Water Pump Report: Measurements and ballistic testing

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I. Objectives

The water pump is a potential candidate for the water ballistic system to be used in the GTurret. It should be capable of firing water from a 45° degree angle and up to 6 meters in length[1]. The measurements are meant to test the actual physical capacities of the pump, and base from those the potential ballistic capacities of the pump.

II. Theory

A. Manufacturer information

Image 1. Photo of the pump, along with its operational settings.

As advertised (*Image 1.*), the pump is rated to output 72 watts of power, 6 amps of current, running on 12 volts of direct current. Unfortunately, no effective ways were found to verify those claims.

The power source for the pump is a detachable battery delivering 12 volts of power, with wires long enough to permit its installation about 10 centimeters at max from the pump itself in any given system, though the wiring can be modified to adapt any lengths that may be required. The pump itself is a rather simple mechanism consisting of two different endings (each with a diameter of 9mm): one is responsible for the suction of the liquids, and the other for the ejection of the liquid. Both ends have screw in caps where plastic tubing can be inserted to ensure a safe and waterproof seal.

B. Pump setup

The theoretical setup of the pump is an ideally hermetic system consisting of water hoses[2] (made out of EVA with a diameter of 9mm), where one end is connected to a water tank, and the other one is connected to a nozzle. The purpose of the nozzle is to control the rate of flow of the water, where varying the nozzle diameter can increase or decrease the exit velocity of the water, as well as varying the shooting pattern of exiting water (from a “spay” mode to a “jet” mode). In the case of the GTurret, the water stream should exit a high velocity, remain as a linear stream from the moment it exits the turret and travels to the desired target with little to no dispersion, to limit collateral damage and ensure accuracy and precision.

Another consideration is the speed at which the pump is able to effectively reach its maximum output flow, which typically is more of a gradual curve that can take up to a few seconds. This could stand as an issue later on, when trying to avoid collateral damage by shooting unwanted targets situated directly in front of the pump.

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[1] As defined in the hard goals of the Problem Formulation.

[2] https://www.biltema.dk/en-dk/boat/vvs/hoses/potable-water-hoses/water-hose-9-mm-x-10-m-2000060028

C. Controlled Experiments

Tests were performed in a outdoors environment, which does not closely replicate the classroom environment the GTurret will be operating in. Due to tight deadlines and a relatively short time span to develop a working ballistic system, it was decided to favor a higher frequency of testing, allowing for a greater collection of data and faster iterations of new designs. This meant testing and experimenting was done outdoors to favor speed, because experiments done indoors implied a greater amount of time dedicated to clean-up.

To perform the experiment, the ejection tube was angled at 0° and 45°, at about an arm length in height above the ground, always facing downwind. The length at which the pump ejects the water is then measured, and the disperstion of the water is visually assessed.

III. Practice

A. Nozzle Design

First iterations of the design of the nozzle consisted of a fully 3D printed cylinder of 9mm in diameter, composed of multiple circular nudges shaped like saw tooths along its shaft, raising the total diameter to around 9.3mm. The specific shape of the nudges allowed for an easier entrance into the tubing, and ensured a good grip onto the tubing once inserted. The conic tip of the nozzle had a 1mm diameter. Testing of this design proved successful, however target shooting length were not reached (<6m). Further iterations of the design were meant to enhance the range by funneling more water through a 1mm tube inside the nozzle itself spanning its entire length, however the limits of the 3D printer tolerances were quickly reached, with multiple prints failing. To correct this, a new design was established, where the nozzle itself is a stainless steel nozzle taken from a 3D printer, screwed onto[3] a 3D printed adapter that would be placed into the tubing like previous iterations of the nozzle. This permitted a greater exit velocity of the water, at the cost of also furthering the pressure in the inner chamber of the nozzle and tubing, which resulted in more force being exerted on the adapter, pushing it outwards of the tube. To prevent this, further testing was done where the different parameters were varied, such as the number of nudges on the shaft of the adapter, their diameter, the diameter of the shaft itself, the length of the screw-in nozzle, having a manually threaded hole or an already printed thread for the screw-in nozzle, and the diameter of the exit hole.

After several iterations of the design, it was finally found that the adaptors who had the greatest amount of nudges (>5), that were significantly thicker than the tubing (>9.8mm), and that had a longer length screw-in nozzle were the best performing in the tests.

B. Tubing Length

No tests were performed to accurately measure the impact of the tubing length on the exit velocity and the potential pressure build-up inside the adapter. It’s however assumed that the length of the tube on either side of the pump (suction and ejection) wasn’t a relevant factor to be taken into account.

IV. (Provisional) Conclusion

A. Pros of the system

The water pump system proved itself to be a good potential candidate for the ballistic system in the GTurret. It delivered good performances when used correctly, and was able to reach the desired shooting lengths using a suboptimal nozzle adapter[4]. If improved through R&D, the system could become much more performant and be able to shoot at greater distances and at a lower dispersion rate.

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[3] M6 Tolerance
[4] As of 15.04.2025

B. Cons of the system

The water pump system isn’t flawless, and experiments have highlighted several of its faults. Firstly, one of the major but inevitable shortcoming of the system lays in its inherent nature: the mix of electronics and water. Much of the pump, electrical board, and batteries need to be physically separated from the system, and tubing firmly sealed to avoid leakage and preventing water from short-circuiting the embedded electrical boards. However, the complete sealing of the tubing was demonstrated to be tricky, with water often leaking from the nozzle from each end of the nozzle adapter.

Moreover, the water pump doesn’t deliver an instantaneous stream of pressurized water, but rather a build up of internal pressure leading to a gradual stream of water being shot out, lessening the initial accuracy and precision, potentially leading to a higher the incidence of collateral damage.

Another negative aspect is the uncertainty of the nozzle design. While it is speculated that a more efficient and performant nozzle design could be developed, the probability that this is an unrealistic feat remains and poses as a risk to the project given, the importance of the ballistic system.