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Heat Transfer in a Vertical Glass Wool Layer under Constant Heat Flux to the Wall

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Abstract

This report deals with the effects of the width of the cavity W, surface temperature of a cold wall T_c and the specific weight of glass wool γ on apparent heat conductivity λ_{eff} (kcal/m h °C) or the coefficient of heat transfer α (kcal/m^2 h °C) are investigated experimentally under constant heat flux to the wall.

These experimental results are compared with the previous results[1] under isothermal condition. The results under constant heat flux show a decrease of $5\sim15\%$ of λ_{eff} or α as compared with isothermal condition in a range of $\gamma=0\sim20$ (kg/m^3). On the other hand, in a range of $\gamma>20$ (kg/m^3), the results of both wall heating conditions show almost the same values of λ_{eff} or α.

It is clear that the value of λ_{eff} or α is independent of the heating condition of the wall in a range of $\gamma>20$ (kg/m^3).

1. Introduction

Glass wool insulating material is widely used for heat insulation of buildings etc.. In a previous report[1], the heat transfer phenomena of a vertical glass wool layer under isothermal heating of the wall was studied. However, in industrial practice, generally numerous heating modes of constant heat flux to the wall, for example, heat accumulators heated by sunheat and thermosyphon heated geothermally.

Therefore, to clarify the influence of heating conditions of the wall on the heat transfer in a glass wool layer is a very important problem in practical application.

This experimental study investigates the effects of the width of the cavity W, the cold wall surface temperature T_c and the specific weight of glass wool γ on apparent heat conductivity with natural convective heat transfer in a glass wool layer under constant heat flux to the hot wall and isothermal cold wall, namely, mixed boundary condition.

The present experimental results obtained are correlated with the apparent heat conductivity λ_{eff} or the coefficient of heat transfer α. The present experiments are carried out in the case of a vertical layer packed with glass wool and saturated with air or water in a range of $0<\gamma<50$ (kg/m^3). The results of the present work are discussed in comparison to previous[1] results under isothermal condition.

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Nomenclature

q: heat flux, input (kcal)/heating surface (m^2)
H: height of cavity (m)
W: width of cavity (m)
X: distance along the hot wall from the bottom (m)
Y: distance perpendicular to the hot wall (m)
H/W: aspect ratio
T_h: surface temperature of the hot wall (°C)
T_c: surface temperature of the cold wall (°C)
λ_{eff}: apparent heat conductivity (kcal/m h °C)
α: coefficient of heat transfer (kcal/m^2 h °C)
γ: specific weight of glass wool (kg/m^3)

2. Experimental device and procedure

The experimental device is depicted in Fig. 1. The experimental device used in this work is the same as that used in previous work[1)], namely, the hot and the cold walls are constructed from five copper plates and Cu-Co thermo-couples (0.3 mm in diameter) are embedded in each copper plate to obtain the temperature distributions of the hot and the cold walls.

Three cavities having a variable width of W (22, 59 and 116 mm) are used under a constant height H (571 mm).

In order to compare the results obtained under both wall heating conditions, the heat flux q to the hot wall is selected so as to obtain the mean surface temperature of the hot wall $T_{hm}=20$°C. Surface temperature of the cold wall is changed from 10°C to −15°C. Test samples of the glass wool guaranteed by the Standard of the JIS A 9505 are used.

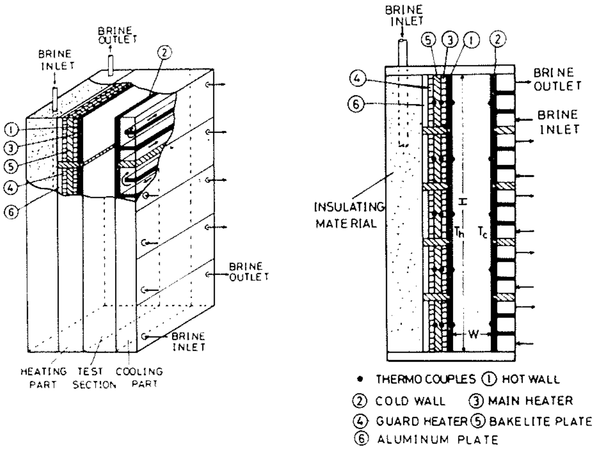

Fig. 1. Schematic diagram of the experimental device.

The experiments are carried out by turning on the selected constant electric current to each heater after packing glass wool in the test section.

Heat transfer is measured after a steady state in the section is reached thermally and hydrodynamically. In each run, it requires about 2~5 hrs to obtain the steady state. The heat loss from the test section is estimated to be within ±3% from the results of preliminary test.

