

Development and performance evaluation of a vacuum drumbased water pumping system

ABSTRACT

A vacuum drum-based water pumping system is a very cost effective system for lifting and carrying water from a nearby flowing canal/nallah as well as from standing water of farm pond/open well. Water can be filled manually or via other devices, such as a solar pump or a treadle pump. Nearly 80% of the drum's capacity is filled with water and the remaining 20% is kept empty. A continuous supply of water is now created by closing both air release valves and opening the discharge cell. But in all actual circumstances, there will be leaks, which will cause the pressure to fluctuate and rise. The major component of the developed system includes MS drum, PVC pipe, jointer, elbow joint, T-joint, L-joint, regulator valve, and foot valve. The testing of vacuum drum based water pumping system was evaluated at constant suction head and carrying different horizontal distances, both affecting the rate of discharge. The result shows that the vacuum drum based water pumping system gave a discharge of 2 lpm to 2.07 lpm at constant suction lift of 1.22 m and distance is varying from 0 m to 12 m. It was also found that the discharge increases with the distance having peak discharge at 6 m i.e. 3.16 lpm and afterwards it decreases gradually as the carrying length increases. The cost of vacuum drum based water pumping system with 5400 litres capacity of water at 1.22 m operating head was found to be Rs 352.41.

Key words: Vacuum, Discharge, Suction head, Carrying water, Economic cost, and Vacuum drum based water pumping system pumping system (VDBWPS)

Introduction

India is an agrarian country with nearly 75% of the people directly or indirectly depending upon agriculture. Water is the prime input in agriculture and there are different means available for water lifting including a wide range of pumps. Most of these irrigation pump sets are mainly operated either using electricity or diesel power, having a significant carbon footprint especially, when the electricity is being generated in thermal power plants.

A vacuum drum based water pumping system is a non-conventional water pumping system that operates as a positive displacement pump and uses vacuum as the pumping medium. Under normal environmental conditions, creation of vacuum requires a removal of gases, contained in atmospheric air, from a given vessel or a chamber. A vacuum is a condition in which the pressure is below atmospheric pressure (Addala, 2015). Similarly reported by Berman, a vacuum is a gaseous environment with lower pressure or density than the standard atmosphere, typically achieved by pumping gas from an airtight vessel (Berman, 1984).

The system does not require conventional fuel sources for its operation and is self-sustaining for pumping water in standing and flowing water, given suitable site conditions. The construction of the system is simple and can be created using materials that are readily available in the local market. The system allows a column to be formed by closing both control valves and opening the discharge cell with vacuum pressure during operation and continuous water syphoning. The air chamber is a standing pipe that equips with the outlet pipeline for increasing the pressure of the discharge (Yenphayab, 2019). A vacuum based water pumping system there has no moving parts, that's eliminating wear and particulate creation of vacuum inside the closed chamber and increasing reliability, also the power required is low as there has no valve are required, and the pumping system is silent, without noise being generated (Young, 1999). Vacuum drum based water pumping system; it also avoids the manpower; provided running water is available under site-specific conditions.

Materials and Methods

The present research work has been carried out in the field of laboratory, Department of Soil and Water Engineering, SVCAET & RS, FAE, IGKV, Raipur

and Centre of Excellence on Protected Cultivation and Precision Farming, IGKV, Raipur, (C.G.), situated in the central part of Chhattisgarh at Latitude 21°14'9'' N and Longitude 81°42'10'' E and at an altitude of 302 meters above from the mean sea level.

A Vacuum Drum based Water pumping system is a non-conventional water pumping system that works as a positive displacement pump using vacuum as a mean of pumping. The Auto-CAD software was used to create a drawing of vacuum drum based water pumping system. The dimension of the vacuum drum based water pumping system is 3000 mm in length, 1828 mm in width and 1371 mm in height, as shown in Fig. 1.

