Int. J. Heat and Mass Transfer. Vol. 14, pp. 561–564. Pergamon Press 1971. Printed in Great Britain

EXPERIMENTAL STUDY OF VELOCITY AND TEMPERATURE DISTRIBUTION FOR FREE CONVECTION IN A CORNER

J. H. VAN LEEUWEN, C. M. LOOMAN and J. SCHENK*
Laboratorium voor Technische Natuurkunde, Technische Hogeschool, Delft, Nederland

(*Received* 4 *May* 1970)

Abstract—Laminar free convection heat transfer in a vertical rectangular corner is investigated experimentally. Results of temperature and velocity measurements are presented in graphical form. In the corner a region of increased velocity was found.

INTRODUCTION

THE PROBLEM of laminar free thermal convection in the air at a vertical flat plate is well known in literature. Theory and experiment are well established since 1930 [1, 2]. In the present paper we report some experimental results on the analogous phenomenon in a vertical right-angled corner. In literature we could not find theoretical or experimental work on this subject: our only reference concerns some theoretical work for the corresponding problem of forced convection [3, 4].

EXPERIMENT

Our experimental set up consisted of two vertical copper plates (height 0·40 m, width 0·30 m) that were assembled to a right angle. The temperature of these plates was controlled by hot water flowing through horizontal channels that were fraised in the back side of our plates. For each plate these channels were united to three separated sections that were supplied with hot water of constant temperature. Each of these six parallel water flows was independently controlled; for that purpose a tap was mounted at the entrance of each section. By carefully adjusting the state of each tap we were able to obtain a uniform wall temperature of the whole corner.

The corner was placed in a special room, where precautions were taken to maintain uniform temperature of air and walls. During the experiments we did not enter since the readings could be made in another adjacent room. In this way we suppressed disturbing convection streams in the environment of our experimental arrangement as much as possible. To ensure a free feeding stream area towards our corner we placed it 1·55 m above the floor. The walls of the corner were lengthened downward by attaching some cardboard planes that were not heated. In this way the corner geometry was continued into the flow entrance region, so as to prevent air flowing from behind into the corner.

The temperature of the air in the corner was measured by thermocouples. The vertical velocity was measured by a specially developed anemometer. This anemometer consisted of two identical thermistors, one above the other at a small distance, the line of connection parallel to flow direction. The temperature difference between these thermistors is a measure for the velocity, practically independent of the temperature of the air. This anemometer was calibrated against the known free convection velocity distribution at the single vertical plate.

* Present address of senior author (J.S.): Lab. Natuur-en Weerkunde, Landbouwhogeschool, Wageningen, Nederland.

For a detailed description of our experimental arrangement and of the anemometer we refer to [5]. The purpose of this paper is to present some results of our investigation, together with a short discussion.

DISCUSSION

Results of our measurements in the corner have been represented in Figs. 1a, b. Figures 2a, b present some measurements below the lower horizontal edge of our plates. In Figs. 1a and 2a isothermal curves are shown. In these figures the relative temperature ϑ is parameter; $\vartheta = (T - T_0)/(T_1 - T_0)$, T being the local temperature of the air, T_1 the temperature of the plates and T_0 the temperature of the air at large distance. In our case we had $T_1 = 60°C$ and $T_0 = 27°C$; the Grashof number was approximately 10^8. In Figs. 1b and 2b we have drawn curves of equal vertical velocity. Absolute values of the velocity

