Creation of a Small Scale Geothermal Heat Source Experiment

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Abstract

The goal of this study was to create a small-scale experiment capable of demonstrating the effectiveness of a geothermal heat pump's source as a function of the medium used, for middle and high school students. The design chosen consisted of two Styrofoam coolers (one used for a source and the other a sink), a copper tube heat exchanger, a pump, and two thermocouples (one in the source and one in the sink). A series of transient tests have recently been completed examining the effectiveness of the three different mediums considered: wet soil, dry soil, and water. These were chosen as they represent typical mediums found in both commercial and residential heat pumps. Using water as the medium greatly outperformed both the wet soil and dry soil. To increase the sink temperature from 33^{o}F to 45^{o}F took approximately 10 minutes for the water medium and 40 minutes and 55 minutes for the wet soil and dry soil respectively.

Keywords

Zero-Energy Building, Geothermal Heat Pump

Introduction

In the spring of 2014 a Zero Energy Building, where more energy is generated through alternative energy than is consumed by the building, was completed at the Advanced Vehicle Test Facility in Chattanooga Tennessee. The purpose of this building was to provide an example to the surrounding community about the need and ability to create highly efficient buildings and the impact they can have on the environment. The key additions to this building were the installation of several solar panels, the improvement of the buildings insulation, and the addition of a geothermal heat pump. For the past several years the authors have attempted to create several small scale apparatuses that can be taken to local middle schools and high schools which demonstrate one or more aspects of this building[1,2,3]. The work presented for this paper details an attempt to create a small scale apparatus demonstrating the effectiveness of a geothermal heat pump. It has been well documented that geothermal heat pumps in general are more efficient than conventional heat pumps and that their efficiency is directly related to the sink or source used.[4,5] Omer provides an excellent summary of the different types of geothermal heat pumps and their applications.[6] Specifically we attempt to show how the heat pumps source greatly changes the effectiveness of the pump by examining three different mediums: wet soil, dry soil, and water. This increased effectiveness results in significantly less power bills for both commercial and residential systems. We believe this simple but effective system will help students understand the importance of these systems with respect to both the economy and the environment.

Apparatus

Figure 1 shows the experimental apparatus created for this study.

Figure 1: Experimental Set-up

For each trial conducted an ice bath was created so that the initial mass and temperature were the same for all experiments. A circulating pump was used to move the water from the ice bath, through a copper coil buried in the geothermal source (where it was heated), and then back to the ice bath. For the first run the geothermal source was filled with water. For the next trial, the source was filled with soil that had been saturated with room temperature water, and for the last trial, the soil was dried out in an oven and then placed back into the source after it had been allowed to cool. It should be noted that there are existing experiments that can be purchased which provide similar results such as the Gunt HL320.07 Underfloor heating/geothermal energy absorber, however these are generally more expensive and much larger.

Results

After turning on the pump the temperature of the ice bath was recorded at five minute intervals. Figure 2 shows the results from all three tests.

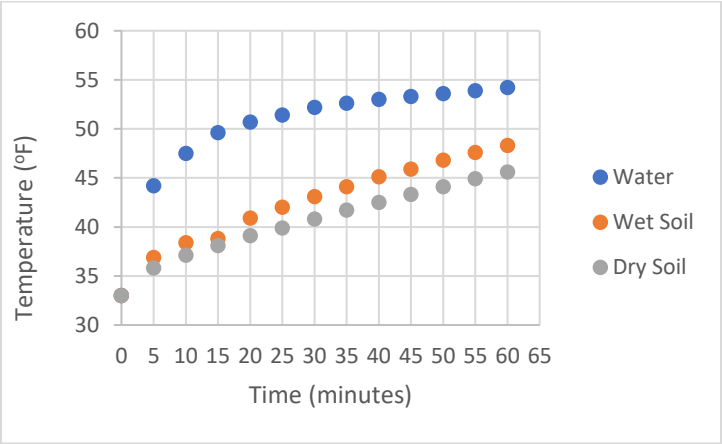

Figure 2: Ice Bath Temperature versus time

From Figure 2, it is observed that the water temperature of the ice bath increases substantially faster when it is circulated through the source containing only water. Within 10 minutes the temperature has increased by approximately 14.5°F while over the same time period it only increased 5.4°F for the saturated soil case and 4.1°F for the dry soil.

Figure 3 shows the temperature taken at the center of each source during testing.

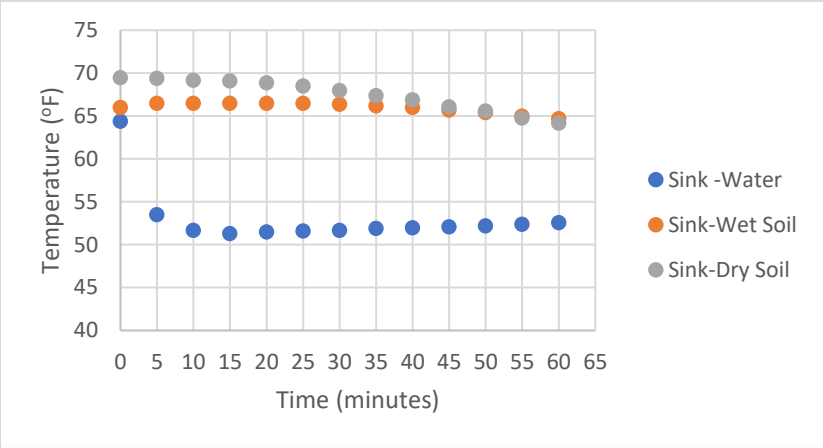

Figure 3: Source Temperature versus time

It should be noted that the initial temperature of the sources was slightly different for each case. For water only, the initial temperature was 64 °F while it was 66 °F and 69.5 °F for the saturated soil and dry soil respectively. Despite the larger initial delta temperature, the water only source outperformed both of the soil tests, and the wet soil outperformed the dry as expected.[5] It should also be noted that the temperature change in the water only source substantially dropped, due to the large rate of heat transfer, indicating it would need to be replaced much quicker than that for the two soil tests.

Conclusions and Recommendations

This small-scale test is a cheap and easy way to demonstrate some of the key requirements to have an effective geothermal heat pump. Because of its small size and the short time needed to complete an experiment, it provides an excellent tool for demonstrating energy related topics to middle and high school students. Currently a more robust system is being developed that can be implemented in a mechanical engineering energy course. This will include additional sensors such as flow meters and soil humidity sensors. Unlike the system proposed here however, the new apparatus will not be portable.

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