Int. J. Heat Mass Transfer. Vol. 19, pp. 1057–1063. Pergamon Press 1976. Printed in Great Britain

ON THE INTRODUCTION OF DISTURBANCES IN A NATURAL CONVECTION FLOW

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(*Received* 8 *July* 1975 *and in revised form* 9 *February* 1976)

Abstract—A consideration of the mechanisms underlying disturbance introduction in a natural convection boundary layer has been carried out. The nature and magnitude of the introduced disturbance are interpreted from measurements of the amplified disturbance downstream. The dependence of the introduced disturbance on input parameters, like amplitude, position and frequency, is studied in detail. The study answers several fundamental questions concerning the artificial introduction of disturbances in a natural convection flow and relates the results obtained to naturally-occurring disturbances. It also brings out several interesting points on disturbance behavior in natural convection flows.

NOMENCLATURE

A, physical amplitude of the vibrating ribbon;

f', non-dimensional velocity, $f' = \frac{U}{U_c}$;

f'', non-dimensional velocity gradient, $f'' = \frac{df'}{d\eta}$;

g, acceleration due to gravity;

G, Grashof number, defined in (1);

Pr, Prandtl number of the fluid;

ΔT, temperature difference between local plate temperature and the ambient medium. For a power-law variation, $\Delta T = Nx^n$, $n = \frac{1}{5}$ gives the uniform flux case;

U, physical velocity at a point in the boundary layer;

U_c, characteristic velocity, defined in (1);

u', measured peak velocity disturbance amplitude;

u'_I, estimated amplitude of introduced velocity disturbance, equation (3);

x, distance along the vertical surface from the leading edge;

y, horizontal distance away from the vertical surface.

Greek symbols

β, coefficient of thermal expansion of the fluid;

δ, characteristic length, defined in (1);

δ_0, characteristic length at ribbon location;

η, similarity variable, $\eta = \frac{y}{\delta}$;

$\Delta\eta$, non-dimensional vibrator amplitude, $\Delta\eta = A/\delta_0$;

ν, kinematic viscosity of the fluid;

ψ, stream function.

INTRODUCTION

AN IMPORTANT consideration in the study of natural convection flows is the origin, nature and behavior of disturbances in the flow. Since these disturbances are believed to cause the breakdown of laminar flow, leading it to turbulence, considerable work has been done on their amplification in an unstable boundary layer. The early stages of disturbance growth and propagation have been largely studied theoretically on the basis of linear stability theory and experimentally with artificially-introduced disturbances, as discussed in detail by Gebhart [1]. Work has also been done on the transition to turbulence and on developed turbulence, resulting from naturally-occurring disturbances, see [2–4]. However, the mechanisms underlying the introduction of these disturbances in the boundary layer are largely unknown. The present study deals with this aspect in natural convection flows.

There are several ways in which a disturbance may be introduced in a natural convection boundary layer. For artificially-introduced disturbances, this is very frequently done by means of a vibrating ribbon positioned in the boundary layer. The disturbance may also be introduced by a variation in the heat input at the heated surface, or by an additional external momentum or energy input into the boundary layer. Most of the experimental work on disturbance behavior in natural convection has been carried out by means of a vibrating ribbon. This mode of disturbance introduction also represents the circumstance for a frequent source of naturally-occurring disturbances, namely external vibrations. Therefore, the present work considers the disturbance input due to a vibrating ribbon and the implications of these results for naturally-occurring disturbances.

The study considers in detail the dependence of the introduced disturbance on the amplitude, frequency, position and dimensions of the vibrating ribbon. Important parameters for the control and variation of the introduced disturbance are determined and studied. The magnitude of this disturbance is estimated from the measured disturbance amplitude downstream. The results are also compared with those for naturally-occurring disturbances. The effect of a variation in input parameters, like magnitude and frequency, on the observed downstream disturbance behavior is also considered in terms of earlier stability studies.

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This work provides important insight into the relatively unknown problem of disturbance introduction in a natural convection flow and determines the parameters that govern the magnitude and behavior of the introduced disturbance. It answers several basic questions of interest and considers other important and interesting points concerning disturbances in a natural convection flow.

