CRAWL SPACE ASSISTED HEAT PUMP

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PROJECT OUTLINE

Project Title: Technology Development of Earth Storage

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Project Goals: Develop technology and demonstrate systems for utilizing heat stored in undisturbed earth for improving the performance of heat pumps.

Carry out laboratory-scale experiments to measure the apparent thermal conductivity of undisturbed earth under unsteady state conditions and at high moisture contents. Construct and operate field experiments to determine heat transfer and recovery capacity of undisturbed earth under residential buildings (crawlspace) and its effect on the performance of heat pumps for both heating and cooling.

Project Status: Laboratory-scale experiment in operation. Field study in a residential crawlspace was initiated.

Contract Number: W-7405-eng-26

Contract Period: January, 1979 to October, 1980

Funding Level: $5,000

Funding Source: U.S. Department of Energy
Division of Energy Storage Systems

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SUMMARY

A variety of experiments and simulations are currently being designed or are underway to determine the feasibility of conditioning the source air of an air-to-air heat pump using stored ground heat or "cool" to produce higher seasonal COP's and net energy savings. The ground would condition ambient air as it is drawn through the crawl space of a house. Tests have been designed to evaluate the feasibility of the concept, to determine the amount of heat or "cool" available from the ground, to study the effect of the system on the heating and cooling loads of the house, to study possible mechanisms which could enhance heat flow through the ground, and to determine if diurnal temperature swings are necessary to achieve successful system performance. All studies are currently operating or will be operational by the end of 1979.

DESCRIPTION

Higher seasonal COP's and output capacity, accompanied by large energy savings, can potentially be realized by conditioning the outside air delivered to an air-to-air heat pump. The concept to be considered is a crawl space assisted heat pump where the air is conditioned by stored earth heat or "cool" as it is drawn through the crawl space of a house. A schematic representation of this concept is shown in Fig. 1.

In 1977, a graduate student at The University of Tennessee conducted a field experiment at a private residence in Oak Ridge, Tennessee, with the heat pump operating in the above mode during the winter season and observed

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that significant increases in air temperature were, in fact, achieved. A number of questions remained which need to be answered, however, before the feasibility and general applicability of the concept can be assured; it is unresolved whether the temperature increase of the air was due to heat addition from the ground or, rather, due to conduction and/or air exfiltration through the floor of the house, and thus the possible effects of the system on the heating and cooling loads of the house are unknown. It is also uncertain what tradeoffs were involved if the temperature change was partially due to house heat losses and partially due to ground heat addition. If the earth in an enclosed space can, indeed, supply a significant quantity of heat to air flowing above it, then further studies of the heat transfer and storage characteristics of the earth become of interest; namely, whether the required heat flux through the soil and to the air is explainable by simple conduction and convection of earth heat, whether the heat flow rate through soil can be enhanced by moisture diffusion induced by temperature gradients, and whether diurnal temperature swings effectively "charge" the upper-most layer of the earth during the daytime. Three separate areas of investigation are underway to address these questions.

The first investigation consists of a field test of a second house modified such that ambient air is drawn through the crawl space and delivered to the heat pump. It is similar to the initial field test except that additional instrumentation is being utilized. The objective of this second field test is to reaffirm the feasibility of the concept as well as to record and understand the transient characteristics and responses of the crawl space. A plastic moisture barrier will cover the earth surface to prevent moisture evaporation. Crawl space air temperatures, ground surface temperatures, and earth temperatures 0.15 m (6 in.) below the surface will be continuously recorded using a 12-point Honeywell recorder and type K thermocouples. An event recorder will also be used to monitor the defrost cycles of the heat pump. Figure 2 shows a schematic of the crawl space and the thermocouple locations.

The second investigation will consist of measuring the temperature rise of ambient air drawn by portable fans through two specially built insulated ducts located in the crawl space of an experimental control house being used in conjunction with energy conservation projects at ORNL. A plan view is shown in Fig. 3. Three sides of the duct will be formed of closed cell polystyrene sheeting 0.30 m (12 in.) thick, with the remaining side being open to the ground. The fan will be cycled through different "on/off" sequences with the use of a 24-hr timer to simulate actual heat pump operation. Two ducts will be used — one with a plastic moisture barrier on the earth surface and the other without — to gain a quantitative understanding of the different heat transfer mechanisms occurring in soil. With all joints in the ducts carefully sealed, the ducts will be thermally isolated from the house as well as the crawl space, and thus any temperature rise resulting from air flowing through the ducts will be due solely to heat addition from the ground. It will, therefore, be possible to determine directly the amount of useful heat available from the ground and, from comparisons with field experiments, it will be possible to determine the source(s) of the heat gains experienced in actual field operation. Moreover, questions concerning the necessity of diurnal temperature swings and the impact of the system on the house environment will both be partially addressed. Duct temperatures, ground surface temperatures, and earth temperatures 0.15 m (6 in.) deep will be continuously recorded using a 12-point Honeywell recorder and type T thermocouples; additionally, air velocity, wet-bulb temperatures, and soil moisture content will be measured periodically.

