Evaluating the effectiveness of thermally controlled underground watering systems

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Introduction

Sheep require a minimum of five gallons of water per day to remain healthy (Anderson & Johnson, 1986). A common solution to freezing waterers is to use an electric water heater but for some farmers, running electricity out to a waterer is not plausible. The purpose of this projects is to determine if newly designed energy free systems will be effective in keeping water from freezing, while remaining cost efficient and low maintenance. Without electricity, the only heat source available is the ground. In Harford County, Maryland the frost line depth is about 30 inches meaning the soil at that depth remains at a constant 58 °F. Both drums that held the working fluid (water) had access to these warmer underground temperatures as a heat source. Convection currents are created when hotter liquid which is less dense and more energized, rises and colder liquid which is denser and less energized, sinks, creating currents. Water has a specific heat of 4.184 J/gram·°C (Kestin et al., 1984), this means that in order to raise one gram of water in temperature by one degree Celsius, 4.184 Joules of energy is required. The specific heat capacity of water is relatively high, meaning it holds heat relatively well. These qualities of water make it a desirable working fluid for these systems. Since the underground drums are closed systems, the system relies on convection and conduction heat transfer among the components of the system to prevent freezing.

Materials and Methods

The system is relatively simple in design, in system 1 (figure 2), the shallower drum system, a 55-gallon metal drum was buried in a hole 36 inches deep. System 2 (figure 3), the deeper drum system, was constructed similarly, except the metal drum was buried at a 49 in. depth and the remaining space between the top of the drum and the surface is 57″ gravel. The drum systems are strategically located in different grazing fields so they can be used at different times. The inside of the drums are lined with plastic bags and filled with 55 gallons of water. In system 2 a PVC pipe is attached to allow the probe to go into the drum to collect temperature measurements. Both drums are insulated around the sides with Styrofoam concrete insulation. On the bottom of each drum are 10, 11.5 in. steel rods (figure 1). The rods conduct heat from the ground below the drum. Rebar is a good conductor of heat and will allow the 58 °F ground heat to be transferred into the water in the drum more efficiently. Six steel rebar plates were modeled in Autodesk Fusion 360, to maximize surface area between the rods and drum. The file from Fusion 360 was uploaded into AutoCAD and SheetCam software to prepare the design to be cut out of a sheet of ¼ inch plate steel. From two 10 ft. rebar rods, twenty 11.5 in. rods were cut, then four of the rods were welded to each of the 18 in. plates and three rods were welded to the 14 in. plates (see figure 4). To put the systems in place, first the holes were dug using excavation equipment, then the rebar spikes and plates were driven into the ground. After this, a thin layer of sand was placed to increase contact between the rebar and the drum, which was placed on top. For system 2 the gravel will fill in the rest of the hole, then the waterers will be placed on top to complete the construction of the systems. Additionally, insulated garage panels were cut, and spray painted black so the waterer could fit in them for extra insulation, increasing the R-value of the system. When the systems are not in use, double pane glass is placed on top of the waterer with the purpose of creating a miniature green house effect. To collect data, a 6 ft. temperature probe is attached to a pole and lowered into the drum to collect one measurement at the top of the drum and one 3 feet deeper at the bottom. The last temperature measurement is taken in the waterer.

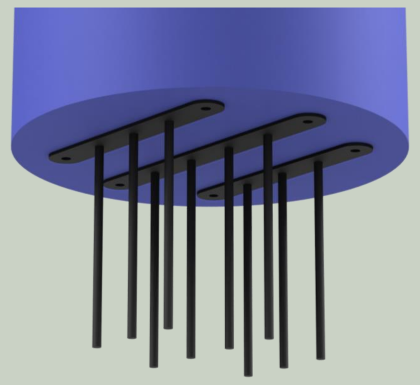


Figure 1: Rebar rods on the bottom of the drum.

Figure 2: System 1.

Figure 3: System 2.

