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# EXPERIMENTAL ANALYSIS OF GEO THERMAL HEAT PUMP SYSTEM WITH THERMAL ENERGY STORAGE

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**ABSTRACT:**

Geothermal heat pumps are effective, environmentally friendly systems for heating and cooling buildings using consistent underground temperatures to extract and distribute heat. This paper reports the development of a ground heat pump (GHP) enhanced with Phase change material (PCM) for heating applications. Introduction of PCM into GHP provides enhanced heat retention and better temperature control by storing and releasing thermal energy. The system combines refrigerant with PCM to improve efficiency as well as performance. Field trials also highlight that GHP with PCM integrates contributes towards less heating energy usage compared to that of air-source heat pumps, with added benefits from the energy savings of the PCM during peak demand. The integration of GHP with PCM can have a high potential for significant change in the heating market through the introduction of efficiency in thermal performance and reduction in greenhouse gas emissions, hence promoting sustainable energy sources and further reducing environmental deterioration.

**KEYWORDS:**
Geothermal Heat Pump,
Phase Change Material,
Heating, Energy Efficiency,
Greenhouse Gas Emissions

## 1. INTRODUCTION:

These are the state-of-the-art, environment-friendly devices called geothermal heat pumps utilizing the constant temperatures that can be found beneath the earth surface for efficient heating and cooling. The study incorporates PCMs in GHP, based on the assumption of further increase in its heat retention ability along with thermal stability. This storage and release of energy in the system enhances efficiency. This combination enables energy efficiency to increase sustainably while reducing greenhouse gas emissions and quicker transition to green heating systems. Field testing has shown that the GHPs with the use of PCM consume less energy than the traditional air-source heat pumps, especially in peak hours.

## 2. OBJECTIVE:

A geothermal heat pump (GHP) system integrated with Phase Change Material (PCM) for heating applications must be designed and evaluated to improve thermal conductivity, increase latent heat storage capacity, lower specific energy consumption during peak load conditions, and advance sustainable heating solutions through reduced greenhouse gas emissions and increased thermodynamic efficiency.

temperature. Therefore, in order to overcome these drawbacks, a sophisticated heating solution utilizing eco-friendly and efficient technology is desperately needed. The inclusion of phase change materials in geothermal heat pumps improves the heat transfer of the systems, increases thermal energy storage, and reduces the environmental impact of heating systems.

## 4. METHODOLOGY:

### 4.1 Engineering on Design:

Applied computer-aided design software: Understand analysis of water temperature and is the thermal energy from a ground source enough to heat up the water sufficiently to simulate and therefore optimize the system.

### 4.2 Prototyping and Modelling:

The above product is made using a variety of materials to test design principles, functionality, and performance in a controlled laboratory setting. Temperature monitoring systems are also employed to measure the output of the product.