3. Experimental results and discussions

a) Temperature distribution of the hot wall

First, the temperature distributions of the hot wall are investigated from the existence of a temperature gradient in a vertical direction (X) of the hot wall under constant heat flux may be considered in general and such a temperature gradient would have an influence on the heat transfer in the glass wool layer.

Typical temperature distributions of the hot wall are shown in Fig. 2 for $\gamma=10$ (kg/m^3) together with the temperature distributions shown by solid lines in case of isothermal condition ($T_h=20$°C).

In Fig. 2-(a) of water as the working fluid, it may be seen that with the decrease of the temperature gradient in the vertical direction of the hot wall along with the decreasing width W, the heat flux q becomes larger in the case of mean fixed temperature of the hot wall $T_{hm}=20$°C.

Fig. 2-(b) of air shows the same qualitative tendency as that of water, but the temperature gradient of air in a vertical direction is smaller than that of water. It can be understood that a disparity between the tendencies of these temperature gradients occurs not only due to the smaller viscosity of air than that of water, but also because of the length of the boundary layer developing in the vertical direction (X) of air being smaller than that of water.

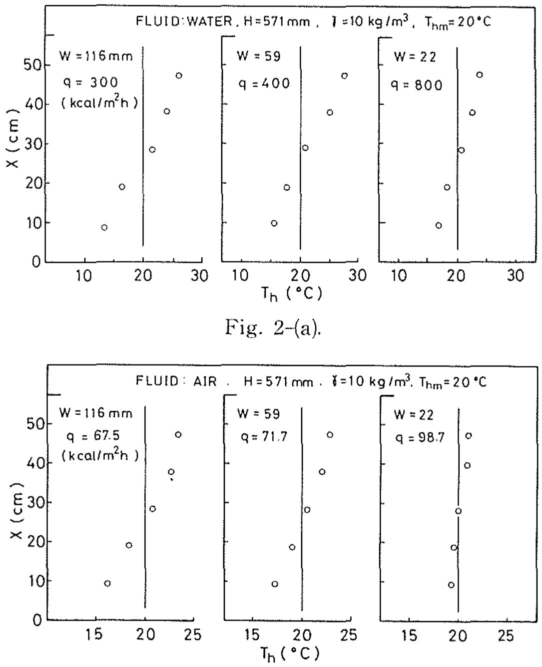

Fig. 2-(a).

Fig. 2-(b).

Fig. 2. Temperature distributions of the hot wall.

b) The effect of the width *W* of the cavity on λ_{eff} or α

Fig. 3 shows the relation between the width W and λ_{eff} or α for variable γ under constant heat flux together with that under isothermal condition indicated by solid lines.

Fig. 3-(a) and 3-(b) show the relation between W and λ_{eff} for water and air respectively. The experimental results in which the value of λ_{eff} increases as W increases are obtained under both wall heating conditions. But, the values of λ_{eff} under constant heat flux for $\gamma=0$ and 10 (kg/m^3) show a decrease of 5∼15% as compared with those under isothermal condition.

On the other hand, for $\gamma=30$ (kg/m^3) the difference of the values of λ_{eff} under both wall heating conditions do not exist. This decrease of λ_{eff} can be explained by the reason that due to the existence of a temperature gradient in the vertical

