

Study on Using the Ground as A Heat Sink for A 12,000-Btu/h Modified Air Conditioner

W. Permchart, and S. Tanatvanit

Abstract—This paper presents the results of the experimental tests of the cooling performance of a 12,000-Btu/h modified air conditioner (referred to as M-AC) that use the ground as a heat sink of a condenser. In the tests, cooling capacity of M-AC with an optimal length of a condensing coil as well as life expectancy of copper coil buried underground were investigated. The lengths of copper coil fabricated and used as condenser coil of M-AC were set at 67, 50, 40 and 30 m whereas that of a 12,000-Btu/h conventional split-type air conditioner (referred to as C-AC) was about 22 m. The results showed that the ground can absorb heat rejected from a condenser of M-AC. The coefficient of performance (COP) of C-AC was about 2.5 whereas those of M-AC were found to be higher. It was found that the values of COP of M-AC with condensing coils of 67, 50 and 40 m long were about 6.9, 5.5 and 3.3, respectively, while that of 30-m-long one was found to be about 2.1. The electrical consumptions of M-AC were found lower than that of C-AC in the range of 11.5 – 15.5%. Additionally, life expectancy of underground condensing coil of M-AC was found to be over 7 years.

Keywords—Air conditioner, condenser, copper coil, ground.

I. INTRODUCTION

AIR conditioning has become necessarily for human life and consequently, the largest energy (electricity) consumer in residential sector. To reduce the energy consumption of air conditioning, particularly in household and building, it could be done by reducing the temperature of sink reservoir.

Generally, there are two large sources of sink reservoirs can be applied, namely water (i.e. sea and lake) and ground [1], [2]. Regarding the ground, two methods are proposed: earth/air tunnel [3] and ground source heat pump [4] – [6].

In cold weather countries, the ground can be used as alternative heat sink/source, particularly for heating and cooling in individual house as well as building called ground/geothermal source heat pump (abbreviated as GSHP) [4] – [6]. GSHP is successful in cold weather area because of a large difference of ambient temperature between winter and summer.

W. Permchart is with the Department of Agricultural Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang (KMITL), Bangkok 10520, Thailand (phone: 662-943-8220; fax: 662-943-8284; e-mail: kpwatcha@yahoo.com).

S. Tanatvanit is with the Environmental Science Program, Faculty of Science Ramkhamhaeng University, Bangkok 10240, Thailand (e-mail: pon2310@yahoo.com).

Moreover, the study results of previous research works related to the characteristics of soil temperatures [7] – [10], they found that the temperatures inside the ground were almost constant year round.

In tropical (hot and moist) areas, it was always lower than the ambient temperature [3], [8] whereas it was both lower and higher than air temperature depending on season in cold weather area. Therefore, GSHP can be applied for human comfort in building both heating mode and cooling mode in winter and summer, respectively.

In 1998, this research work was started at KMITL, Bangkok. The temperatures of soil at 1.0 – 1.5 m deep inside the ground were found to be almost constant in the range of 27–28 °C year round [11]. Then, the feasibility study of using the ground as a heat sink for a condensing unit of a 12,000-Btu/h modified air conditioner was started to be studied.

To use the ground as a heat sink for a condenser of an air conditioner, a new design of a condenser of an air conditioner (referred to as M-AC) was performed based on soil properties and equations of conductive heat transfer [12].

Eventually, the 67-m-long copper coil (compared to 22-m-long coil of a conventional air conditioner, referred to as C-AC) of a condenser without a condensing fan was obtained. Fig. 1 shows the general view of ground loop condenser of M-AC buried in 1 m deep inside the ground as well as a testing room in the experimental tests.

The results showed that the soil can absorb and dissipate the heat rejected from a condenser without an increasing of soil temperature near buried pipes, significantly. Moreover, the coefficient of performance (COP) of M-AC was found to be higher than that of C-AC.

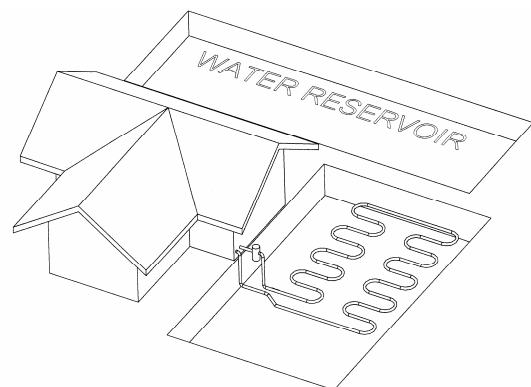


Fig. 1 General view of the ground loop condenser of M-AC

In addition, the electrical consumption of M-AC was found to be about 13% saving compared to that of C-AC owing to there was no condensing fan and electrical consumption of a compressor was slightly lower. Although this study seemed to be satisfactory, some aspects, especially, life expectancy of copper coil and suitable length of condensing unit of M-AC, were still interested topics to be investigated.