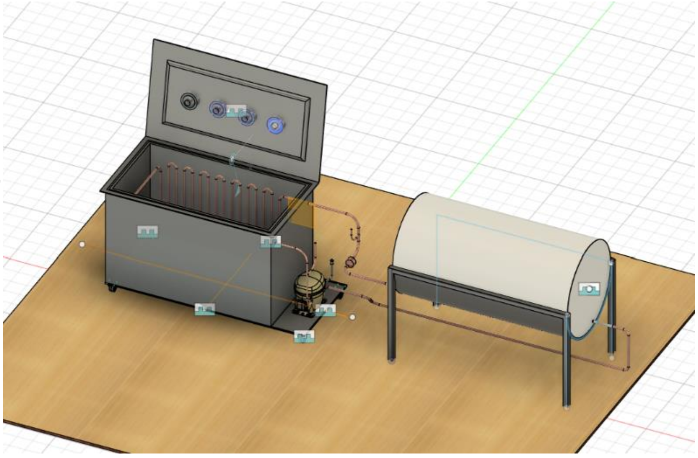

Fig-1: Isometric view of the system

Fig-2: Snake loop coil assembly

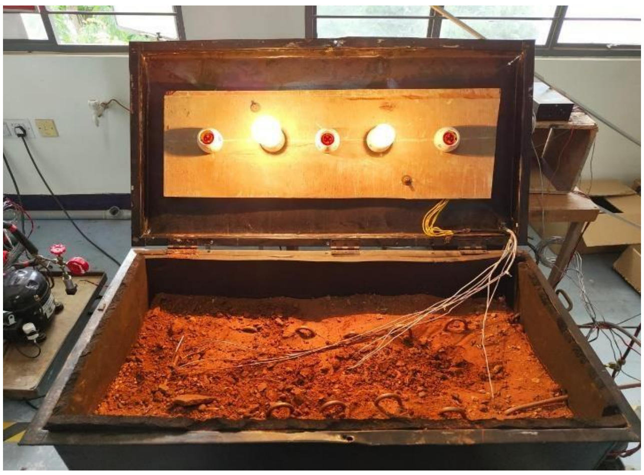

Fig-3: Working of fabricated product

## 5. PROPOSED METHODOLOGY:

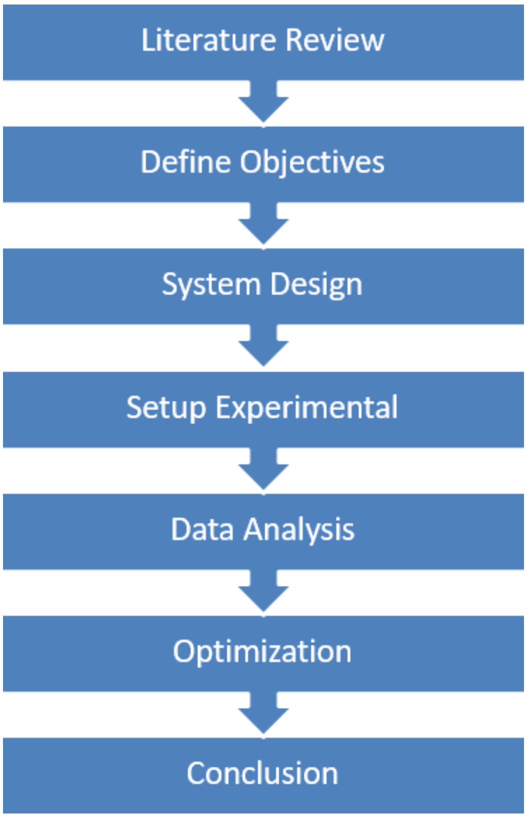


Fig-4: Workflow diagram

We consulted materials and methods based on literature reviews for PCMs and GHPs. Among the available ones, we selected one based on its best thermal properties. From the chosen PCM module, evaluation was conducted in terms of conductivity and stability. Excellent heat transfer was ensured upon design, fabrication, and integration of the GHP system chosen. Baseline performance metrics were established during the initial system tests without PCM. After PCM introduction, controlled tests were carried out using temperature sensors that monitored the efficiency of the system. Field tests revealed that, in contrast to conventional air-source heat pumps, the GHP-PCM system had higher energy efficiency, heat retention, and reduced emissions. This pointed out that the system can be deployed for efficient and sustainable heating applications.

## 6. CHOICE OF COMPONENTS:

### 6.1 Compressor:

Each compressor has unique performance profiles and is available in varying sizes and configurations. For this experiment, we selected a 180–400 W, 501 CFM-capacity compressors. We selected R134a/R600a, which, although other refrigerants also provide alternatives, under normal working conditions at 220-240V and 50-60 Hz, they balance between energy efficiency and environmental friendliness.

### 6.2 Condenser:

Condenser is integral in a radiant cooling system which it allows a building to discharge its absorbed heat. During condensation, refrigerant gas cools into liquids with high pressure and thereby expels energy due to the phase change involved. Condensers that are either water cooled or air-cooled bring about a suppression in performance across the entire system. The most relative properties of copper tubescan be listed as:

1) High thermal conductivity.
2) Easy maintenance
3) Economic viability

### 6.3 Refrigerant:

Refrigerants in refrigeration and air-conditioning application primarily involve the transmission of heatthrough and cooling effect. Some of the most popular HFCs include R-134a, highly valued because of their performance and less negative impact on the environment. R-134a has a low degree of flammability, is less sensitive to leakage, stores properly in the long term, and is hence widely applied to numerous cooling applications.

### 6.4 Phase change material:

During indoor overheating, it captures excessive heat over the course of the day and then becomes liquid. It cools down the area and conserve energy when the temperatures lower due to releasing the collected thermal energy when it is turning into solid. More to that, paraffin wax is designed such that it will retain its energy after sunset, thereby assuring effective night temperature control.

## 7. RESULT AND DISCUSSION:

This project shows the effectiveness of a geothermal heat pump system integrated with phase change material for water heating. Designed in this system were thermal storage, ground heat pumps, monitoring setup, and a module of PCM used to incorporate paraffin wax. As the thermal energy is absorbed and released as part of the phase changes in the PCM, GHP transmits heat from earth. It was heated up to 60°C within five minutes through the heat exchanger while water is passing through. A comprehensive mathematical model has been iteratively formulated and solved. The set of variables tested for the system comprises ground temperatures, refrigerant flow rates, and PCM thermal characteristics. It showed potential for sustainable applications in water heating by a performance study showing an increase in heat retention and energy efficiency.

### 7.1 Pumping water temperature:

The evaluation of pumping water temperature in parallel well and vertical well layout was shown in Fig.5, 6.