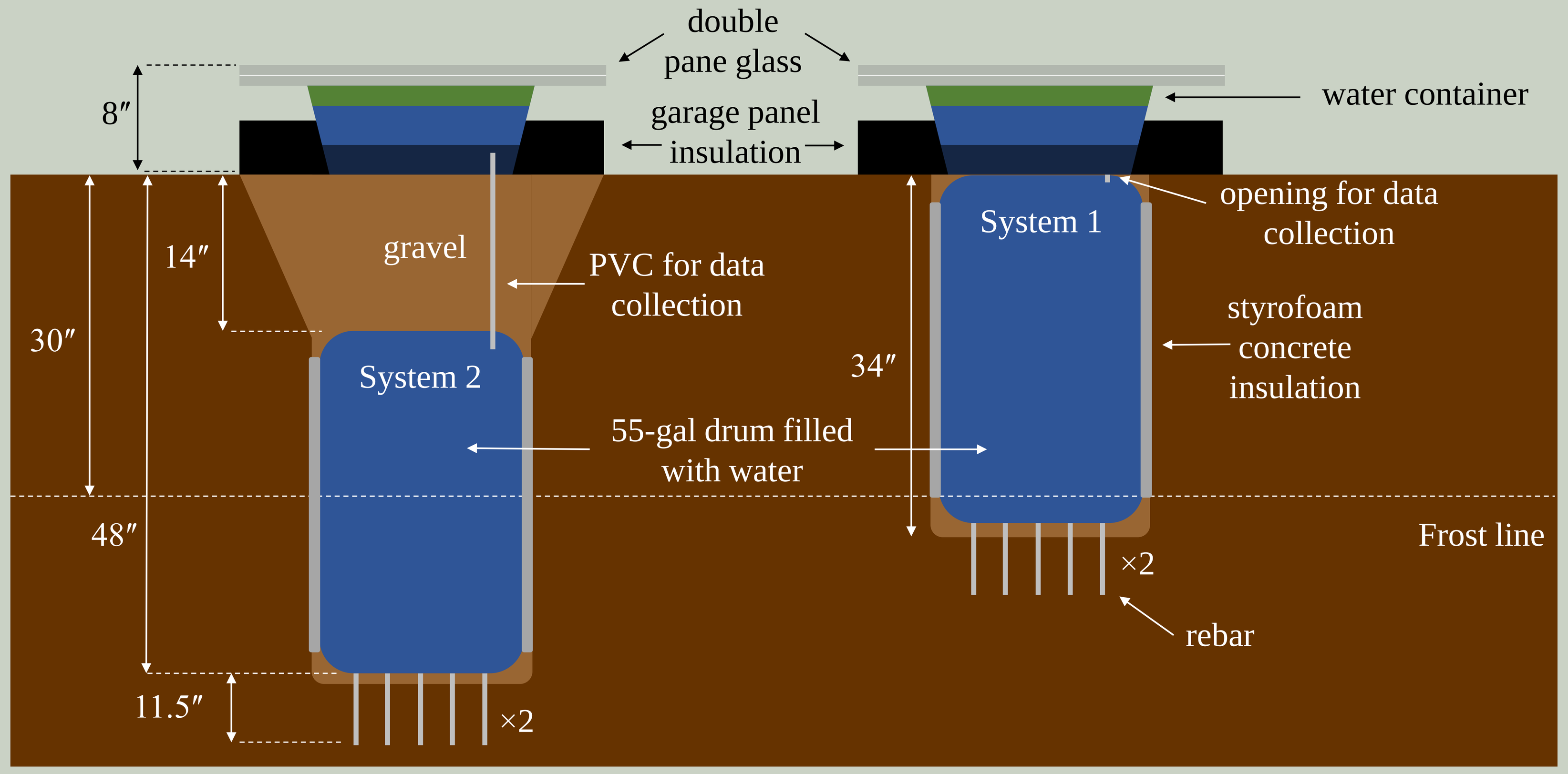
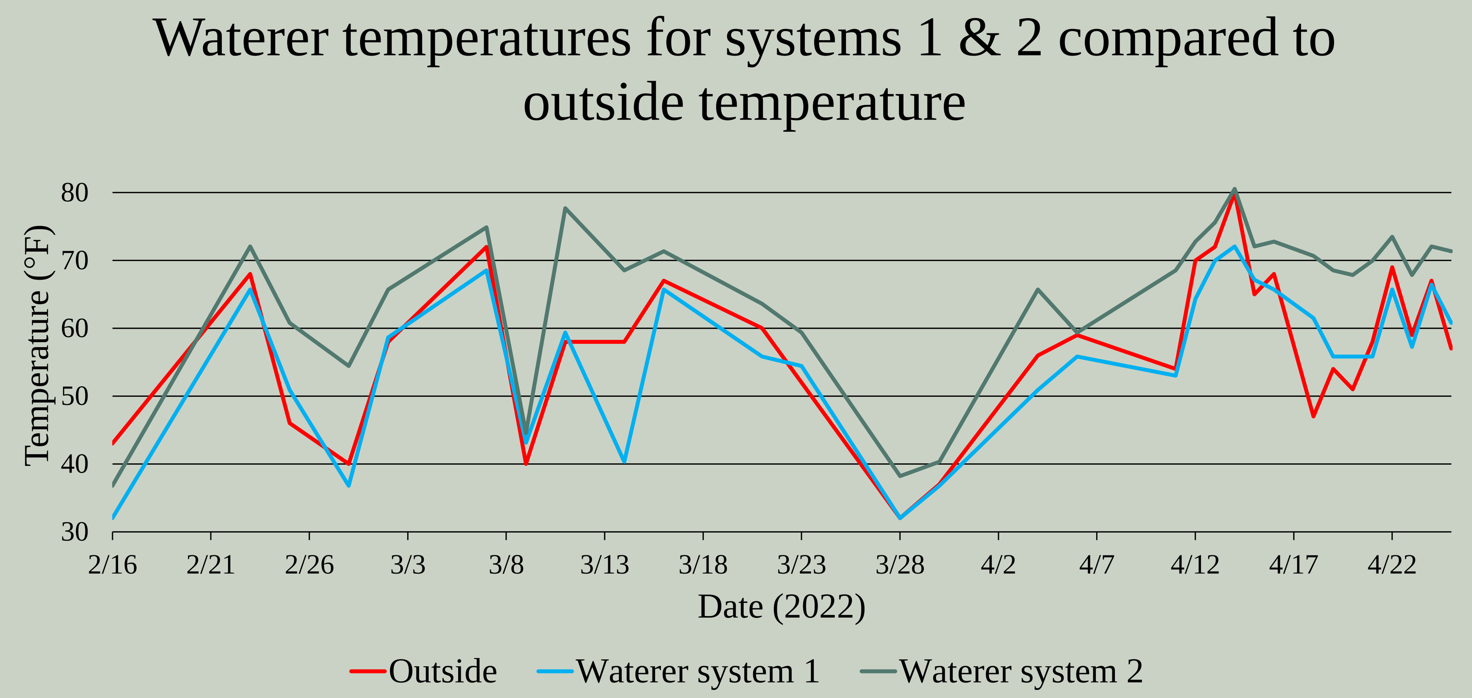