RESULTS AND DISCUSSION

The natural convection flow considered in this study is that arising adjacent to a heated flat vertical surface, with a uniform surface heat flux. The magnitude of the introduced disturbance at the ribbon location usually being too small to be measured accurately, the study of the input disturbance is based on the measurements downstream, in conjunction with the results of linear stability theory. This work is, therefore, inevitably linked with the earlier studies on the stability of natural convection boundary layers.

The artificial disturbances in this study were introduced by a vibrating ribbon in the unstable portion of the boundary layer so as to allow the introduced disturbance to amplify downstream. The vibrator amplitudes were kept small, less than about 1% of the boundary-layer thickness at the ribbon location, in order to permit the use of linear stability analysis in the evaluation of the nature, magnitude, and form of the input disturbance, from the measurements of the amplified disturbance downstream.

The experimental arrangement employed is discussed in detail by Jaluria and Gebhart [5, 6]. These studies were primarily concerned with stability and transition in natural convection, whereas the present work deals with the mechanism of disturbance introduction in the flow. The artificial disturbances were introduced in the boundary layer by means of a ribbon vibrating horizontally in the flow. The fluid was water at room temperature (22°C), $Pr = 6.7$. The vibration of the ribbon was sinusoidal and its amplitude and frequency could be controlled and measured. The ribbon could be positioned at any location in the boundary layer, longitudinally (in x) and laterally (in y). The downstream measurements of the velocity disturbance were taken by means of hot wire anemometers. Further details are given in [5] and [6].

Several effects arising from a variation in vibrator parameters were studied. It was found that the amplified velocity disturbance downstream was also sinusoidal at the frequency of the input disturbance, as discussed later. Detailed measurements of the velocity disturbance amplitude distribution across the boundary layer were made and the maximum amplitude determined. The first experiment carried out was on the effect that a variation in the vibrator amplitude has on this measured maximum velocity disturbance amplitude u'. Several experimental results were obtained and Fig. 1 shows the typical variation obtained.

It is seen that as the vibrator amplitude is increased, the measured disturbance amplitude increases linearly

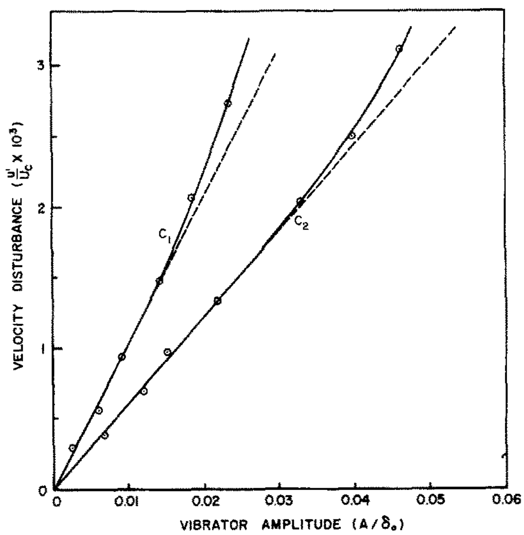

FIG. 1. Dependence of the velocity disturbance amplitude, at $G = 330$, on the vibrator amplitude, the ribbon being at $G = 110$. Curve C_1: vibrating ribbon positioned at the inflexion point in the base velocity profile; Curve C_2: vibrating ribbon positioned at $\eta = 3.0$.

up to a point beyond which the appearance of significant nonlinear effects in disturbance growth mechanisms causes a faster disturbance amplitude growth, see Jaluria and Gebhart [5] and Klebanoff *et al.* [7]. This deviation from linearity at large vibrator amplitude is discussed later. The maximum velocity disturbance amplitude u' is non-dimensionalized by the characteristic velocity U_c, at the location where measurements are taken, and the physical vibrator amplitude A by the characteristic length δ, at the location of the ribbon

$$U_c = \frac{\nu G^2}{4x}, \quad \text{where} \quad G = 4\left[\frac{g\beta x^3 \Delta T}{4\nu^2}\right]^{1/4}$$

