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Heat Transfer Characteristics of Two Phase Closed Thermosiphon for Geothermal Energy (2nd Report: Heat Transfer Behavior on Site)

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SYNOPSIS

Heating and refrigerating technique such as snow melting of road and cold storage by utilizing temperature difference between underground soil and atmosphere is widely used[1-4] in a cold area.

In the 1st Report, heat transfer characteristics of two phase closed thermosiphon for extracting geothermal energy is studied fundamentally. In the empirical study, heat extract rate is measured in connection with the change of atmospheric temperature utilizing real two thermosiphons on the site. Temperature distribution on the surface of the thermosiphon and underground soil around it is also measured. Based on the data of the empirical experiment, it is confirmed that prevention of freezing for fire hydrant can be achieved by geothermal heat utilizing two phase closed thermosiphon. Present paper describes the heat transfer behavior of the thermosiphon as the 2nd report.

1. INTRODUCTION

In the empirical study, actual extracting test of geothermal heat is carried out on the site utilizing the real thermosiphon continuously for three month without supply of power and maintenance. Heat extracting rate and surface temperature

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distribution of the thermosiphon including heat release plate are measured. Temperature distribution profile of soil around the thermosiphon is also investigated and it was found that the thermal influence by extracting heat with the thermosiphon is limited within the distance of 1m around the thermosiphon.

2. NOMENCLATURE

Notation
A: area (m^2)
d: diameter (m)
ℓ: length (m)
q: heat flux (W/m^2)
T, ΔT: temperature, temperature difference (C), (K)

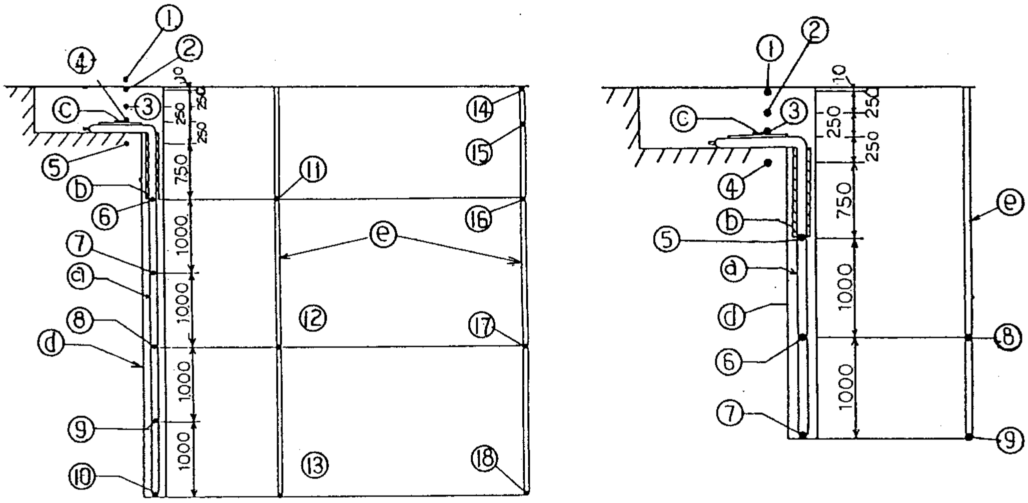
Subscript
e: effective
i: inner
o: outer

3. EXPERIMENTAL APPARATUS and PROCEDURE

Empirical experiment is carried out for the investigation to prevent freezing of outdoor fire hydrant using two real closed thermosiphons. Diameter and effective length of them (each d_o=48.6mm, ℓ_e=5.0m and d_o=48.6mm, ℓ_e=3.0m) are shown in Fig.1. Heat release plate is welded at the top of the thermosiphon, and upper part of thermosiphon is covered with cylindrical insulating material of 20∿30 mm thick to prevent heat release to the underground soil. R-22 is used as a working fluid, because its physical property is well known and it can cover the working temperature range (-20°C ∿ 20°C) in this outdoor experiment under the condition of appropriate vapour pressure.

Two kinds of thermosiphons are installed in the soil as indicated in Fig.1 and Fig.2, and the measuring instrument for temperature is laid in the soil between the two thermosiphons. The instrument to measure heat release quantity and temperature is the type of built-in buttery to work out continuously for three month on the site where a power source is not supplied.