II. MATERIALS AND METHODS

A. Experimental Set-up

The experiments were carried out using a room having the dimension of 2.5 m × 4.0 m × 2.5 m (W×L×H). Fig. 2 shows the photograph of copper coil buried in the ground at 1 m deep inside the ground of the M-AC whereas Fig. 3 shows the photograph of the condensing unit of the M-AC. In the experiment, it was varied in four values of lengths: 67 (the first design) [11], 50, 40, and 30 m in length. The amounts of required R-134a refrigerant of M-AC were 5.8, 4.6, 3.8, and 2.4 kg, respectively, whereas that of C-AC was about 1.2 kg.

B. Experimental Tests

The test runs were done in the daytime (8.00 a.m. - 5.00 p.m.) The thermostat was set to control a constant room temperature at 24°C (compressor will be cut off when room temperature is below 24°C). Schematic diagram of the experimental set-up is shown in Fig. 4.



Fig. 2 Photograph of copper coil of the M-AC buried in the ground



Fig. 3 Photograph of condensing unit of M-AC

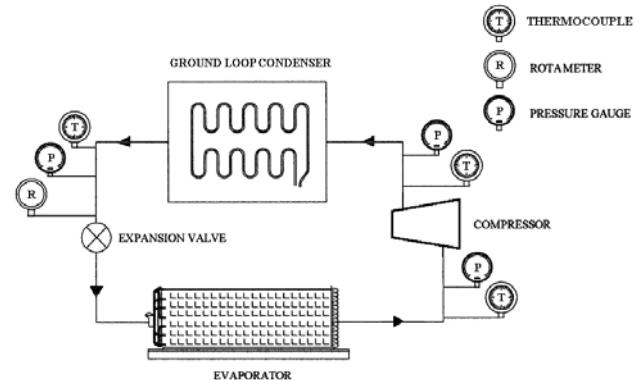


Fig. 4 Schematic diagram of the experimental set-up

As seen, a flow meter (rotameter) was installed to measure the mass flow rate of R-134a refrigerant at outlet of ground loop condenser whereas pressure gauges and thermocouples were connected to copper coil at different positions of air conditioner to measure pressures and temperatures of refrigerant, respectively.

The electrical consumption of M-AC (compressor and evaporating fan) was also measured during test runs. To maintain similar condition, the experimental tests were conducted in one week for each case of M-AC (different values of condensing coil lengths).

Based on the analyses of the coefficient of performance (COP), the cooling capacities of M-AC for each case were compared [13].

III. RESULTS AND DISCUSSION

A. Cooling Performance of M-AC

The experiments seem to be done under similar condition (the values of ambient temperature and solar intensity were similar). Compared to the results obtained from the first-phased work [11], the experimental results in this research are shown in Table I. As seen, COP values of M-AC were higher than that of C-AC except for the case of 30-m coil length. They were observed that temperatures of R-134a leaving the ground loop condenser were lower than that leaving the condenser of the C-AC (i.e. 31, 34, 38, and 43°C for 67, 50, 40, and 30-m coil lengths, respectively, instead of 40°C like C-AC).

Moreover, the different value of enthalpy of M-AC was lesser but the rate of heat rejected from a condenser was higher when compared to those of C-AC because of an increasing in the flow rates of R-134a (see Table I).

Meanwhile, the different values of enthalpy at evaporator of all test runs were almost equal because of the same treated cooling loads during the experiments.

These can be explained that unlike in the case of 30-m coil length, not only a higher temperature of R-134a leaving the ground loop condenser but a lower flow rate of R-134a refrigerant as well, it made the 30-m coil length seems to be not suitable for consideration to apply in real case while the 40-m coil length is seem to be more suitable.

TABLE I
THE VALUES OF COP FOR DIFFERENT CONDENSING COIL LENGTHS OF M-AC
COMPARED TO THAT OF C-AC

| | Flow rate of R-134a (kg/s) | COP |
|-------------|-------------------------------|-----|
| M-AC (67 m) | 0.0358 | 6.9 |
| M-AC (50 m) | 0.0289 | 5.5 |
| M-AC (40 m) | 0.0201 | 3.3 |
| M-AC (30 m) | 0.0141 | 2.1 |
| C-AC (22 m) | 0.0145 | 2.5 |

For the electrical consumption, the total consumption of M-AC was lower than that of C-AC, mostly resulting from the removal of a condensing fan and slightly resulting from the decreasing of an electrical consumption of the compressor. In average, they were 9.6 – 10.4% and 1.9 – 5.1% of electric saving, respectively (see Table II).

Besides, during the test runs, the ground temperatures closed to the buried coil were slightly increased ($<1.5^{\circ}\text{C}$). This indicates that the ground can potentially behave as a good heat sink. In addition, there are at least two advantages of M-AC over C-AC; 1) reduce the problem regarding heat rejected to surrounding air, and 2) reduce noise from a condensing fan.

For life expectancy of the underground condenser of M-AC, it was found that copper coil could have been used as an underground condenser of a 12,000-Btu/h air conditioner without any damages for more than 7 years. Meanwhile, cost effective can be estimated to be 4 years of payback period.

However, in this work, the soil was wet ($>65\%$ of moisture content) ensuring the ability of soil to dissipate heat. Therefore, the performance of M-AC in arid soil might be questioned and need to be investigated.