$$\delta = \frac{4x}{G}. \tag{1}$$

Denoting the characteristic length at the ribbon location by δ_0, the nondimensional vibrator amplitude $\Delta\eta$ is:

$$\Delta\eta = \frac{A}{\delta_0}.$$

In the curves shown, Fig. 1, the disturbance was introduced at $G = 110$, which is in the unstable portion of the stability plane, and the frequency of the ribbon is close to that predicted by linear stability to be most amplified, see Gebhart [1]. Therefore, this results in disturbance amplification downstream. The measurements of the maximum velocity disturbance amplitude are at $G = 330$.

The main point observed from the curves in Fig. 1 is the linear dependence of the measured velocity disturbance on the vibrator amplitude at smaller amplitudes. Since from linear stability theory, the amplitude at a given G is proportional to the introduced disturbance amplitude, it is clear that the amplitude of the disturbance introduced in the flow is directly proportional to the amplitude of vibration of the ribbon, assuming the deviation from linear to be due to nonlinear growth mechanisms.

In the present study, the vibrator amplitude $\Delta\eta$ was kept small enough so as to ensure a linear dependence of the introduced disturbance amplitude on $\Delta\eta$. In the range of investigation, no nonlinearity was observed in the motion of the ribbon. Measurements were also taken at lower values of G where nonlinear effects in disturbance growth mechanisms were not large enough to cause the deviation observed in Fig. 1 and a linear plot was obtained. These considerations confirm the above observation that the amplitude of the introduced disturbance varies linearly with the vibrator amplitude, in the range of the experiment, and that the deviation from linear for amplified disturbances downstream is due to significant nonlinear effects in disturbance growth. The application of the results of linear stability theory to the measurements must, therefore, be restricted to the linear portion of the curve in Fig. 1.

The measurements also indicated that the disturbance amplitude variation across the boundary layer, not shown here, was close to that predicted by the theory, refer Gebhart [1]. The boundary-layer flow, therefore, interacts with the introduced disturbance, which is obviously very different in form from that observed downstream due to the localized nature of disturbance input, and gives rise to the disturbance profile that conforms to the analytical results. Unfortunately, accurate measurement of the disturbance at the ribbon location is very difficult due to the very small amplitude values. From linear stability, the disturbance at the ribbon is only about 1/60 of the amplitude at $G = 330$, which is itself a small velocity disturbance, being about 2% of the maximum in the base velocity. It would, however, be very interesting to observe the changing form of the disturbance as the flow proceeds immediately downstream from the ribbon location.

The interaction of the boundary layer with the localized introduced disturbance to bring it to conform to the predicted form is over a very short distance, as also observed by Dring and Gebhart [8] and Knowles and Gebhart [9]. In the study carried out by Dring and Gebhart [8], measurements taken at $x = 5.08$ cm, the ribbon being at $x = 3.81$ cm, showed the disturbance field to be close to that predicted. This, therefore, indicates the difficulty of determining the form of the disturbance in the immediate vicinity of the ribbon, before the instability mechanisms of the flow transform it to yield the characteristic eigenfunctions determined by analysis. However, the observation that the input disturbance amplitude is proportional to the vibrator amplitude has important implications, as discussed later.

Figure 1 indicates another very important point. The velocity disturbance amplitude curves shown were obtained for two different lateral positions, in y or η, of the vibrating ribbon, keeping the vertical position x unchanged. The curve C_1, for which the measured disturbance amplitude is higher at a given vibrator amplitude, was obtained with the ribbon positioned near the inflexion point in the base velocity profile, $\eta = 1.35$, and the curve C_2 with the positioning at $\eta = 3.0$. Figure 1, therefore, also indicates the dependence of the magnitude of the introduced disturbance on the lateral position of the vibrating ribbon.