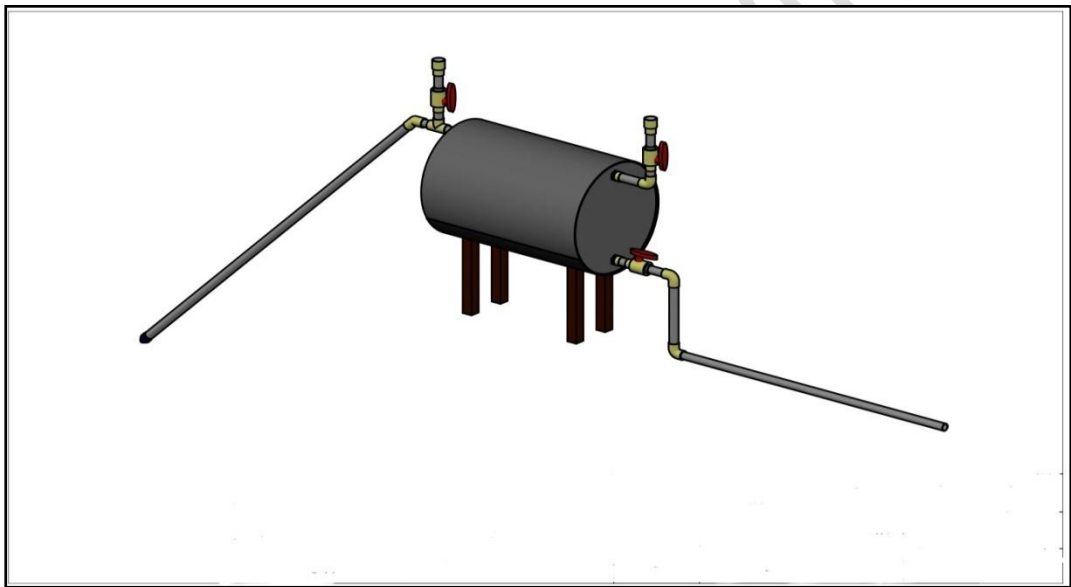


Fig. 1: 3D view of vacuum drum based water pumping system

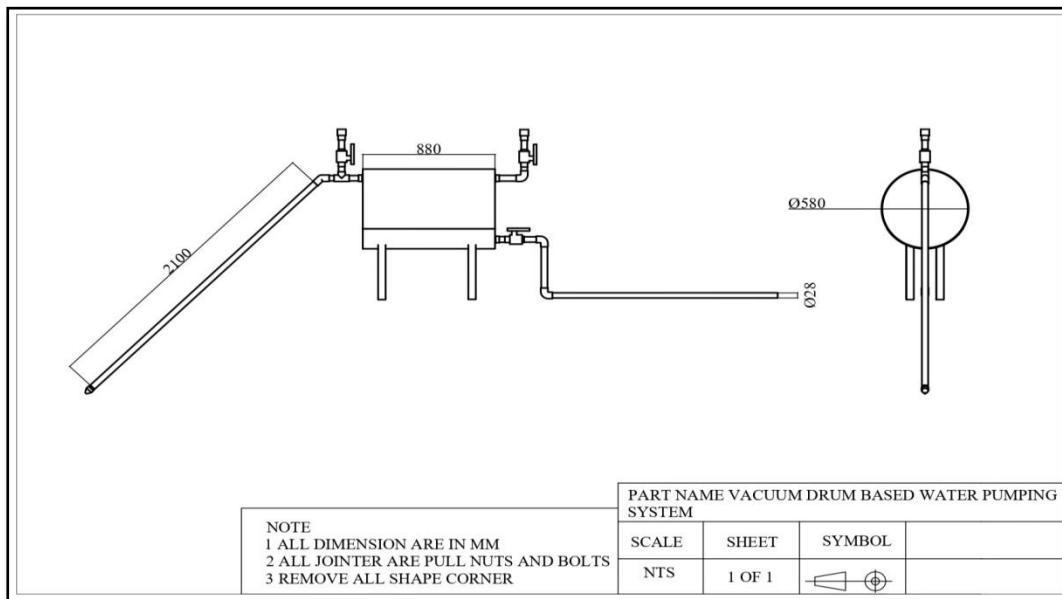


Fig. 2: Isometric view of vacuum drum based water pumping system

Major components of vacuum drum based water pumping system (VDBWPS)

MS Drum: The drum was made of mild steel iron (MS) having the capacity of 200 litre and the weight of 22 kg. The MS drum is supported on stand at the ground surface in the source of water. The dimension of the MS drum was 580 mm diameter and length 880 mm.

Main stand: It was made of mild steel having overall dimension of 762 mm in length and width of 609 mm. It is the most essential part of vacuum drum based water pumping system, and provides strength and also has stability of the overall system body. The frame holds weight of the entire systems.

PVC pipes: It is made of plastic pipe and having 25 mm diameter, used for the plumbing or other purpose of water pumping system and strength, durability, installation, has to high as compare to the mild steel pipe. The PVC pipe of 5 m length has been used in the system.

T-joints and L-joints: In general the most widely used joints are T and L. These joints are made of PVC material, and has diameter of 25 mm for both. These joints have been used for interconnecting PVC pipe in the system.