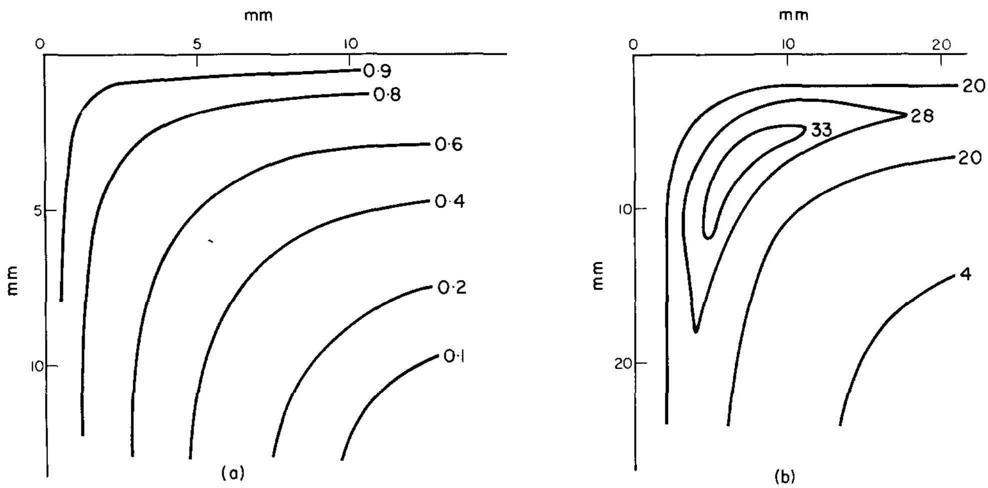

FIG. 1. Temperature and velocity distribution in the corner at a height of 0·19 m. The isotherms are labelled by the parameter ϑ, the lines of constant vertical velocity by the velocity in cm/s. The horizontal distance from the edge is indicated in mm.

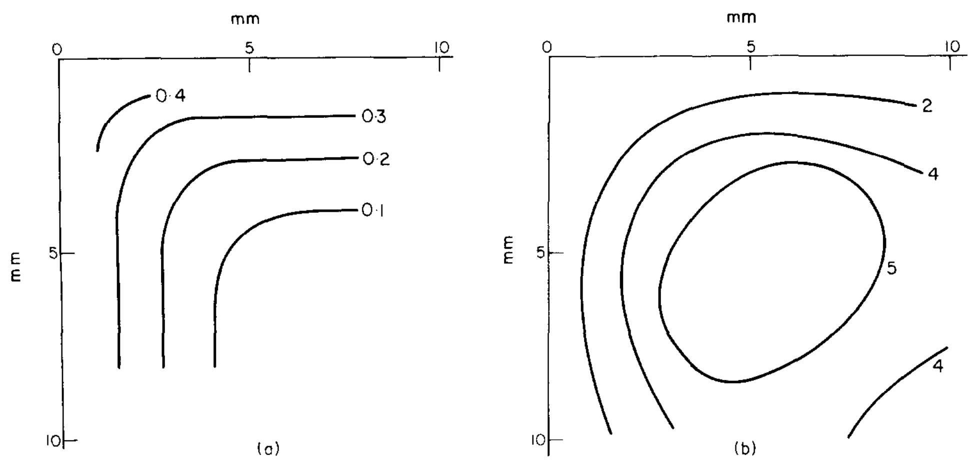

FIG. 2. Temperature and velocity distribution 5 mm below the lower horizontal edge. The isotherms and the lines of constant velocity are labelled as in Fig. 1. The horizontal distance from the edge is indicated in mm

in cm/s are indicated in the figure. Figure 1 shows also that the temperature and velocity field remain approximately that of the single plate up to some distance from the edge. In Fig. 3 we show how the heat transfer coefficient of the vertical isothermal wall is reduced in the neighbourhood of the inner edge of a corner.

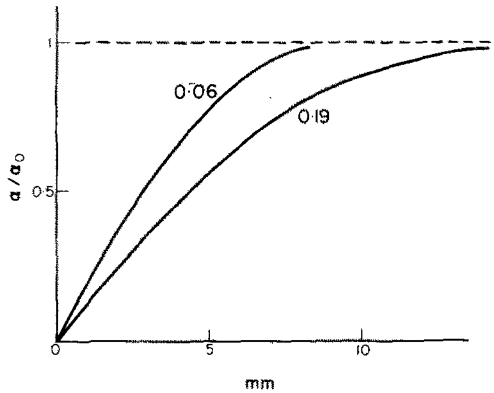

FIG. 3. The coefficient of heat transfer in the corner α at two heights, divided by the corresponding value α_0 at the single plate. The indicated heights are measured in m. Horizontal distance from the edge in mm.