Figure 4: Diagram of the under and above ground portions of systems 1 and 2.

Results



Graph 1: The temperature of the water in the waterers of system 1 and system 2, and the outside temperature was taken between 11:00 AM and 2:00 PM. Data was collected from February 16th to April 25th, 2022.

The temperature of the waterers for systems 1 and 2, as well as the outside temperature was recorded once a day between 11:00 AM and 2:00 PM. A paired samples *t*-test was performed to compare the mean difference of water temperatures of system 1 and system 2. There was a significant difference in mean water temperatures between system 1 ($M = 58.23$, $SD = 9.92$) and system 2 ($M = 67.53$, $SD = 10.77$); $t(39) = -8.44$, $p = .003$. Since $p < .05$, there is significant evidence to conclude that the mean temperature of system 2 is higher than that of system 1, as stated by the alternative hypothesis, $\mu_1 - \mu_2 < 0$.

Conclusion

The newly designed energy free systems were effective in keeping water from freezing, while remaining cost efficient with no maintenance. The materials for each system were sourced from a local farm, making the systems easily replicable. It was determined that system 2 water temperatures were significantly higher than system 1, which is desirable to prevent freezing. The systems required no maintenance through the winter of 2021–2022 and construction costs were relatively low. Future research would be necessary to develop a continuous data collection mechanism that would evaluate the low-end threshold.

References

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Kestin, J., Sengers, J. V., Kamgar-Parsi, B., & Levelt Sengers, J. M. H. (1984). Thermophysical properties of fluid H_2O. *Journal of Physical and Chemical Reference Data*, *13*(1), 175–183. doi:10.1063/1.555707