To examine the above dependence more closely, the mechanism of disturbance introduction by a vibrating ribbon in the boundary layer is considered. The velocity disturbance introduced by the ribbon is a function of its amplitude and the velocity gradient, since the disturbance arises due to the resulting interaction in a region of varying velocity. Similar to the concepts involved in the mixing length in turbulent flows, the magnitude of the velocity disturbance introduced by the ribbon is estimated as the difference between the velocities, in the theoretical base velocity profile, corresponding to the peak to peak positions (in y, or η) of the vibrating ribbon. This would imply a linear dependence of the amplitude of the introduced disturbance on the vibrator amplitude, if the velocity gradient remains unaltered. This simplistic model gives the peak amplitude but does not specify the amplitude distribution, or the region of influence of the ribbon that arises from continuity.

The above points can be considered mathematically in terms of the variation, across the boundary layer, of the nondimensional velocity gradient f''. The nondimensional stream function $f(=\psi/\nu G)$ gives rise to the velocity f' in terms of the characteristic velocity U_c and the physical velocity U as:

$$f' = U/U_c. \quad (2)$$

Figure 2 shows the variation of the velocity gradient f'' across the boundary layer for the isothermal and the uniform heat flux vertical surface. Employing Taylor's series for the vibration of a ribbon with amplitude $\Delta\eta$, vibrating about a mean position where the velocity gradient is f_v'', the magnitude of the difference in velocity, $|\Delta U|$, corresponding to the peak to

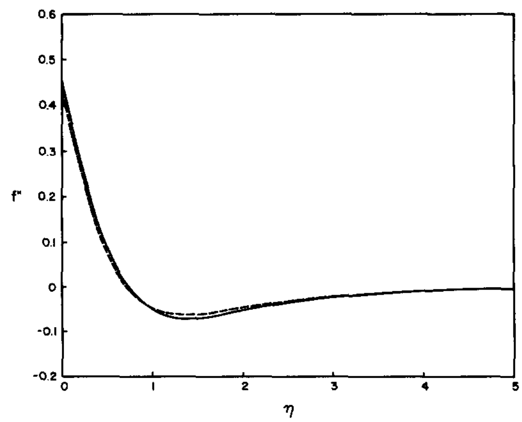

FIG. 2. Variation of the nondimensional velocity gradient f'' across the boundary layer. ----, uniform heat flux surface; ——, isothermal surface.

peak positions of the ribbon is given by

$$\frac{u'_I}{U_c} = \frac{|\Delta U|}{U_c} = \Delta\eta |f_v''| \quad (3)$$

where u'_I/U_c is the estimated nondimensional amplitude of the introduced disturbance when only the first term in the series is retained. The next term is proportional to $(\Delta\eta)^3 f_v''''$. Since in the present study, $\Delta\eta$ is restricted to about 0.1, the first term is generally much higher than the higher order terms and the introduced disturbance amplitude u'_I is proportional to the vibrator amplitude $\Delta\eta$, as observed experimentally. However, it must be noted that if the ribbon is positioned near the peak in the base velocity profile, where $f_v'' = 0$, the dependence of u'_I on $\Delta\eta$ would, obviously, be much different and would not be linear. The limitation on $\Delta\eta$ necessary for a linear dependence of u'_I on $\Delta\eta$ can be estimated from a consideration of the magnitudes of the terms in the series expansion, for a given ribbon position.

It is also seen that the magnitude of the introduced disturbance is dependent on f_v'' and hence on the lateral position of the vibrating ribbon. The nondimensional amplitude is independent of the longitudinal position (in x) of the ribbon, if the lateral position (in η) and $\Delta\eta$ are unaltered. This implies that the physical introduced disturbance amplitude u'_I varies as the local characteristic velocity U_c.

From Fig. 1, the disturbance introduced by a ribbon placed near the inflexion point, $\eta = 1.35$, is about 1.7 times that by a ribbon placed at $\eta = 3.0$ for the same vibrator amplitude, in the linear region of the curves. As seen from Fig. 2, this is quite close to the ratio of f_v'' at the two locations, lending support to the above arguments.

Since f_v'' is an important parameter in the introduction of the disturbance, the lateral positioning of the vibrating ribbon in the boundary layer is an important consideration. It was found by Polymeropoulos and Gebhart [10] that positioning of the ribbon at the inflexion point was important in stability studies due to the importance of the outer critical layer in stability, and this position was employed for several subsequent experimental studies on instabilities in natural convection flows.