From Fig. 2 we see clearly, that the velocity in the air is not negligible below the lower horizontal edge of the plates. This finding is contradictory to what is mostly accepted in theoretical calculations on free convection about vertical surfaces. It is obvious that this circumstance will complicate the mathematical treatment of our problem. The most prominent conclusion from our investigation, however, is the occurrence of a kind of "chimney effect". This effect is found already below the lower edge (Fig. 2b) but is very obvious in Fig. 1b. In the edge a region of maximum velocity occurs where the velocity increases appreciably above the values that are found under comparable conditions at the single vertical plate. The consequence of this experimental result is that a theoretical, mathematical treatment probably cannot produce a similar solution, analogous to that for the single plate [1]. In this connection we mention still that the well known similarity transformation of Pohlhausen [1] does not apply to obtain coincidence of the experimental isothermal curves of different heights.

Consideration of the temperature distribution along the diagonal of the corner learns that an inflexion point occurs at some distance from the vertical edge. A graphical representation of this distribution may be obtained, e.g. from Fig. 1a. Stating symmetry with respect to the diagonal plane we tried to find from this graph a numerical estimate of the horizontal velocity in this plane. For that purpose we introduced the energy equation for a rectangular coordinate system with the vertical axis in the edge and one horizontal axis perpendicular to the diagonal plane. From symmetry considerations and accounting for experimentally known values of temperature gradients and vertical velocity we found that the horizontal velocity, anywhere at the diagonal, was directed towards the point of maximum velocity. This conclusion would very well agree with the "chimney effect" mentioned before. The order of magnitude of this calculated horizontal velocity component is 1 cm/s, big in comparison with the horizontal velocity anywhere else in the corner but small compared with the vertical velocity component.

REFERENCES

1. E. SCHMIDT and W. BECKMANN, Das Temperatur- und Geschwindigkeitsfeld vor einer Wärme abgebenden senkrechten Platte bei natürlicher Konvektion, *Techn. Mech. Thermodyn.* **1**, 341–349, 391–406 (1930).
2. A. J. EDE, *Advances in Heat Transfer*, Vol. 4. Academic Press, London (1967).
3. G. F. CARRIER, The boundary layer in a corner, *Q. Appl. Math.* **4**, 367–370 (1946).
4. F. K. MOORE, *Theory of Laminar Flows*. Vol. 4, p. 380. University Press, Princeton N.J. (1964).
5. J. H. LEEUWEN and C. M. LOOMAN, Temperatuur- en snelheidsveld bij vrije convectie in een hoek, Internal Reports Technische Natuurkunde, Delft (January 1969, October 1969).

ETUDE EXPÉRIMENTALE DE DISTRIBUTION DE VITESSE ET DE TEMPÉRATURE POUR UNE CONVECTION NATURELLE DANS UN ANGLE

Résumé—On étudie expérimentalement le transfert thermique pour une convection naturelle laminaire dans un dièdre rectangulaire vertical. On présente graphiquement les résultats des mesures de température et de vitesse. Il existe dans l'angle une région de vitesse accrue.

EXPERIMENTELLE UNTERSUCHUNG DER GESCHWINDIGKEITS- UND TEMPERATURVERTEILUNG BEI FREIER KONVEKTION IN EINER ECKE

Zusammenfassung—Der Wärmeübergang bei laminarer freier Konvektion in einer vertikalen, rechtwinkeligen Ecke wurde experimentell untersucht. Die Ergebnisse der Temperatur- und Geschwindigkeitsmessungen werden in graphischer Form dargestellt. In der Ecke wurde ein Gebiet mit erhöhter Geschwindigkeit entdeckt.

ЭКСПЕРИМЕНТАЛЬНОЕ ИЗУЧЕНИЕ РАСПРЕДЕЛЕНИЯ СКОРОСТИ И ТЕМПЕРАТУРЫ ПРИ СВОБОДНОЙ КОНВЕКЦИИ В ПОВОРОТНОМ КАНАЛЕ

Аннотация—Экспериментально исследуется теплообмен при ламинарной свободной конвекции в вертикальном прямоугольном поворотном канале. Результаты измерений температуры и скорости приводятся в виде графиков. Найдена область увеличения скорости в поворотном канале.