Ram Pump Final Report

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Abstract

The team this semester focused mainly on rebuilding and improving the ram pump and its lab set-up. Major changes to the system from last semester include a more compact head loss system, higher overhead drive tank (to better simulate Honduras parameters), and an attempt to improve the air chamber design, In the end, the team was able to construct a working prototype that succesfully pumped and delivered water through the entire head loss system. However, due to time constraints, the future team will have to make additional imrpovements to the system. They include a larger, encased recycling system, and more structural supports to minimize instability. Although the intial run proved succesful, additional testing could not be conducted due to computer malfunctions and again, time constraints. Had given the time, experimentaiton would be conducted regarding the flow rate, head loss, reliability, and scaling. Future teams can now focus on these experimentations since the prototype is basically complete.

1 Introduction

AguaClara creates sustainable water treatment plants that are powered entirely from the force of gravity and hydraulic principles, making them completely electricity-free. Plant operators need a supply of clean water to mix stock concentrations of coagulant and chlorine for treatment processes in addition to having water for restrooms in the plant. However, since plant outlets (and the source of clean water) are located at much lower elevations than the plant itself, this presents difficulties in transporting treated water back into the plant for filling chemical stock tanks and plumbing without carrying the water or using an electrical or gaspowered pump. The ram pump is being considered as a solution because it utilizes the water hammer effect to pump water to a higher elevation than the source water and does not require electricity.

The ramp pump technology has first tested and patented in Europe in the late seventeen hundreds; John Whitehurst invented a non-self-acting ramp up and Joseph Montgolfier added a valve which made the innovation self-acting. For the early half of the seventeenth century, most ram pumps were imported from Europe. It was only after the 1840's when farmers in the US started using American Models. By 1879 the ram pump was included among the top 55 most important inventions in the history of man kind, it's ability to use the weight of falling water as a mechanism to raise itself a considerable height is invaluable.[?] A ram pump is typically used to pump water from a stream to a village that is up a hill or some distance away. The pump operates continuously and the delivered water empties into a reservoir for the village to use. The AID Foundation in the Philippines has made significant progress by working with other partners to install ram pump in needy villages. The implementation of this technology won them an Ashden Award in 2007.[?] It is known for a inexpensive and reliable source of water for livestock and irrigation. By using a ram pump, one can utilize off stream watering. This allows easy access to water and reduces stream bank erosion and prevalence of waterborne diseases in animals. Off stream watering removes livestock from these areas.[?]

In accordance to AguaClara's core values of sustainability and electricity-independence, the ram pump utilizes only gravity and hydraulic principles to raise water to higher elevations using the momentum of water falling from a shorter elevation. Through a series of interlocking valves controlling synchronized pressure systems, the ram pump allows the water hammer to build up and then uses that pressure to drive the process. This requires no external energy to pump the water to a higher altitude.

The ram pump is incredibly essential as it allows filtered water to be efficiently pumped back to the plant for use in the chemical stock tanks and bathrooms. The recent installation of a ram pump in San Nicolas, Honduras, shows that the most important metrics to experiment on are efficiency, durability and compactness. The team will obtain real-time data (such as influent flow rate, delivery rate, the amount of head loss that must be overcome) from Honduras and replicate the same conditions in the lab by manipulating the overhead drive tank height and the head loss generating system. We plan to significantly improve the performance of the ram pump through design improvements that not only warrant a higher delivery rate but also increase the longevity of the pump. Once we have arrived at a final model, we would also like to scale the pump for plants with different flow rates and consider incorporating it into the CAD models of plant designs.

2 Literature Review

The ram pump uses a cyclic water hammer and hydraulic principles to bring water from a lower to a higher elevation without using electricity. The empirical formula for the flow rate produced by this process is as follows:

$$Q = \frac{ESF}{L} \tag{1}$$

where Q=pumping rate; S=drive flow rate; E= energy efficiency; F=height from source; L=height to destination [?]

The team wants to use the same velocity that is delivered into the ram pump at the water treatment plants in Honduras in the lab. In the previous report, the team also looked into the effects the air chamber has on the delivery flow rate Because the air chamber was placed after the waste valve, it did not seem to make a dramatic change to the delivery flow rate. Now that the design is different, the effect can be re-measured. The team created an air chamber which has a bike tire inside of it which absorbs the pressure shock from each ram pump cycle. In previous years the entire tire was inside the chamber so no adjustments could be made. Ideally the chamber will allow the bike tire's nozzle to remain outside of the chamber. This allows air to be either pumped into the tire or taken out fo the tire. The pressure in the tire can now also be measured since the nozzle is outside of the sealed air chamber. The team made an air chamber this year which allowed the nozzle to remain outside of the chamber, however due to techinical difficulties, a pressure sensor could not be applied there and the team had to revert back to the previous design. More work can be done next semester to implement this improvement.