Considerations in the present work too indicate the importance of the inflexion point in the positioning of the ribbon. $|f_v''|$ is a maximum at the inflexion point, in the boundary-layer region outside the peak in the base profile, and hence the disturbance introduced is largest for a given vibrator amplitude. The same, and higher, values of $|f_v''|$ may be obtained near the vertical surface, $\eta = 0$ to 0.5. However, positioning the ribbon so close to the surface is expected to cause a considerable effect on the introduced disturbance due to the disturbance damping at the wall. Also, the sharp temperature gradient near the surface makes it desirable to have the ribbon away from it in order to avoid any significant effect on the heat transfer from the surface due to the presence of the ribbon. Another consideration that may be important in the positioning of the ribbon concerns the effect of a slight shift in ribbon position on the introduced disturbance amplitude. Clearly this effect is minimum at the inflexion point and large close to the wall, as seen from Fig. 2.

A comparison is now made of the estimated magnitude of the velocity disturbance introduced, u'_I, from the above considerations, equation (3), with that determined from the downstream measurements, using linear stability theory results. Employing the linear portion of the disturbance curve C_1 in Fig. 1, the nondimensional disturbance amplitude u'/U_c at the ribbon location, for the vibrator amplitude $\Delta\eta$ of 0.02, is determined from the results of linear stability theory (Gebhart [1]) as $u'/U_c = 8.0 \times 10^{-5}$. The estimated amplitude of the introduced disturbance u'_I/U_c is 12.1×10^{-4}. There is, therefore, about a tenfold difference between the estimated disturbance amplitude and that from the measurements downstream. This is not surprising, since the ribbon generates a localized velocity disturbance which gets distributed over the entire boundary region by continuity. The estimate in equation (3) is for this localized disturbance which rapidly interacts with the flow to give rise to the observed form of the disturbance downstream. A more realistic comparison of disturbance amplitudes would be between disturbances of similar form, i.e. of similar distribution across the boundary region.

Obviously, there is an unknown factor that correlates the maximum localized disturbance amplitude introduced, estimated as u'_I, and the peak disturbance amplitude in the disturbance profile resulting downstream through continuity and conservation of energy considerations. This factor would depend on the volume of the fluid to which the localized disturbance is imparted by the ribbon, and hence on its height. As mentioned earlier, to determine this factor, detailed information on the disturbance in the immediate neighborhood of the ribbon must be known and the change in its form from the input to the one that conforms to the disturbance profile predicted by stability analysis must be studied. Since this change takes place over a very short distance, as observed by Dring and Gebhart [8], and since accurate measurement is very difficult due to the extremely small magnitude of the disturbance, it is hard to determine the relationship between the disturbance estimated from equation (3) and the resulting maximum disturbance amplitude in the established disturbance profile. However, it was observed from several measurements taken in the present study that this factor is a function of the ribbon height, being essentially independent of the lateral position and amplitude of vibration.

Therefore, the above results permit a realistic consideration of the effect of the ribbon position and amplitude on the introduced disturbance. The effect of a change in the ribbon height is more involved and must be determined experimentally.

The results of an experiment to study the dependence of the magnitude of the disturbance introduced on the height of the vibrating ribbon are shown in Fig. 3. The ribbon introducing the disturbance had

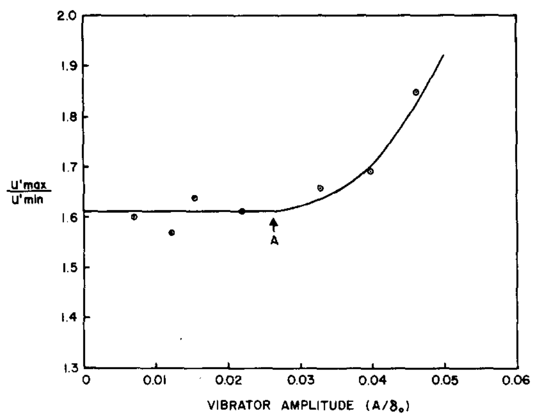

FIG. 3. Variation of the ratio of the measured velocity disturbance due to a ribbon segment 9.5 mm high (max.) to that due to a segment 3.17 mm high (min.) with the vibrator amplitude; $G = 330$. The vibrating ribbon is at $G = 110$ and $\eta = 3.0$.

