Ram Pump (and Hydraulic Test Facility)

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Abstract

The ram pump team will investigate the use of a ram pump that would be installed on the treated water line between the AguaClara plant effluent and the distribution storage tank. The ram pump would use a little of the excess elevation difference between those two locations to pump a small flow of water for use in the facility bathroom and to fill chemical stock tanks.

students	4
skills	fabrication, strong in fluid mechanics

1 Introduction

Ram pumps are a well established technology that can lift a small amount of water to a high elevation by using the energy of a large flow of water that is dropping a small elevation. This technology could be used to pump a small amount of the treated water into an elevated storage tank. The elevated water would be used to fill stock tanks and to provide water for the bathroom at the water treatment plant. See the Hydraulic Engineering Course notes on Hydraulic Transients to learn about the theory of using pressure transients to pump water. Explore commercially available ram pumps as well as the possibility of fabricating our own pump. The available head between the AguaClara plant and the distribution tank is highly variable between plants. In some locations it might be necessary to increase the size of the pipe between the plant and the distribution tank. An alternative may be to add a parallel line that is used exclusively by the ram pump.

There is extensive information on the web including plans for ram pumps from Clemson Universityand Detailed plans from Warwick University. The concepts presented in the notes on Hydraulic Transients may be used to estimate the required size of the ram pump. It is very likely that we can build our own pump given the success of the PVC ram pump by Warwick University. The design must be modified to collect all of the “wasted” water because that water must all go to the distribution tank. It is possible that the ram pump would be installed at the distribution tank or that it would be installed in the pipe gallery of the stacked rapid sand filter.

Given the extensive online documentation for ram pumps it should be possible to build and test one during the spring semester. The goal is to build one for testing at one of the water treatment plants (or distribution tanks) in Honduras during the summer of 2012.

2 Preliminary Guidance

The CEE 4540 capstone design project from the fall of 2011 included 3 teamsthat focused on design of a ram pump system for AguaClara facilities. The conclusions seem to be:

- Don't build an elevated storage tank. Instead build a larger ram pump to provide sufficient flow to fill the stock tanks in a reasonable length of time (perhaps 10 minutes). This conclusion needs to be reevaluated given the option of including a small elevated tank (the size of one stock tank) that would be located above the chemical stock tank platform.
- Given the stock tank volume and the target fill time calculate the target pumping rate
- The target pumping rate can be met either by sending all of the plant flow through a ram pump with a small elevation difference or by sending a fraction of the plant flow rate through a ram pump with a larger elevation difference. Evaluate these tradeoffs. If the distribution tanks are sited so that there isn't much head available, then the first option will be the preferred choice.

3 Experimental setup

Design and build a high flow ram pump test station in the project lab that uses approximately $100\,ft$ of $2\,in$ PVC pipe to carry water between two reservoirs with an elevation difference of perhaps $50\,cm$. We will install a ram pump in the pipe between the two reservoirs. Run the long pipe with the ram pump in a U or W shape to get a long pipeline. Have the ram pump elevate water to the laboratory ceiling and then use supercritical flow to bring the pumped water back into the high elevation tank.

In a full scale installation the ram pump will be connected to the pipe leading to the distribution tank. The water velocity in that pipe line will oscillate as the ram pump cycles. An air chamber on the distribution tank line downstream of the ram pump could be used to reduce the velocity fluctuations. This downstream air chamber will increase the acceleration of the water in the upstream pipe when the main valve is opened. This will reduce the cycle time for the pump and increase the pumped flow rate. Conventional ram pumps don't connect to a downstream pipeline and thus the hydraulics of our ram pump are novel. The laboratory setups with the long pipeline will allow us to test the effect of a downstream air chamber.

The duration of the pumping phase of each cycle is proportional to the velocity of the water in the feed pipe, the length of the feed pipe, and inversely proportional to the pumped water pressure. Evaluate the pumping efficiency as a function of the length of the feed pipe while holding the driving elevation constant. It is possible that a longer feed pipe will improve performance by increasing the volume of water pumped per cycle. This assumes that there are some losses associated with cycling the valves.