Regulator valve: Three regulator valve of diameter 25 mm has been installed in the system. Out of the 3, one control the outlet of water and the two regulate the pressure within the system.

Solvent cement: Solvent cement is used for proper sealing of all parts of the system. It is in liquid form that has to be applied on the mouth of two interconnecting pipe and then joined. Solvent cement is strong adhesive and dries within few second.

Jointer and Socket: These are used to joint two interconnecting pipe. Special attention has to be given while joining so as to avoid leakage in the system.

Foot valve: Foot valve is also known as one way valve or check valve that only allow the inlet of water and omit the back water flow and fixed at the bottom end of the suction pipe. It includes the strainer which helps to prevent the foreign material at the time of suction. It also maintains the water in the suction pipe during functioning of the system. The dimension of foot valve is 28 mm diameter.

Working of vacuum drum based water pumping system

A water pumping system is a very effective system for lifting and carrying water to farm pond/open well from a nearby canal/nallah. It consists of MS drum, PVC pipe, elbow joint, T-joint, jointer, regulator valve, foot valve, frame. A drum with 200 litre capacity is fixed on a foundation of suitable height. Two holes of 1” diameter is attached with air release valve at 90 degree angle and third hole of 1” is given for discharge cell. One of regulators is attached with suction pipe whose one of the ends is connected with foot valve which has to be submerged in water body. For operation, drum has to fill-up with water via air release valve. Water can be filled manually or through other means like solar pump, gym cycle pumps etc. Only 80% of the drum capacity is filled with water while the rest 20% space is left out. Both air release valve are now closed and discharge cell is opened creating a continue supply of water. However, in all the real situations, the pressure will not remain constant and increased due to the presence of leaks. A site with quick and shallow surface flows, such a canal, nallah, or river, is ideal for the operation of the developed vacuum drum-based water pumping system.

The working of the developed vacuum drum based water pumping system for require suitable site condition, where fast and shallow surface flow are available such as canal/nallah or river.

Testing procedure of developed vacuum drum based water pumping system

Measurement of suction lift: The suction lift is the vertical distance between the water level in the pond, canal or river and water level in the drum where the water stored. It is measured by the difference of lifted level of the two concerned points. The suction lift was adjusted by fixing the carrying distance at different points in the slope of field.

Measurement of discharge by the pumping system: The pumping discharge was measured using the volumetric method, calculating the time taken to fill a bucket of known volume. The pump discharge was calculated in litres per minute, by dividing the amount of water discharged by the measured time. The time required to fill the bucket was counted with a stopwatch.

Results and Discussions

When the suction lift is constant at 1.22 m and distance is varying from 0 m to 12 m, it was observed that the discharge of water varying from 2 lpm to 2.07 lpm. It was also found that the discharge increases with the distance having peak discharge at 6 m i.e. 3.16 lpm and afterwards it decreases gradually as the carrying length increases. This may be due to the fact that directly at the discharge near the drum, there is possibility of entry of air into the drum. With increase in carrying pipe length the opportunity of entry of air reduces while after some length the friction losses escalates and reduces the discharge. At constant suction lift of (1.22 m) and varying horizontal carrying distance as detailed in Table 1.

Table 1: Testing of vacuum drum based water pumping system at constant suction lift of (1.22 m) and varying horizontal carrying distance

S. No.	Bucket vol. (lit)	Time, (sec)	Discharge, (lps)	(lpm)	(lph)	(lpd)	Distance, (m)
1	1	30	0.033	2.00	120	2880	0
2	1	27	0.037	2.22	133.3	3200	2

3	1	23	0.043	2.61	156.5	3756.5	4
4	1	19	0.053	3.16	189.5	4547.3	6
5	1	24	0.042	2.50	150.0	3600	8
6	1	27	0.037	2.22	133.3	3200	10
7	1	29	0.034	2.07	124.1	2979.3	12