A, the disturbance at the greater ribbon height being larger, nonlinear effects arise there and the disturbance growth increases as shown. Clearly, further work is needed to determine the exact and detailed dependence of the introduced disturbance on ribbon height.

The downstream propagation of the introduced disturbance is shown in Fig. 4 where the ratio of the measured velocity disturbance amplitude at $G = 350$ to that at $G = 300$ is shown as a function of the vibrator amplitude, for given ribbon height and positioning at the inflexion point. Further details of the measurements and the arrangement employed are given in [6]. The disturbance growth at $G = 350$ deviates from the upstream linear growth behavior at a lower vibrator amplitude, given by point A. This is due to the larger amplification region for the introduced disturbance, see Jaluria and Gebhart [6]. The ratio of the two measured disturbance amplitudes, for vibrator amplitude less than that at A, is close to that predicted by linear stability analysis. At point B, the curve for $G = 300$ also deviates from linear growth. An interesting feature is seen in that the relative growth rate of the disturbance at $G = 300$ quickly becomes greater than that at $G = 350$ and the ratio decreases. The introduced disturbance being the same in both cases, at a given vibrator amplitude, Fig. 4 indicates the growth of the introduced disturbance with G and the downstream effects arising from its growth.

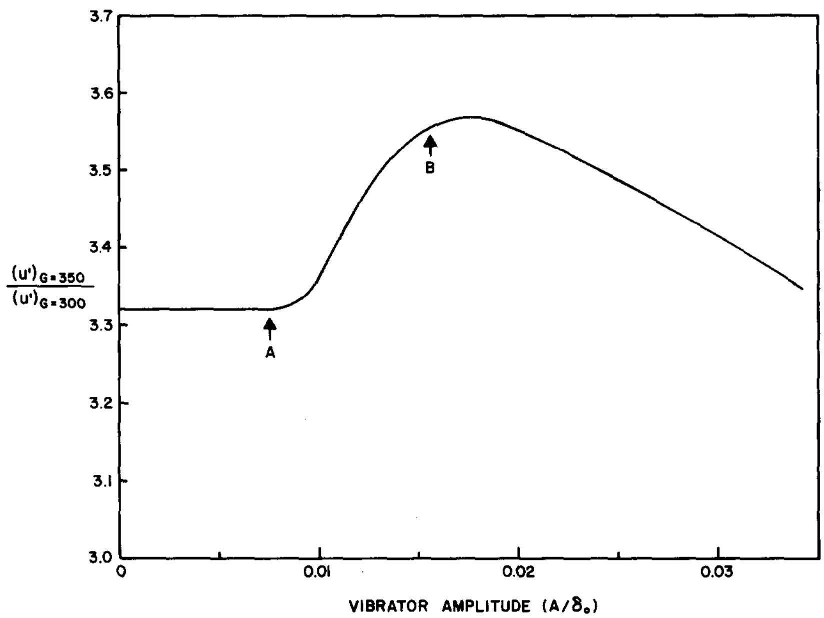

FIG. 4. Dependence of disturbance amplitude growth from $G = 300$ to $G = 350$ on the vibrator amplitude. The vibrating ribbon is positioned at $G = 150$ and at the inflexion point in the base velocity profile.

segments of two different heights, one three times the other. This allowed a simultaneous introduction of disturbances arising from two different ribbon heights, at a given position and for specified vibrator amplitudes. Measurements were taken downstream at locations corresponding to the sections of greater height, termed maxima, and to those of smaller height, termed minima. It has been found, Jaluria and Gebhart [5], that these regions of greater and smaller disturbance amplitudes retain their relative positions downstream owing to the vertical propagation of the disturbance. Figure 3 shows a sample of the results obtained in these experiments at the location $G = 330$. In the region of predomination of linear growth mechanisms, the larger ribbon height is found to give rise to a disturbance about 1.6 times larger than that by the smaller ribbon height. At point