We will need to instrument the ram pump to measure flow rates, head loss in the piping system, cycle times (based on pressure traces), and pressure of high pressure line. Some of these measurements will be incorporated into the Hydraulic Test Facility.

Evaluate fabrication methods to improve performance and reduce costs. Evaluate the benefits for the high pressure air expansion tank given the short distance that we will be pumping the water. Test effect of running the ram pump with the high pressure side closed. Will the operator need to disable the ram pump when water isn't needed? What does a ram pump do if the high pressure side is blocked?

4 Hydraulic Test Facility

The hydraulic test facility will a 1/2 hp sump pump to pump up to 3 L/s of water from a tank on the floor to an elevated tank through a 1.5 inch diameter pipe (1). The elevated tank will have a 2 inch diameter over flow pipe. The overflow pipe is not large enough in diameter to handle the return flow of 3 L/s without an excessive depth of water above the pipe. A much longer weir will be created by using an inner tank that is the constant head tank. The inner tank will overflow into a slightly larger diameter outer tank. The outer tank will have the 2 inch diameter over flow pipe. The inner, constant head, tank will be connected to the 1.5 inch diameter pipe from the sump pump and a 3 inch diameter pipe fittings for the hydraulic test section.

The floor tank will larger than the elevated tank to ensure that it can fill the constant head tank. The floor tank will hold the sump pump and will have a mini tank with an LFOM that returns the water from the test section to the lower tank. The LFOM will have a height range of 20 cm and it will be possible to exchange LFOMs with different flow ranges for accurate flow measurements. The LFOM will have a pressure sensor connection to record the depth of water in the mini tank that is correlated with the flow rate through the test section.

A differential pressure sensor will also be connected between the constant head tank and the mini LFOM tank to measure the total elevation difference across the test section.

The elevated tank or the LFOM return will be adjustable height using an 80/20 frame. If the elevated tank is adjustable, then the 1.5 inch sump pump pipe and the 2 inch return pipe will have compression fittings that make it easy to swap different lengths of tubing to allow changes in the constant head tank height.

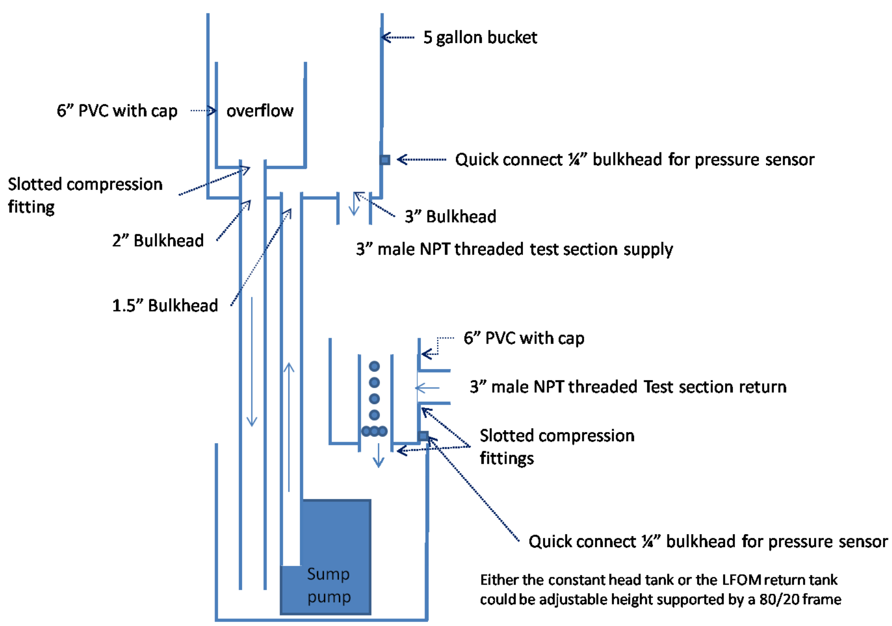

Figure 1: Hydraulic test facility schematic.