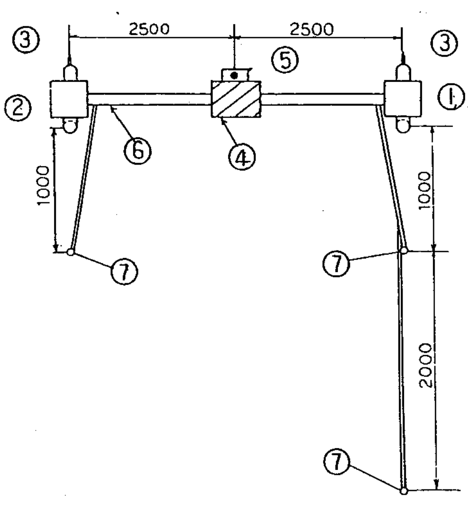
Experimental data is taken in and recorded continuously in every hour for three months on the site, and the data is processed and integrated under the condition of on line system. The thermocouples are installed on the surface of each thermosiphon along the vertical axis at the pitch of every one meter. The thermocouples to measure the temperature of underground soil is installed on the



ⓐ Thermosyphon (OD 48.6mm)
ⓑ Insulation t=20～30mm
ⓒ Flowmeter of heat
ⓓ Containning hole (150mm ϕ)
ⓔ Vinyl chloride pipe (OD 35mm ϕ)
①～⑱ Thermocouples

(a) Thermosiphon (L=5m)　　(b) Thermosiphon (L=3m)

Fig.1 Layout drawing of two thermosiphons and instruments



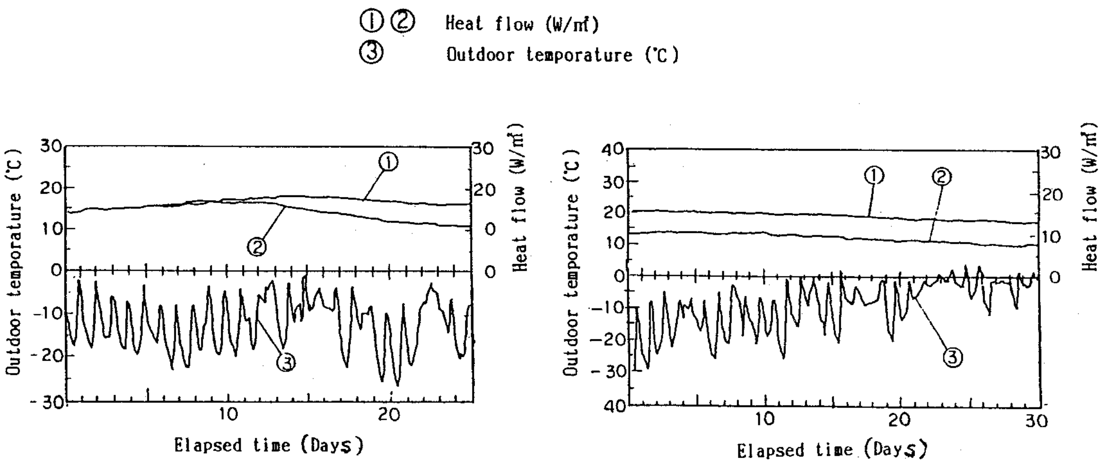
① Thermosyphon (L=5m)
② Thermosyphon (L=3m)
③ Container of heat frow-meter
④ Container of instruments
⑤ Measuring box of atmospheric temperature (1.5m hight from GL)
⑥ Piping pit
⑦ Vinyl chroride pipe for mounting thermocouples

Fig.2 Layout drawing of two thermosiphons and instruments surface of vinyl chloride pipe having 35mm o.d (two of 5.5m length, one of 3.3m length) which is laid in the underground soil vertically with each thermosiphon as shown in Fig.1 and Fig.2. Besides the above, four pieces of thermocouples are installed, one for heat release plate, two for containing room of the heat release plate, and one for atmosphere. Sensor to measure heat release rate is installed on the heat release plate of the thermosiphon. The thermosiphon together with its attachment has been placed in service continuously for three months without any adjustment.

4. EXPERIMENTAL RESULT and DISCUSSION

4.1 Heat Release Rate from the Heat Release Plate

Heat release rate from the heat release plate of the two thermosiphons and atmospheric temperature are shown together in Fig.3. Fig.3 (a) shows the heat release rate and the atmospheric temperature for 25 days from 29th, Dec, 1984 and Fig.3 (b) shows the heat release rate and the atmospheric temperature for 30 days from 24th, Jan, 1985. Heat release rate is observed as about $15W/m^2$ when the atmospheric temperature changes from $-25^{\circ}C$ to $-2^{\circ}C$ and decreases to the range of 10 W/m^2 to 15 W/m^2 when the atmospheric temperature indicates from $-10\ ^{\circ}C$ to $-5\ ^{\circ}C$. The heat release rate of the two thermosiphons are approximately the same just after the start of operation, but the heat release rate of the one of 5m length begins to increase and the difference of heat release of the two thermosiphons reaches about 7



