 50 times the expected delivery flow per 'cycle'. The design size of the pressure chamber of the ram pumpwith a diameter of 2 inches was 4"φ x 62", while the 3 inches pump has a design dimensions of 4"φ x 140".

4. Delivery Pipe

A 200ft PVC pipe was used based on the distance from the ram pump to the point of utilization in both ram pumps, A delivery pipe diameter of $1\frac{1}{2}$" was used for the 3-inch ram pump and 1 inch for the 2" ram pump.

5. Performance of the DHRP

Table 5. Performance characteristics of the designed downdraft hydraulic ram pumps.

Characteristic	**Mean Value**	
	2-inch pump	3-inch pump
Minimum inflow (gal/min)	2.4	20.4
Vertical fall (ft)	1	1
Vertical lift (ft)	8	8
Minimum discharge flow (gal/min)	0.20	1.53

The observed minimum inflow in gallons per minute were 2.4 and 20.4, for the 2-inch and 3-inch ram pumps respectively. Both ram pumps were used in 1 foot vertical fall and 8 feet vertical lift. However, the minimum discharge flow of the 2-inch pump was 0.2 gallon per minute and 1.53 for the 3-inch pump. Lowering further the vertical fall or the inflow will stop the operations of the pumps.

6. Discharge Flow, D

The minimum discharge flow of a 2-inch and 3-inch ram pumps were observed to be 0.20 gal/min and 1.53 gal /min, respectively, as taken from the relationship, D = 0.6 x Q x F/E.

The Q is the minimum water inflow;F Vertical fall (F) and vertical lift (E) is one and eight feet respectively. These means the minimum inflows an minimum fall required to start the operation, below these values the pump can notbe self- actuating.

7. Cost of the locally designed DHRP

The cost of the DHRP fabrication and materials depends on the size of the ram pump as shown in Table 6. A 2 inch diameter ram pump costs Php15,000.00 per unit including labor of installation. Maintenance cost is almost negligible since the machine last up to 25 years.

While the 3 inch diameter ram pump cost per unit is Php. 30,010.00 similarly includes the data of estimation cost and maintenance cost.

Table 6. Cost of the Hydraulic Ram Pump

Size of the pump	Estimated cost/ unit total (including labor)		
2” dia. ram pump	P 15,000.00	P 10 (maintenance)	P 15,010.00
3” dia. ram pump	P 30,000.00	P 10 (maintenance)	P 30,010.00

8. Field Test and Demonstration

The 3-inch was used in the installation and field demonstration. The pump was installed in 3 areas namely; in the towns of Nueva Era and Paoay, Ilocos Norte, and in Gregorio Del Pilar, Ilocos Sur. Brangay officers and Mayors from these locations were invited during the installation and demonstration.

The operation of using the ram pump was explained and discussed during the installation.

Installation with barangay officials and farmers

Ram Pump in Operation

9. Socio-Economic Feasibility

The socio-economic feasibility of the ram pump was evaluated by comparing it with an irrigation pump powered by 3-horse power gasoline engine. The two pumps were used to irrigate fields planted with corn Table 7.

Table 7. Benefit of irrigating one hectare of corn using the hydraulic ram pump and gasoline engine-driven pump

Parameter	2-inch Hydraulic ram pump	3 hp Gasoline driven pump
Crop water requirement (m^3/ha)	6,100.00	6,100.00
Discharge rate (L/sec)	0.17	3.00
Investment Cost (IC)	12,000.00	12,000.00

Fixed Cost (FC)	4,200.00	4,200.00
Variable cost (VC) (Labor cost for installation Fuel and Oil)	500.00 0	0 28,640.74
Total Cost (FC + VC)	4,700.00	32,840.74
Cost of pumping water, P/m^3	0.79	5.32
Savings on cost of gasoline	85.20%	
Capital recovery	2,704.93	2,704.93
Payback period (year)	0.28	0.57
ROI (%)	360.33	176.33
Benefit Cost Ratio	14.2	9.02

Socio-economic analysis on the feasibility of the device revealed 85.20 percent savings on cost of gasoline over a gasoline powered water pump. In terms of capital recovery, both have P2,704.93, The ram pump has shorter payback period of 0.28 year than the gasoline engine powered pump with payback period of 0.57 year.

On the other hand, the return on investment, the ram pump has higher return on investment of 360.33 % than the gasoline fed pump with return on investment of 176.33 percent. Again, the ram pump gave higher benefit cost ratio than the gasoline fed pump, being 14.2 and 9.02, respectively.

10. Acceptability of the Machine

Feedbacks on Informant Interview taken from three towns is presented in Table 8. There were 10 respondents from Nueva Era, Ilocos Norte, 5 from Paoay, Ilocos Norte, and 10 from Gregorio Del Pilar, Ilocos Norte. Hydraulic ram pumps were installed in these areas for irrigation and domestic purposes. Nineteen or 76% of the 25 respondents stated that the cost of the ram pump is lesser than the traditional pump. Twenty two (22) or 88% out of the 25 respondents said that the ram pump can easily operated by both male and female operator. Same number of respondent claimed that lesser maintenance required by the pump than the traditional gasoline pump.

Table 8. Results of Feedbacks on the Informant Interview

ITEM	LOCATION*			All Areas (%)
	Nueva Era, Ilocos Norte	Paoay, Ilocos Norte	Del Pilar, Ilocos Sur	
Total Number	**10**	**5**	**10**	**25**
Cost (lesser than traditional)	**7**	**4**	**8**	**76%**
Ease of Operation	**8**	**5**	**9**	**88%**
Maintenance (lesser)	**9**	**4**	**9**	**88%**
Parts locally available	**10**	**5**	**10**	**100%**
Environmentally friendly	**10**	**5**	**10**	**100%**
Accepted (willing to invest)	**10**	**5**	**9**	**96%**

***1 Mayor and 3 Barangay Chairmen from each location**

All of the respondents (100%) said that the parts of the ram pump are available in the locality, and it is friendly to the environment since, no pollutants emitted during the operation of the ram pump.

Almost all of the respondents 24 (96%) accepted the use of the ram pump and willing to invest on it.

Limitations of the Technology

The device will operate in areas with flowing/flowing water source. A water fall of less than 1 foot can not operate the device.

V. Conclusions

It is concluded that the local hydraulic ram pump with a diameter of 2 inches at 1ftvertical fall can deliver minimum of 2.4 gallons/min to a vertical lift of 8 feet. On the other hand, the 3 inch diameter pump at 1 foot vertical fall can deliver 20.4 galloons per minute the to a vertical lift of 8 feet. Below 1 foot vertical fall. Operation of both ram pumps stop.

This is very significant for areas far above the water source. However this pump can only be used in areas with flowing water.

Since the device does not use fuel and electricity it can help farmers and other users to lessen operating expenses for their farms and home fixtures. It can therefore be adapted by small farmers because of its low installation cost.

The downdraft type hydraulic ram pump where installed, occupies less space that the traditional types of ram pump.

All of the respondents wanted to invest on such pump because it is easy to install and operate, friendly to the environment,and maintenance free.

VI. Recommendations

1. Further, study should be done on the performance characteristics of the downdraft hydraulic ram pump to determine the highest discharge flow, vertical lift, and vertical fall in order to optimize the design.

2. Study the possible means to further decrease installation/investment costs.

3. The optimum sizes of the downdraft hydraulic ram pump to be suitable to the certain source and application.

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VIII. Acknowledgement

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C. Summary of Yearly Comments of Evaluators and Action Taken by Researchers

- Include cost per unit
- Estimate maintenance cost

D. Problems Encountered and Recommendations

I. Technical: None
II. Administrative: None