Figure 5 shows a few recorded traces of the measured disturbance. These indicate the close conformity between the frequency of the observed disturbance and the vibrator frequency, thereby indicating the constancy of the frequency of the disturbance as it is convected downstream from the location of its introduction. In all cases, only one disturbance frequency

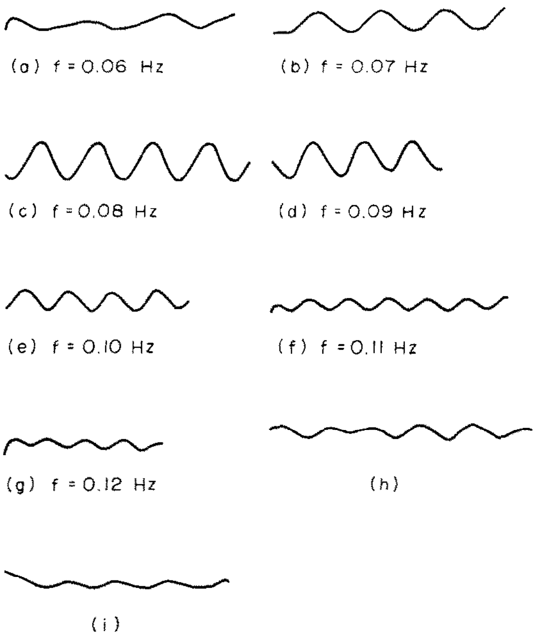

FIG. 5. (a)–(g): Recorded velocity disturbance at $G = 300$, $\eta \simeq 1.0$, $x = 38$ cm, for varying input frequencies. Input disturbance is at $G = 150$ and at the inflexion point. Time increases from left to right. (h)–(i): Recorded velocity and temperature disturbances, respectively, at $G = 472$ and $x = 61$ cm, for naturally-occurring disturbances.

is observed, showing the dominant effect of the introduced disturbance. However, it must be noted that if the input frequency is very far from the region of rapid amplification, or of frequency filtering, as described by Gebhart [1], the components of the naturally-occurring disturbances in the highly amplified region would dominate and the disturbance observed downstream would be expected to have other frequency components. Over the range of input frequency variation shown in Fig. 5, this does not occur and the artificially-introduced input disturbance dominates. The observed disturbance also shows a very strong frequency filtering effect in that disturbances in a narrow range of frequency are very rapidly amplified downstream.

Dring and Gebhart [8] observed higher harmonics in the measured disturbance at low input frequencies, probably due to other effects in the vibrator motion or coupling between this and the fluid motion. In Fig. 5, and in several similar experiments carried out, no such effects were observed. However, the presence of other frequencies, besides the input, could be observed at frequencies far from the range shown due to the selective amplification of disturbances by the boundary layer discussed above. Due to this, naturally-occurring disturbances would give rise to amplitudes comparable to those due to the artificially-introduced disturbance. This was found to be the case, despite efforts to keep the background disturbances at a minimum. The downstream effect of the naturally-occurring disturbance was also measured in the present work to ascertain that it was small in comparison to that due to the artificially-introduced disturbance, in the frequency range considered, so as to permit a study with controlled disturbance.

The measured natural disturbances are also shown in Fig. 5. These measurements were taken at $G = 472$ for $x = 61$ cm, which was found to be in laminar flow, and the recorded trace of the velocity and temperature disturbance indicates the almost sinusoidal form. In this recorded data, as well as in several other similar measurements, the observed disturbance frequency in laminar flow was found to be very close to that predicted by linear stability theory to be most amplified. Natural disturbances arise from ambient disturbance sources such as vibrations, see the discussion by Tani [11]. Vibrations would give rise to disturbances by mechanisms very similar to those considered in this work. However, the disturbance being, in general, introduced over the entire boundary region, the disturbance introduced at the neutral stability location gives rise to the largest disturbance downstream due to the largest amplification region. For the natural disturbance data shown in Fig. 5, the nondimensional disturbance amplitude at the neutral stability location is estimated to be 2.1×10^{-5}. The results of the present work can then be employed to estimate the magnitude of the required input disturbance and the corresponding vibrator amplitude. Therefore, these results obtained from artificially-introduced disturbances can also be employed in a study of naturally-occurring disturbances.