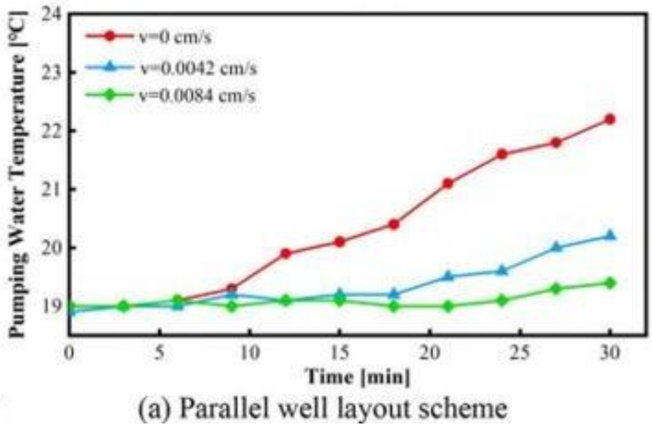


Fig-5: Parallel well layout

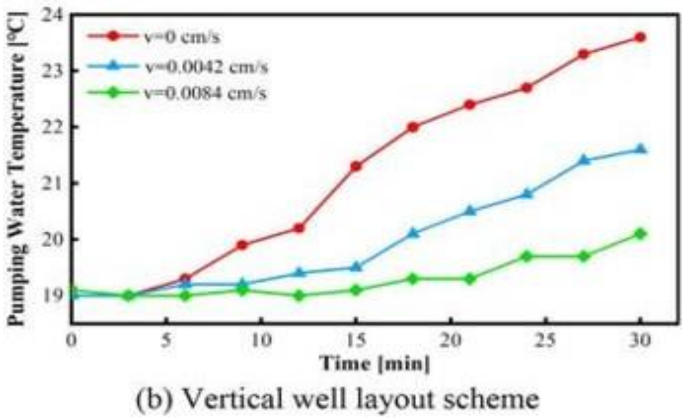


Fig-6: Vertical well layout

according to system, the temperature of the system increases through both of the scheme. But it was efficient in the vertical well layout.

### 7.1 Experimental Procedure:

1. Tested the system and used a weather station to measure wind speed, sun radiation, air temperature, and relative humidity.

2. Constructed and designed a reflecting profile for a strip mirror.

3. According to the latitude, the collector system and pipes were fitted with the correct slope.

4. Record every 30 minutes, from 9:00 AM through 4:00 PM, the temperature of Fresnel mirror, inlet and outlet water temperatures, and the PCM free conduction output.

5. The Day 1 processes were repeated on PCM integration and same parameters recorded on Days 2-4.

6. All the sets 2, 3 and 4 were repeated steps to confirm the results for some days.

### 7.2 Temperature Estimation

The main intent of the data obtained in the experimental setup is concerned with the thermal performance throughout the day for the geothermal heat pump system. The temperature variation in some of the crucial parts has been monitored in the system over time, including the compressor and soil and water. Upon running the system, starting from 9:00 AM to 1:30 PM, a straight-line increase in temperature values can be seen.

1. By 1:30 PM, the compressor's temperature had risen from 29.9°C at 9:00 AM to 45.1°C.
2. The soil temperature ranged between 28.9 and 36.9°C by the same time period.
3. As early as 1:30 PM, the water temperature increased from 22.5°C at 9:00 AM to 58.5°C.

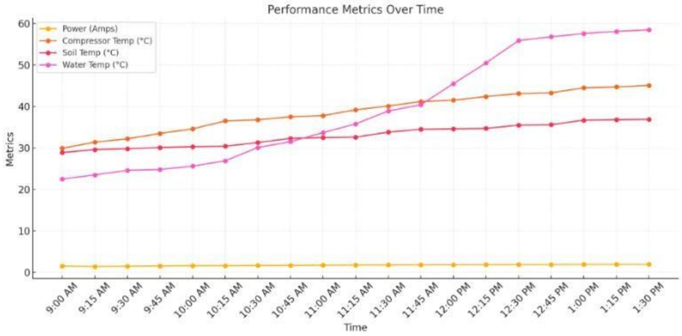


Fig-6: Time vs Temperature metrics graph

This also indicates how well the system accumulates thermal energy within the day. As both the water and soil temperatures would rise gradually with the passage of time due to this absorption of energy, fluctuations in temperature show how nicely the geothermal heat pump system utilizes both convective and radiative thermal exchange techniques. For optimal thermal control, this process helps one estimate the overall heat loss of the system and storage capacity of energy.

### 8. CONCLUSIONS

In a nutshell, data collected from the geothermal heat pump system shows quite notable thermal performance and efficiency in energy absorption and storage. The consistent rise of water, compressor, and soil temperatures during the day shows that the system can use convection and radiation well to transfer heat. The rise in water temperature from 22.5°C to 58.5°C represents that the system is fully utilized and stored thermal energy since soil and compressor temperatures were rising continuously, thus showing that the system has peaked performance. The results show that the geothermal heat pump system holds large potential for application in sustainable energy systems due to its ability to capture and store thermal energy, thus providing better performance and less heat loss when combined with thermal storage. It is underscored that there is a need to have a deeper understanding of thermal transactions in the system for improving heat control and maximum energy productivity.

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