(a) 25 days from 29th,Dec,1984 (b) 30 days from 24th,Jan,1985

Fig.3 Change of heat flow and out door temperature

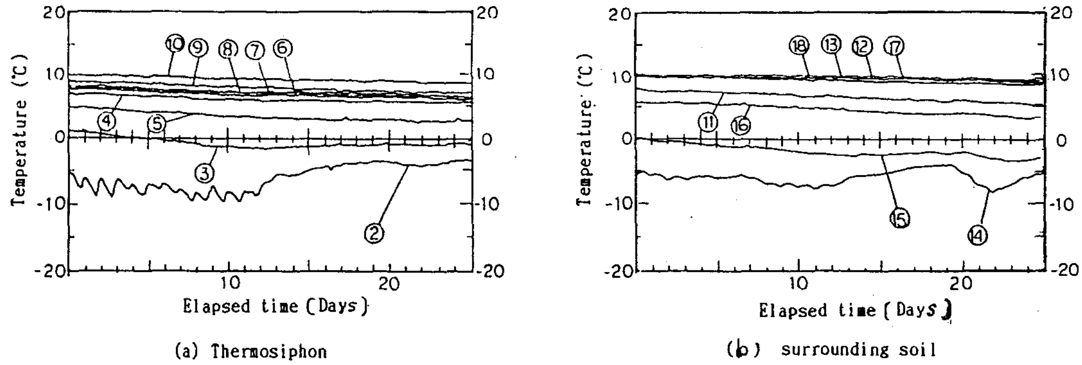


Fig.4 Temperature distribution of the thermosiphon and surrounding soil

to 8 W/m^2 and stabilizes.

4.2 Temperature Distribution Profile of the Thermosiphon

The temperature distribution of the thermosiphon (5m length) along its axis and the temperature distribution of the soil around the thermosiphon are shown in Fig.4 as a function of the elapsed time. The numbers showing the temperature proceeding lines in Fig.4 are corresponded to the one in Fig.1 (a). It is a remarkable phenomenon that the underground soil temperature at the depth of 0.5m shows under the freezing point, but the surface temperature of the heat release plate is from 6 °C to 7°C contrarily, and the room temperature of the heat release plate shows approximately 0°C.

It becomes clear according to the above mentioned temperature distribution that the prevention for freezing of fire hydrant is possible by utilizing geothermal heat with the two phase closed thermosiphon as studied in this experiment. The thermal influence of the thermosiphon to the surrounding soil by collecting heat seems to be limited to the range near the surface of ground and within the range of 1m around the thermosiphon as seen in Fig.4 (refer to the temperature difference between 6-11-16, 8-12-17, 10-13-18 in Fig.4, and the temperature distribution of underground soil is kept stable at the depth of more than 3m.

5. CONCLUSION

The extract system of geothermal energy with two phase closed thermosiphon to prevent freezing of fire hydrant in cold area is investigated experimentally on the site, and following subjects are obtained as the conclusion.

(1) It is confirmed that heat extracting rate of approximate 10 ∿ 15 W/m^2 from the heat release plate is possible.
(2) The surface temperature of the heat release plate was 6 °C to 7°C when the atmospheric temperature varied from -25°C to -2°C.
(3) Thermal influence by heat extract from the underground soil with the thermosiphon appears in the limited range of soil only, that is near the surface of the ground and within the distance of 1 m around the thermosiphon, and no influence is found in the other.

It is proved as described (1), (2) and (3) above that prevention of freezing of fire hydrant is possible by geothermal energy utilizing thermosiphon with R-22 as the working fluid.

REFERENCES

(1) Tien, K. C., Zarling, J. P. "Review on Application of Heat Pipe and Thermosiphon in Cold Area" Proceedings of Japan Association of Heat Pipes, pp. 46-74 (1991)
(2) Mizuno, S. Akagawa, K. Kutsuna, T. Matsui, N. Ito, K. Kato, T. Hangai, M. "Long-Term Storage of Solar Energy Underground and Use for Vinylhouse Heating," Refrigeration, 57-654, pp.349-357 (1982)
(3) Matsui, N. Mizuno, S. Akagawa, K. Kutsuna, T. Ito, K. Kato, T. Hangai, M. "Green House Heating with Thermosiphon Heat Pipes for long Term Underground Storage System of Solar Energy" Reprint of Memories of the Faculty of Engineering, Post graduate course of Natural Science of Kobe Univ, 1-B, 1-16, pp1-14 (1983)
(4) Japan Association of Heat Pipes (Negishi, Oshima, Itoh), "Practical Heat Pipes", published by Nikkan Kogyo Shinbunsha, pp.184-190,(1985)