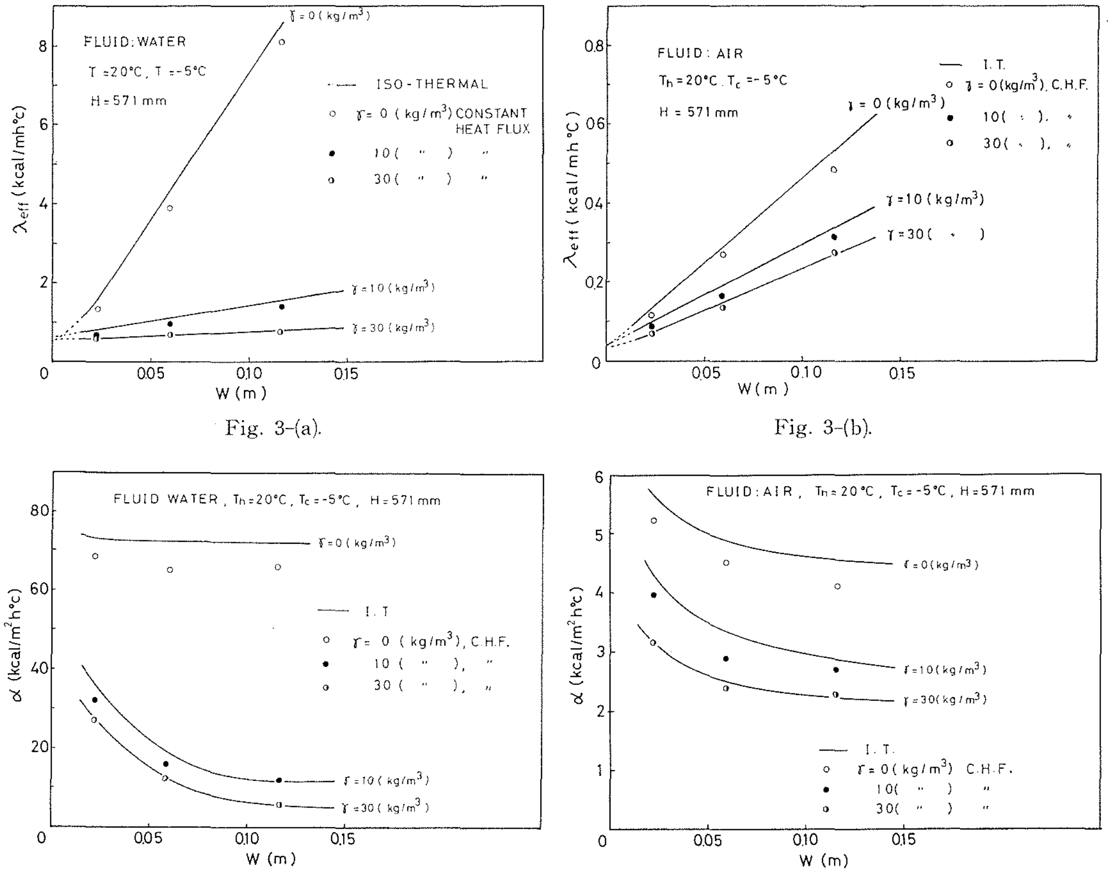

Fig. 3-(a). Fig. 3-(b).

Fig. 3-(c). Fig. 3-(d).

Fig. 3. A relation between the width W and λ_{eff} or α.

direction as shown in Fig. 2, the increased length of boundary layer in the present experiments occurs and the value of λ_{eff} representing the mean heat transfer in the glass wool layer decreases as compared with that under isothermal condition without a temperature gradient.

Fig. 3-(c) and 3-(d) illustrate the relation between W and α connected with λ_{eff}. It could be understood from these figures that as W increases, the values of α decreases. This may be explained by the following reason. The term of α does not contain implicitely the value of W. Moreover, as W increases under constant height (H=571 mm), the circulation speed of fluid becomes weak and consequently the net heat transfer from the hot wall to the cold wall decreases.

c) The effect of specific weight of glass wool γ on λ_{eff} or α

Fig. 4 illustrates the effect of the specific weight γ on λ_{eff} or α for variable W. Fig. 4-(a) and 4-(b) show the relation between λ_{eff} and γ for water and air respectively. The relation between λ_{eff} and γ under both heating conditions has the same qualitative tendency having a strong natural convective effect in a range of $\gamma<20$ (kg/m³).