The purpose of the air chamber is to provide a constant supply of water to the delivery pipe while preventing harmful effects from the water hammer pressure surge. According to the Development Technology Unit at Warwick University, there is a range of volume of air that should be in the air chamber depending on the volume of water pumped per cycle (each cycle is one opening of the delivery valve). The recommendation they give is that there should be from 20 to 50 times the volume of air in the chamber as compared to the volume of water pumped per cycle. This will mean that the change in pressure after each cycle will have a negligible effect on the pressure of the air chamber, leading to a more continuous delivery flow. One can write the equation in the following form:

$$V_{air} = \frac{cQ\Delta t}{n} \tag{2}$$

where V= volume of air in chamber; c = a constant in the range [20 to 50]; Q = the pumping rate; t = time interval; n = number of cycles in the time interval [?]. To optimize the delivery flow rate, the team wants to stabilize the head loss and to do that the change in pressure will be measured and by using easy data, the team can find a way to do this for the new design.

Regretfully, the team did not have enough time to start testing and verify the equations this semester.

3 Methods

3.1 Apparatus

A schematic of the setup can be seen in Influent water flows out of a overhead drive tank (i) through a 2" extention within the pipe.. A manual valve (b) is used tostop the water flow when necessary. While the manual valve is open, it flows through the extension through a contraction into a one inch drive pipe (c). The check valve (e) is initially closed while the waste valve (d) is initially open. As water flows through the drive pipe via gravity, the flow velocity builds up and closes the waste valve. This produces a high pressure known as the water hammer and forces the check valve open. Water then rushes into the air chamber (f), causing the air column to compress. The compressed air then forces the water back, closing the check valve. By pushing down on the water surface, the air chamber also allows water to be delivered at a steady rate rather than in pulses. Between the opening and closing of the check valve, water is delivered through the 1/2" delivery pipe (g). The pressure surge from the water hammer dissipates and the waste valve opens up once more, restarting the cycle. (Waste water from the check valve, which is treated water and will be distributed in actual plants, is then pumped to the recycle tank (j) in our set-up.) from the air chamber, water is delivered through our head loss system (h), which is a coiled 3/8" tubing that simulates 7.0 meters of head loss that is mimicked based on designs for treatment facilities Honduras. The sections of the delivery system going up add up to the desired head of 7.0 m, and as water flows, the up sections will fill with water while the down sections will involve free falling water, implying that the pressure is (almost) constant in these sections. Thus, the head accumulates and simulates the 7.0 m head encountered in the plant in San Nicolas. Lastly, to reuse the water during our experiment, water from the recycle tank is pumped up to the overhead drive tank; the water level in the drive tank is maintained by the overflow weir (i),which brings excess water back to the recycling tank. See 2 for the actual set-up.