B. Cooling Capacity of M-AC

The experimental tests of cooling capacity were performed by using 3 and 4 electric heater wires of 1.0 and 0.2 kW_{th} , respectively as the varied cooling load. It was varied in the range of 2.0 to 3.4 kW_{th} . The results show higher cooling

TABLE II
THE ELECTRICAL CONSUMPTIONS OF VARIOUS ELEMENTS OF AN AIR
CONDITIONER FOR DIFFERENT CONDENSING COIL LENGTHS OF M-AC
COMPARED TO THAT OF C-AC

| | Comp. (kW) | Evap. Fan (kW) | Cond. Fan (kW) | Total (kW) |
|-------------|---------------|-------------------|-------------------|---------------|
| M-AC (67 m) | 0.921 | 0.061 | - | 0.982 |
| M-AC (50 m) | 0.934 | 0.061 | - | 0.995 |
| M-AC (40 m) | 0.953 | 0.061 | - | 1.014 |
| M-AC (30 m) | 0.984 | 0.061 | - | 1.045 |
| C-AC (22 m) | 0.971 | 0.061 | 0.102 | 1.134 |

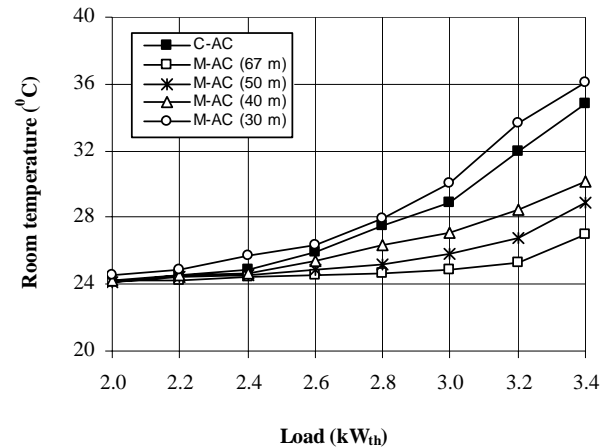


Fig. 4 Cooling capacity tests of M-AC

capacities of M-AC (in the range of 2.4 to 3.0 kW_{th} for 40 to 67-m coil lengths, respectively) compared to 2.2 kW_{th} for the C-AC as shown in Fig. 4.

Additionally, the values of soil temperature were found not to be increased significantly while running M-AC. It's increased less than 1.5°C . This indicated that the ground behaved as a good thermal energy sink.

IV. CONCLUSION

The study indicates that it is possible to use ground as a heat sink of condensing unit of 12,000-Btu/h air conditioner. There are many advantages to use M-AC. The most interesting ones are followed:

- saving energy and reduce the problem regarding heat rejected to surrounding air;
- reducing the noise of condensing fan;
- cost effective can be estimated to be 4 years of payback period and less than life expectancy of the copper coil used as the ground loop condenser.

Even though the results of the experimental study of using M-AC are satisfactory, some comments remain to be considered. Burying pipes requires available ground area that limits its implementation to individual houses and buildings with sufficiently large garden. The ground-area which pipes are buried should be protected to avoid soil contaminants in case of refrigerant leakage.

In this research work, the tested area was located near a water reservoir with many small rocks in soil, resulting in a high thermal conductivity of soil leading to a high performance of the system. Therefore, the feasibility of this system for dry area of tropics might be questioned.

In addition, the COP comparison between C-AC and M-AC was based on different amount of R-134a refrigerant used in each experiment. Hence, M-AC seems to be interesting system for tropical climate and awaits further investigation.

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W. Permchart, born in Chonburi (Thailand), July 5th 1969, earned Ph.D in Energy Technology from Joint Graduate School of Energy and Environment at King Mongkut's University of Technology Thonburi (KMUTT), Thailand in 2003.

He has been promoted to be an associate professor at the Department of Agricultural Engineering, KMITL (Thailand) since 2006. He issued one book named Pumps Application Engineering (Bangkok: KMITL publisher, 2002) and two publications; 1) Co-firing of Sugar Cane Bagasse with Rice Husk in a Conical Fluidized-bed Combustor, 2006, *Fuel Journal*, Vol. 85 (4), pp.434-442, and 2) Utilisation of Used Palm Oil as an Alternative Fuel in Thailand, 2007, *API Journal*, Vol. 941, pp. 62-68. His research interest is related to bio-energy conversion and energy conservation technology.

Assoc. Prof. Dr. Permchart is members of The Thai Society of Agricultural Engineering (TSAE) as well as Council of Engineer (COE) of Thailand.



S. Tanatvanit, born in Supanburi (Thailand), October 23rd 1972, earned Ph.D in Mechanical Engineering from Sirindhorn International Institute of Technology (SIIT), Thailand in 2004.

She is a lecturer at Environmental Science Program, Faculty of Science, Ramkhamhaeng University, Thailand. Technology of energy conservation in buildings and industries is her research interest. Her current research project is related to the development of light weight concrete (LWC) without steam drying for construction.

Dr. Tanatvanit has been an energy management expert of the Department of Alternative Energy Development and Energy Conservation (DEDE), Ministry of Energy, Thailand since 2005.