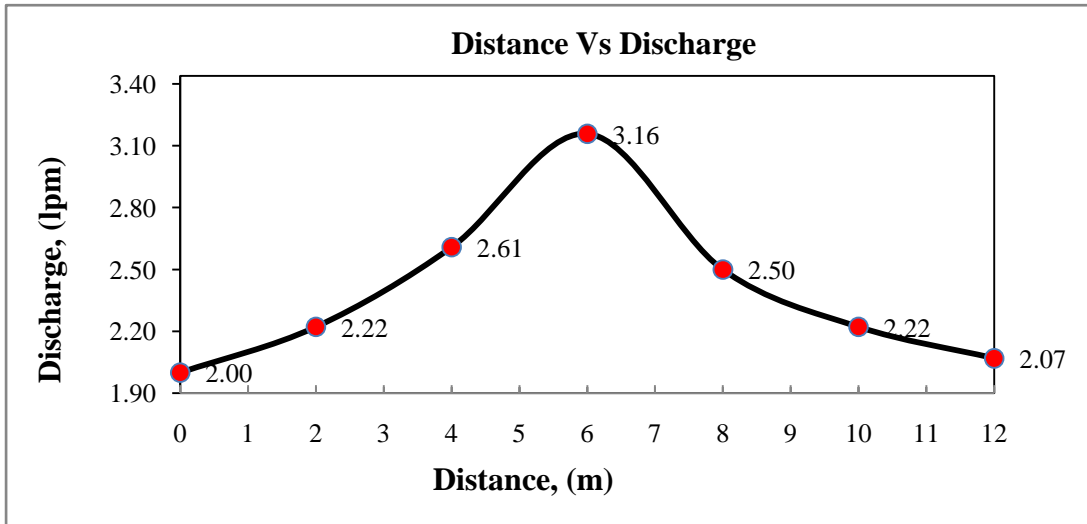


Fig. 3: Relationship between discharge and varying horizontal carrying distance at constant suction lift (1.22m)

When the suction head is constant at 1.08 m and distance is varying from 0 m to 12 m, it was observed that the discharge of water varying from 2.22 lpm to 2.40 lpm. It was also found that the discharge increases with the distance having peak discharge at 5 m i.e., 3.53 lpm and afterwards it decreases gradually as increasing the distance. At constant suction lift of (1.08 m) and varying horizontal carrying distance the system performance is as detailed in Table 2.

Table2: Testing of vacuum drum based water pumping system at constant suction lift of (1.08 m) and varying horizontal carrying distance

S. No.	Bucket vol. (lit)	Time, (sec)	Discharge, (lps)	(lpm)	(lph)	(lpd)	Distance, (m)
1	1	27	0.037	2.22	133.3	3200	0
2	1	24	0.041	2.50	150	3600	1

3	1	20	0.050	3.00	180	4320	3
4	1	17	0.058	3.53	211.7	5082.3	5
5	1	21	0.047	2.86	171.4	4114.2	7
6	1	23	0.043	2.61	156.5	3756.5	10
7	1	25	0.040	2.40	144	3456	12

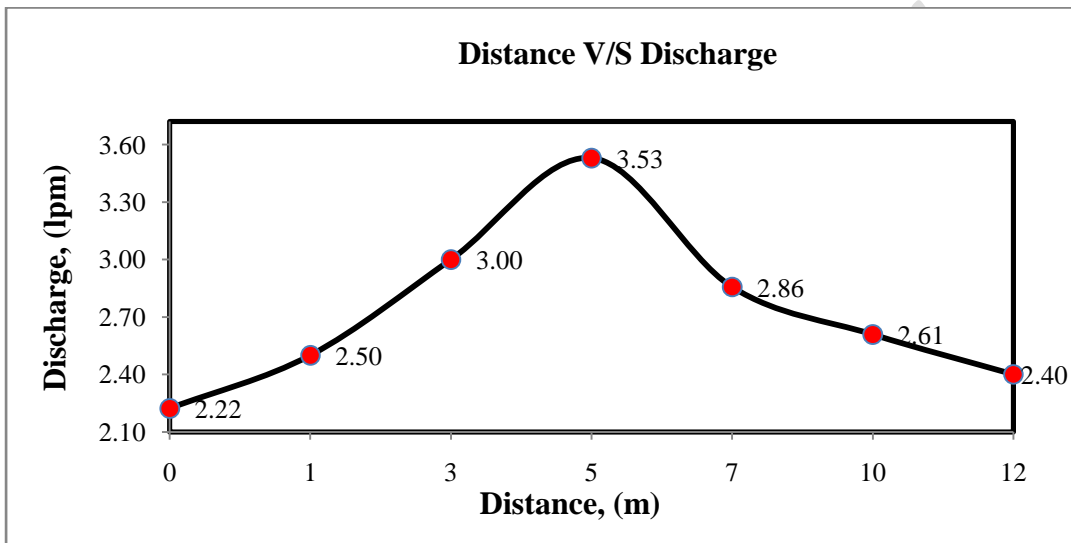


Fig. 4: Relationship between discharge and varying horizontal carrying distance at constant suction lift (1.08 m)

When the suction head is constant at 1.08 m and distance is varying from 0 m to 12 m, it was observed that the discharge of water varying from 2.22 lpm to 2.40 lpm. It was also found that the discharge increases with the distance having peak discharge at 5 m i.e. 3.53 lpm and afterwards it decreases gradually as increasing the distance. At constant suction lift of (0.92 m) and varying horizontal carrying distance the system performance is as detailed in Table 3.