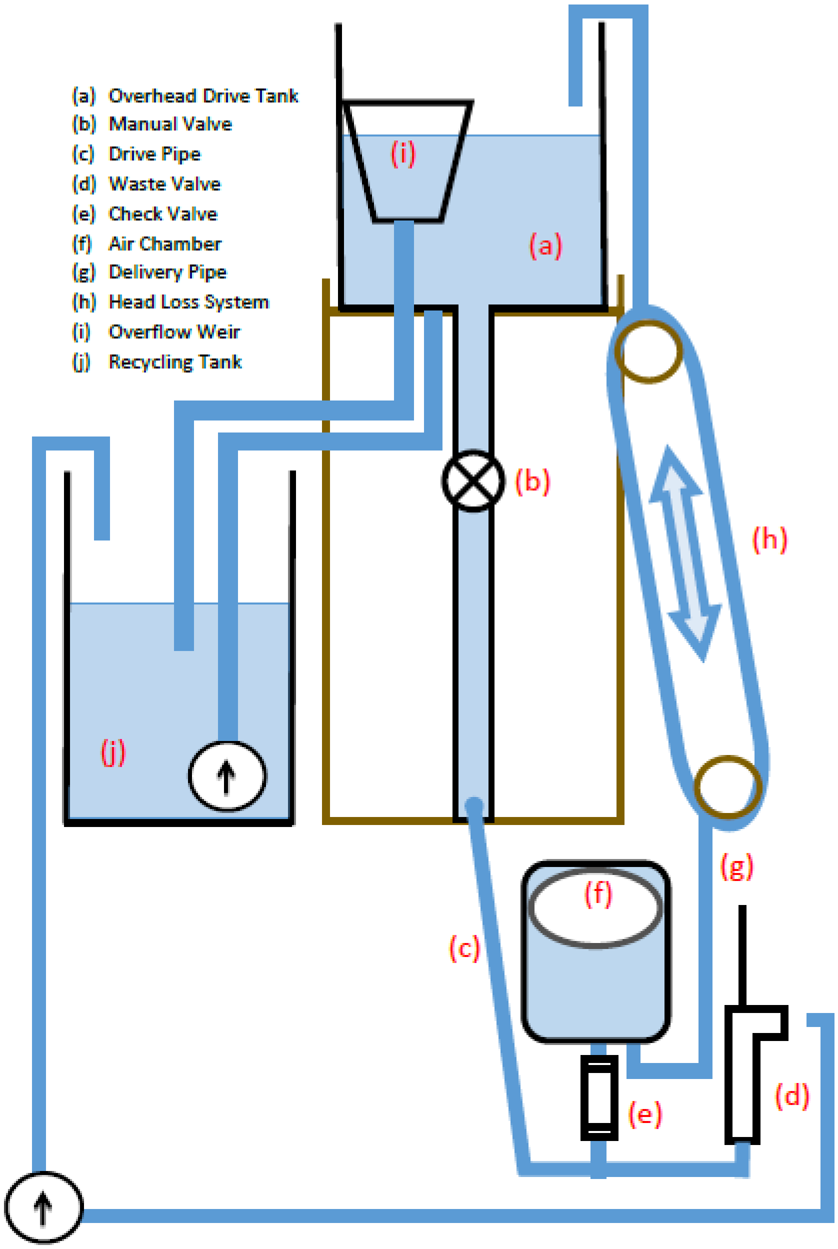

Figure 1: Schematic of Ram Pump Apparatus

Figure 2: Actual Set-Up of Ram Pump Apparatus

3.2 Head Loss System

The team is currently testing out a head loss generating system that involves tubing instead of PVC pipes. The structure of the system has been modified to accommodate for this new head loss generator. Last semester, the head loss system used up a great deal of space and didn't achieve the head loss required.

This semester, we've condensed it a great deal with the hopes that it will not only open up lab space but also achieve seven meters of head loss (see 3) Don't forget to place the figure after the paragraph you mention it in. Now that the system is connected to the ram pump, testing will begin. Pressure sensors will be applied at the beginning and the end of the head loss system. The sensors will be located at (g) from 1 and at the end of (h). Don't for get to update this to reflect what you actually did during the semester. The final report should be describing what you've done.

Figure 3: Team Member Ruju with the Head Loss System

The tubing is currently 50 feet long with a 3/8 inch inner diameter and 1/2 inch outer diameter. The equation for head loss is as follows:

$$H_f = F\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

where H_f is total head loss, F is friction factor related to the roughness inside the pipe, L is the length of the pipe, D is the diameter of the pipe, V is the average liquid velocity in the pipe, and g is the Universal Gravitational Constant ($g = 9.81\frac{m}{s^2}$).

As evident from the equation, head loss is directly proportional the the length of the pipe. Since the tubing being used is coiled instead of straight, the team assumed that only the sections where the water is traveling upwards should be accounted for because in the downward sections, gravity is helping the water fall instead of the ram pump. This assumption was made because the ram pump should be pumping against gravity, but in these downwards sections the pumped water travels through the tubing with the help of gravity. However due to inadequate testing there is not enoughd data to verify or deny this assumption. Essentially, the effective length is close to the vertical height of the coils multiplied by the number of coils. However, the exact performance of the coiled tubes is unclear, because not only do we need to account for head loss in the tubes, we need to account for head loss where the tube curves and where it exits the air chamber. From last semester's experiments, water has also been observed to build up at the bottom of each pipe, which detracts from the effective length of the system. To remedy this, the team has angled the tubing to ensure that air is always present in each section of the pipe. Because of these uncertaities that are difficult to account for, calculating the theoritical head loss is unreliable; therefore, head loss values should be measured directly from EasyData and varied by changing the length of the tubing.

In conclusion, the head loss system is a new implement created by the AguaClara team and has not been robustly tested; as a result, the team will mostly rely on the actual pressure reading from the sensors and adjust the length of the piping until we each the desired head loss, and then continue to monitor the sensor for a steady head loss generation.