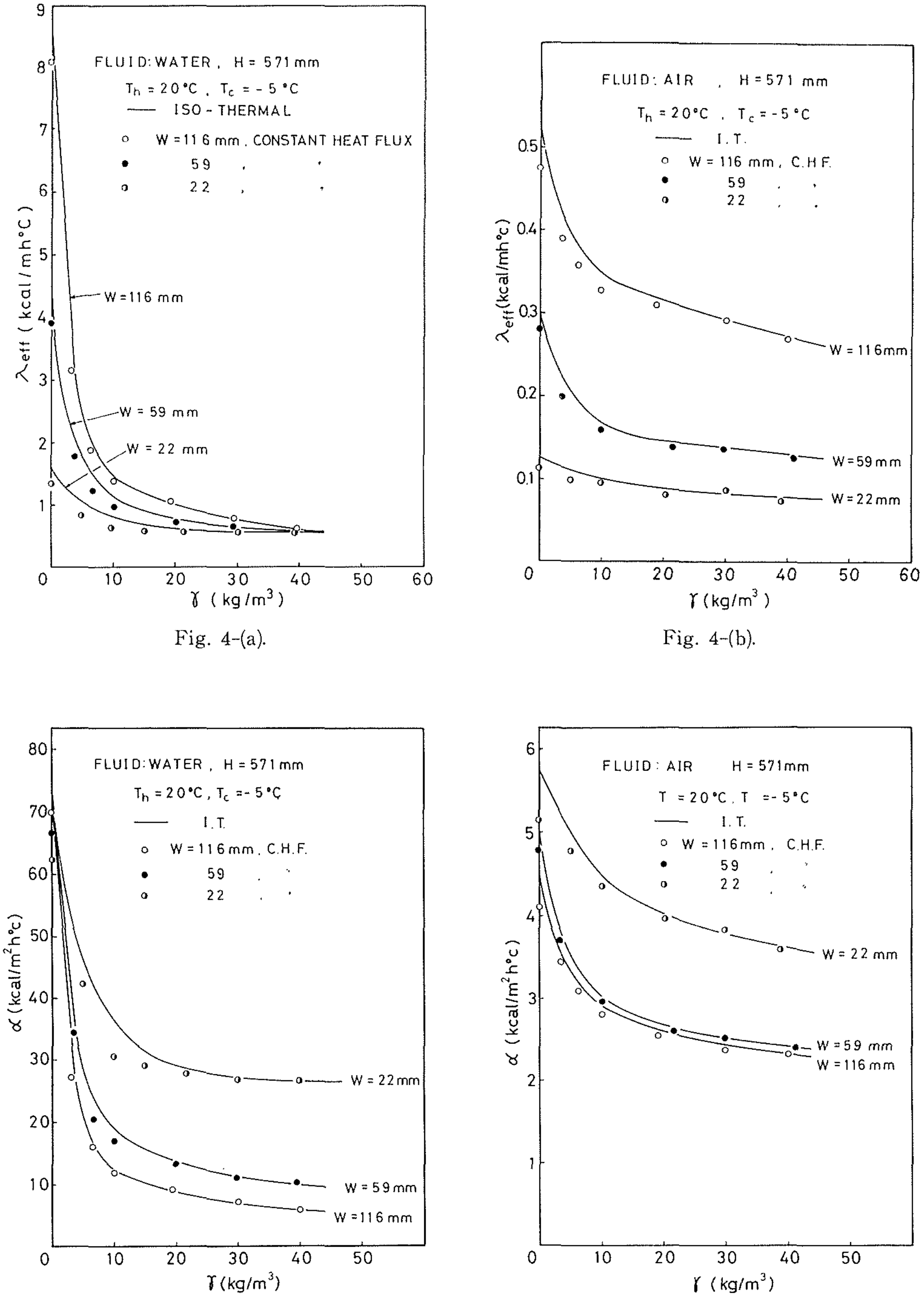

Fig. 4-(a).

Fig. 4-(b).

Fig. 4-(c).

Fig. 4-(d).

Fig. 4. A relation between the specific weight γ and λ_{eff} or α.

In a range of small W (22 and 59 mm), the values of λ_{eff} under constant heat flux cause a decrease of 5~15% as compared with those under isothermal condition for $\gamma<20$ (kg/m^2). On the other hand, a disparity of the values of λ_{eff} under both wall heating conditions does not exist for $\gamma>20$ (kg/m^3). When W becomes 116 mm, the values of λ_{eff} is not affected by the wall heating condition. This can be understood that the wall heating condition does not affect λ_{eff} because of the weak natural convection in the layer with the increasing W. On the contrary, Fig. 4-(b) for $W=116$ mm using air shows the decrease of λ_{eff} as compared with that for isothermal condition. This may be explained because when air having a small viscosity is used, the value of λ_{eff} is dependent on the wall heating condition in a wide range of W.

Fig. 4-(c) and 4-(d) illustrate the relation between γ and α. It can be seen from these figures that the values of α decreases as W increases due to the reason as aforementioned in chapter (b) of temperature distribution.

d) The effect of the cold wall surface temperature T_c on λ_{eff}

Fig. 5 shows the relation between T_c and λ_{eff} together with that under isothermal condition indicated by solid lines.