Table 3: Testing of vacuum drum based water pumping system at constant suction lift of (0.92 m) and varying horizontal carrying distance

S. No.	Bucket vol. (lit)	Time, sec	Discharge, (lps)	lpm	lph	lpd	Distance, m
1	1	26	0.038	2.31	138.4	3323.0	0

2	1	23	0.043	2.61	156.5	3756.5	2
3	1	19	0.052	3.16	189.4	4547.3	4
4	1	16	0.062	3.75	225	5400	6
5	1	20	0.050	3.00	180	4320	8
6	1	23	0.043	2.61	156.5	3756.5	12
7	1	28	0.035	2.14	128.5	3085.7	14

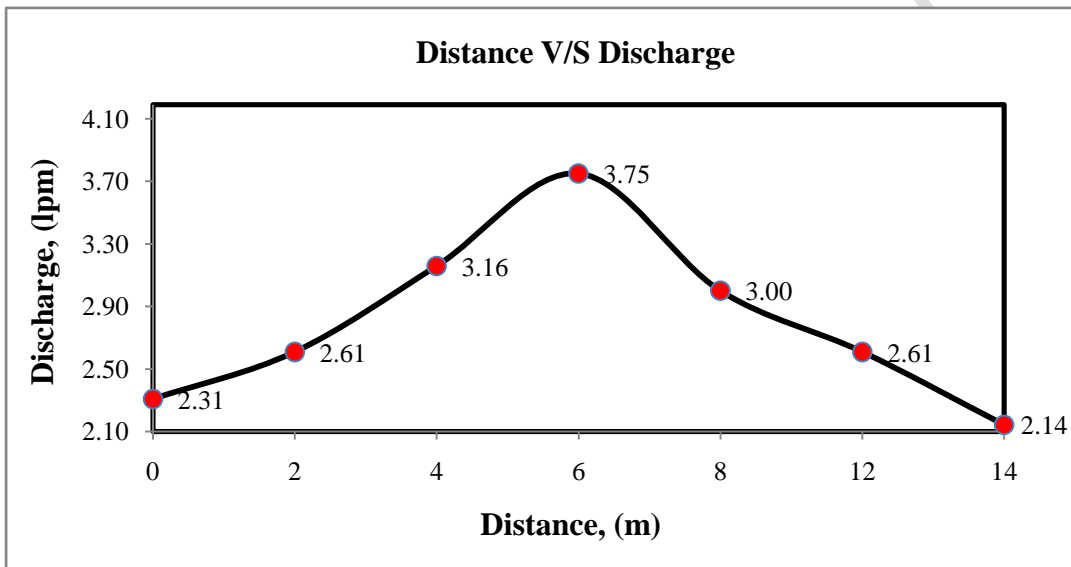


Fig. 5: Relationship between discharge and varying horizontal carrying distance at constant suction lift (0.92m)

The test was conducted at three different suction lifts via; 1.22 m, 1.08 m and 0.92 m. The highest discharge was found at suction lifts of 0.92 m at a distance of 6 m with the peak discharge of 3.75 lpm.

Economic analysis of vacuum drum based water pumping system

Economic evaluation is a comparative analysis of inputs and outputs of two or more than two alternative activities. The economical cost evaluation of vacuum drum based water pumping system is to evaluate the optimum course of action. During the performance evaluation of vacuum drum based water pumping system at varying suction lift and distance, it was found that the average discharge of vacuum drum based water pumping is 5400 lpd at 0.92 m of suction lift. It has always been a demand that the "technology should be technically feasible,

economically viable and socially acceptable". The developed technology under this study seems acceptable as a technology provided site specific and technically required conditions are met with. The discharge of Vacuum drum based pumping system seems quite less; however, it is suitable under different specific situation including standing water. The performance of the VDBWPS has also been compared with the conventional system of using electric AC motor (12 Volts).

Conclusions

The vacuum drum based water pumping system (VDBWPS) was developed with the dimension of 580 mm diameter and length of 880 mm, PVC pipe 25mm diameter and length 5 m length, and with overall height of 1.09 m. The system can give a discharge of 3600 lpd to 5400lpd at suction lift of 1.22 m to 0.98 m and carrying distance of 1 m to 10 m from the pumping site and can constantly feed small agricultural field, utilizing the vacuum generation inside the closed vessel or drum.

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