3.3 Experimental Methods

The over head drive pipe was tested along with the the recycling system. The team also tested if water can be pumped from the water container (recycling tank) on the floor through the bent piping into the over head drive tank. By testing this section of the pump, via pumping water up from the recycling container to the overhead tank, the team realized that the ram pump was not ready to be tested as the system experienced leaks and the piping connection was weak and had to be glued. Also, the system shakes due to inadequate support at the base. Adding some weight to the bottom of the structure will solve the issue; however, this will have to be addressed by the next team.

Regarding the waste valve, it seemed like enough pressure wasn't being built up in the system because the weight wasn't being pushed up/down as it should. The waste valve wasn't screwed in correctly due to some damaged threads, so another part was ordered to ensure that the valve was straight.

4 Analysis

4.1 Issues

During preliminary testing, the team ran into numerous issues that prevented sucecsful run of the pump. The next team should take care to avoid the following problems.

- Leaks were noticed from various parts of the system such as: some joints, into and out of the over head drive tank, the waste valve, and the air chamber.

- The air chamber could not withstand the pressure of each cycle due to improper gluing. The air chamber is fixed, but if the next team wishes to create another air chamber (ie one where the bike tire nozzle is on the outside or different sizes), take care to not use old, chunky glue and wait for the glue to set completely.
- Make sure to order all correct parts as soon as possible to save time.

4.2 Initial Run

Once all of these issues were resolved the team could move on for their first initial run. The waste valve needed a little bit of assistance to start working properly. However, once prompted the system ran for about twenty seconds without any failures in the waste valve or the swing valve. In addition the pump was able to pump through the entire headloss system. Although the team is unsure of how much headloss the coiled tubing is, it is uplifting that the pump can push the water through the system. The recycling system was too small to run the system for a long time. The recycling tank is on the small side, but due to time constraints and material constraints the team stuck with with they had. So after twenty seconds of run time, the recycling tank over flowed and therefore the system needed to be stopped. The recycling pump was not fast enough. More water was coming out of the waste valve than coming out of the recycling tank. For the next run, the team will like to test flow rate and headloss. The team also needs to figure out a way to remove water from the headloss system after running the pump.

5 Conclusion

In conclusion, we built a succeeful prototype but could not conduct sufficient testing due to time constraints. We spent most of this semester building the ram pump with a lot of construction modifications, and were on track until the end of April, when we were scheduled to start the experimentation phase. We did not allot enough time in our task list for troubleshooting the system, i.e. fixing leaks and waiting for ordered parts to arrive; therefore we could not conduct any experiment past the initial run.

6 Future Work

After our initial run, it was noted that the priority of the next team in regards to modifying the set-up is to come up with a more effective recycling system. In the current set up, the leaks are substantial since the ram pump is not inside a container. This means that the waste valve spews water on every cycle. Also, the recycling pump is not consistent and shuts off whenever air enters into the system and thus needs to be unplugged to restart. Our suggestion for the next team is to look into the bin used last semester (Fall 2013) and construct something similar, but definitely with water-tight connections since leaking was also a huge problem with the bin. Another construction modification is to stabilize the ram pump more, because in the current set-up the shock waves shake the whole ram pump system. More metal connecting rods forming a cage around the pump should be sufficient. The team should also check that all the leaks are fixed and all joints are glued properly, and move the computer away from its curent location to prevent another disaster.

In terms of expeerimentation, the next team will have to test for the following metrics:

Flow Rate

One of the main goals is to maximize the delivery flow rate and improve efficiency. To achieve this, the team plans on manipulating the weights on the waste valve and changing the design of the ram pump from that of the previous semester. The team was thinking to have numerous weights of the same mass so that they could try creating a linear relationship between the weights (by adding more or taking off some) and efficiency of the pump. The team also modified the tire pump input so that the pressure in the air chamber can be measured and its effect on delivery flow rate can be tested. Delivery rate and the corresponding head loss will be recorded through EasyData.

Reliability

To check for wear points of the ram pump and ensure its continual performance, the team plans on leaving the pump on for extended periods of time and also researching the lifespan of individual parts of the pump. Since the recycling system ensures that the set-up is completely autonomous, the team has the option of leaving it on overnight for a few days at once; members will then take turns to check on the pump at various times to make sure all is running smoothly. In addition, the team will keep in contact with Drew and assess any performance issues encountered in Honduras.

Scaling

The team also plans to adjust the size of the ram pump to meet the demands of higher flow rates. This will be done through increasing the size of all parts, and a different method than the overhead drive tank might be needed to simulate the higher influent flow rates.

References