The third investigation will address two issues partially addressed beforehand: specifically, the effect of diurnal temperature swings on the thermal conditions of the ground and the effect of moisture diffusion on the heat transfer characteristics of soil. Mathematical and computer modeling techniques are being employed to determine the storage and recovery capabilities of the earth when exposed to cyclic temperatures and to evaluate the effectiveness and importance of the temperature swings in charging the earth system during the daytime. The enhancement of soil heat transfer is being studied in a 0.61 m (2 ft) square box 0.30 m (1 ft) high, capable of maintaining a constant free surface water level in the soil test section and an imposed heat flux through the bottom. Temperatures are measured throughout the box using type K thermocouples and three Honeywell recorders; moisture content is monitored using fiber glass encased moisture probes. A schematic of the testing device is shown in Fig. 4.

STATUS

The heat pump modifications have been made for the second field test, and data acquisition has begun. Preliminary results show that for ambient air at 0°C (32°F) and ground surface temperatures of 10.6°C (51°F), air was delivered to the heat pump at 5.0°C (41°F). Acquisition of materials and instrumentation for the duct experiment is underway, and it is expected that the ducts will be constructed and operational by the end of 1979. To date, the effective thermal conductivity of wet clay as measured in the thermal conductivity experiment has been found to be 1.21 W/m °C (0.7 Btu/h ft °F) which conforms with literature values, and thus no significant heat transfer enhancement has been found.