Fig. 5-(a) and 5-(b) for air demonstrate the results for $W=22$ and 116 mm re-

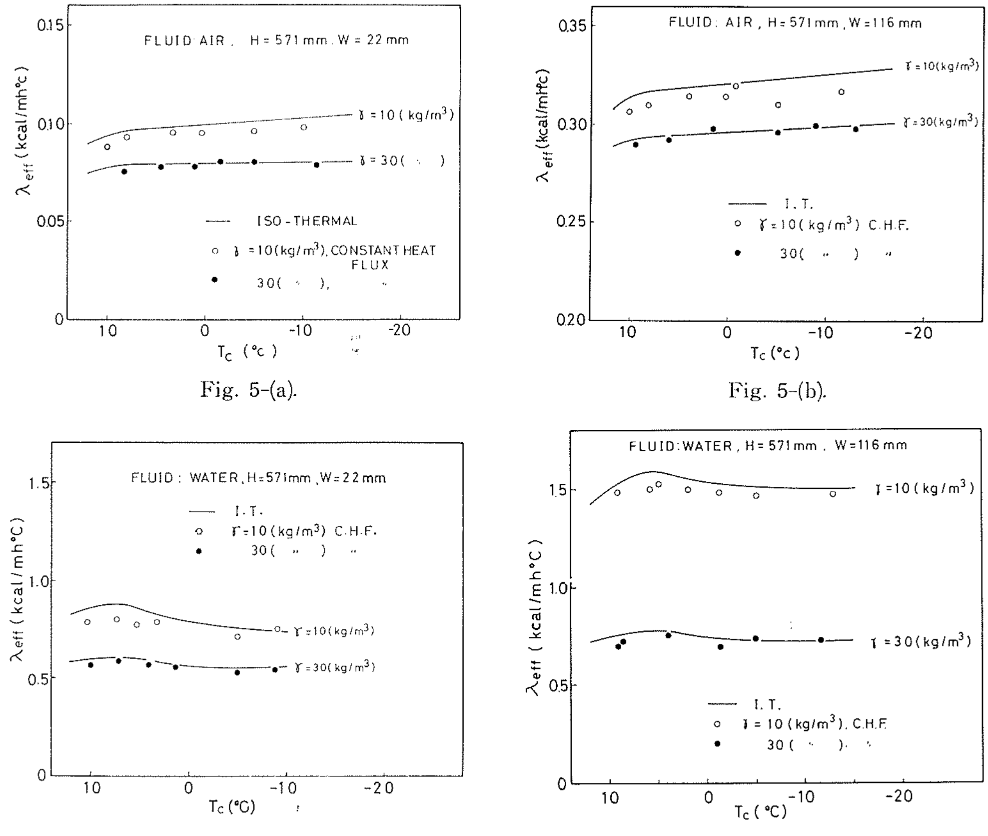

Fig. 5-(a). Fig. 5-(b).

Fig. 5-(c). Fig. 5-(d).

Fig. 5. A relation between the cold wall surface temperature T_c and λ_{eff}.

spectively. It can be said from these figures that the values of λ_{eff} under constant heat flux show a decrease of 5～15% as compared with those under isothermal condition for $\gamma=10$ (kg/m^3) because of the existence of the temperature gradient in the vertical direction. On the other hand, for $\gamma=30$ (kg/m^3) the values of λ_{eff} are independent of the heating conditions of wall due to the increased resistance to a movement of air in the layer with the increasing γ.

Typical results of experiments for water are shown in Fig. 5-(c) and 5-(d). A maximum value of λ_{eff} exists at about $T_c=5$°C under isothermal condition, while the existence of a maximum value of λ_{eff} is not clear under the condition of constant heat flux. This can be explained from the fact that temperature distribution in the vertical glass wool layer is affected by the temperature gradient of the wall in the vertical direction, that is, the fluid layer at 4°C distributes complicatedly in the glass wool layer, consequently, the effect of suppression by density inversion on natural convection becomes weak.

4. Conclusions

The mechanism of heat transfer in a vertical rectangular cavity packed with glass wool under constant heat flux to the wall is investigated.

(1) For $0<\gamma<20$ (kg/m^3) the values of λ_{eff} under constant heat flux result in a decrease of 5～15% as compared with those under isothermal condition. On the other hand, for $\gamma>20$ (kg/m^3) the value of λ_{eff} is independent of the wall heating condition.

(2) The temperature gradient of the hot wall in a vertical direction induced by constant heat flux increases as W increases under the present constant height H, and this temperature gradient decreases the heat transfer in the glass wool layer.

(3) The net heat transfer in the glass wool layer is clearly shown by using the coefficient of heat transfer α which not implicitly contain the term of W.

References

1) Seki N., Fukusako S. and Inaba H.: Bulletin of the Faculty of Engineering, Hokkaido University, No. 84, (1977), p. 59.
2) Lorentzen G. and Brendeng E.: Proceeding of the 10th International Congress of Refrigeration, Vol. 2. (1959), p. 294.
3) Achtziger J.: Kälte Technic, Vol. 11, (1964), p. 308.