CONCLUSIONS

This study considers the mechanism underlying the introduction of a disturbance in a natural convection flow. The configuration considered is that of a vertical boundary-layer flow adjacent to a uniform heat flux surface, the disturbance being introduced by means of a vibrating ribbon in the flow. The dependence of the introduced disturbance on various vibrator parameters and its downstream behavior are studied in detail. The nature and magnitude of the introduced disturbance are studied by means of the measurements taken on amplified disturbance downstream, in conjunction with the results of linear stability analysis. A comparison of the results for these artificially introduced disturbances with those for naturally-occurring disturbances, as well as a consideration of their relevance in the natural circumstance, are made. The study, therefore, determines the important parameters that govern the magnitude, form, and nature of the input disturbance. It brings out several points of interest and importance in an area which, though important, has not been considered in detail heretofore.

Acknowledgements—The author acknowledges the helpful discussions with Professor B. Gebhart during the experimental work, as well as the support from the National Science Foundation under Research Grant GK 18529.

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SUR L'INTRODUCTION DE PERTURBATIONS DANS UN ECOULEMENT DE CONVECTION NATURELLE

Résumé—On a considéré les mécanismes agissant à la suite de l'introduction de perturbations dans une couche limite en convection naturelle. La nature et la grandeur de la perturbation sont interprétées à partir des mesures à l'aval sur la perturbation amplifiée. On étudie en détail l'influence des paramètres d'entrée, tels que l'amplitude, la position et le fréquence sur l'évolution de la perturbation. L'étude donne une réponse à plusieurs questions fondamentales concernant l'introduction artificielle de perturbations dans un écoulement de convection naturelle et relie les résultats obtenus au cas de perturbations apparaissant naturellement. Elle fait également ressortir plusieurs points intéressants sur le comportement de perturbations dans les écoulements de convection naturelle.

ÜBER DAS EINFÜHREN VON STÖRUNGEN IN NATÜRLICHE KONVEKTIONSSTRÖMUNGEN

Zusammenfassung—Es werden die Mechanismen, denen die Einleitung von Störungen in die Grenzschicht bei natürlicher Konvektion unterliegt, untersucht. Die Art und die Größe der eingeführten Störung wird aus Messungen der stromabwärts verstärkten Störung ermittelt. Die Abhängigkeit der eingeleiteten Störung von den Eingangsgrößen, wie Amplitude, Frequenz und Ort wird im Detail untersucht. Die Studie beantwortet mehrere grundsätzliche Fragen in bezug auf die künstliche Einführung von Störungen in natürliche Konvektionsströmungen. Die Ergebnisse werden mit denjenigen verglichen, die man bei natürlich auftretenden Störungen erhält. Die Arbeit zeigt interessante Gesichtspunkte in bezug auf das Verhalten von Störungen in natürlichen Konvektionsströmungen auf.

О ВВЕДЕНИИ ВОЗМУЩЕНИЙ В СВОБОДНОКОНВЕКТИВНЫЙ ПОТОК

Аннотация — Рассматриваются механизмы введения возмущения в пограничный слой в условиях свободной конвекции. Характер и величина введенного возмущения оцениваются из результатов измерений усиленного возмущения вниз по потоку. Подробно исследуется зависимость введенного возмущения от его начальных параметров, таких как амплитуда, положение и частота. Проведенное исследование даёт ответ на несколько основных вопросов относительно искусственного введения возмущений в свободноконвективный поток. Полученные результаты сравниваются с данными по естественно возникающим возмущениям. Выявлены некоторые интересные особенности природы возмущения в свободноконвективных потоках.