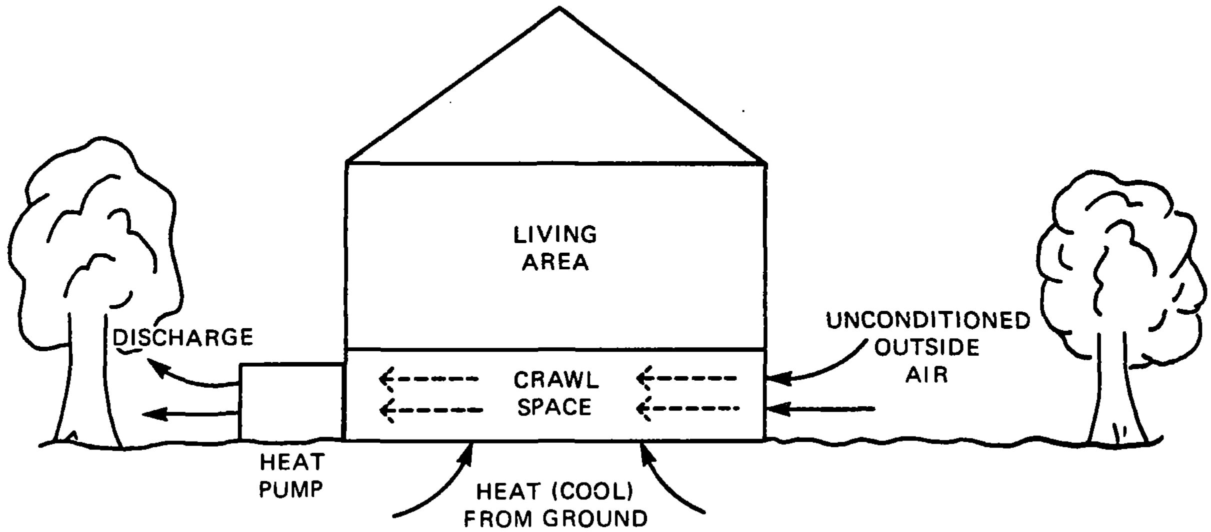

Fig. 1. Crawl Space Assisted Heat Pump

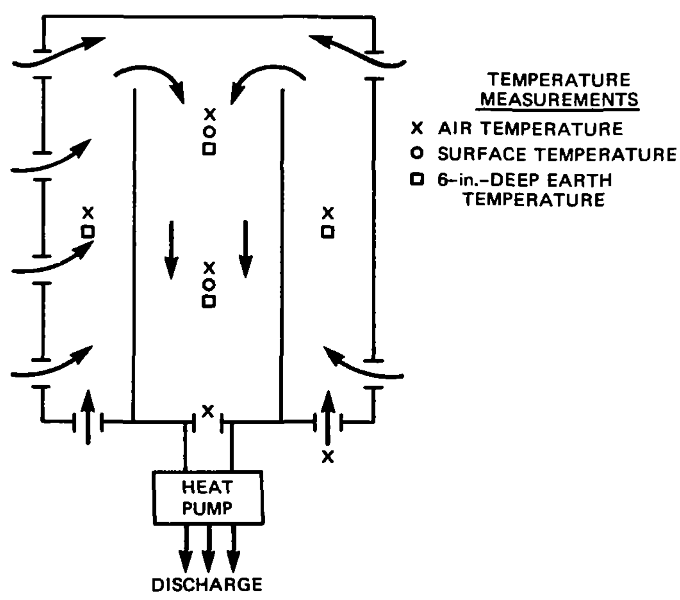

Fig. 2. Field Test Configuration

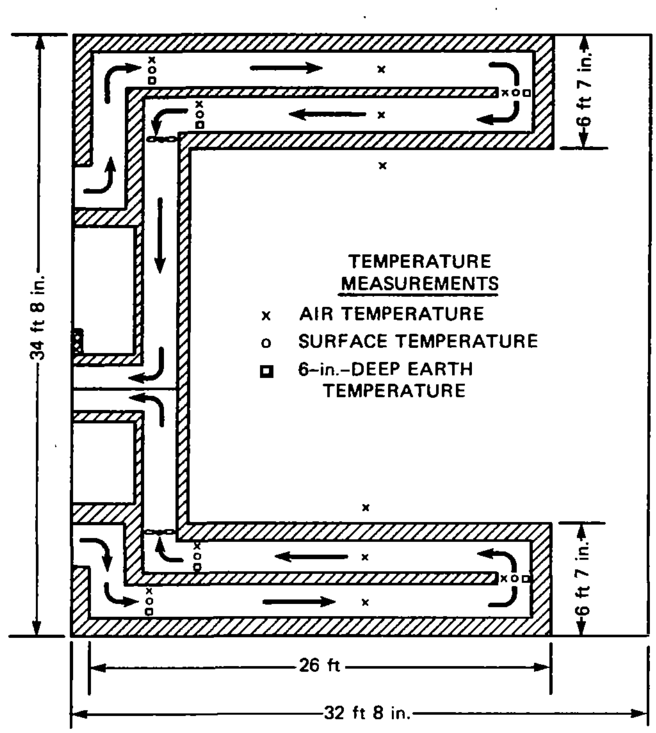

Fig. 3. Plan View of the Duct Experiment

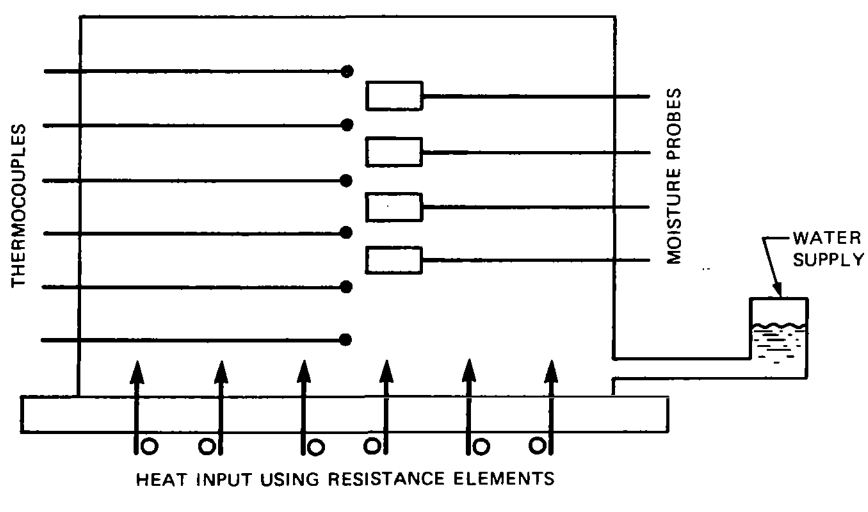

Fig. 4. Thermal Conductivity Testing Device