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Effect of free stream turbulence on flat plate heat transfer†

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Abstract—The effect of free stream turbulence on surface heat transfer was investigated for a smooth flat plate. The free stream turbulence was introduced by a turbulence grid. Turbulence intensity was measured with a hot-wire anemometer both in the boundary layer and in the main stream. Under the same conditions, the local heat transfer coefficient on the flat plate surface was measured using an unsteady method. The heat transfer coefficient was found to increase with increasing turbulence level, rapidly in the range of small turbulence level and slowly in the high range. At a turbulence level of 7–8%, the heat transfer coefficient levels off to a value about 55% higher than that obtained for very small free stream turbulence.

1. INTRODUCTION

HEAT TRANSPORT occurs through convection in a developing boundary layer on a heated surface. Therefore, any factor that affects the boundary layer may affect the heat transfer. Normally, free stream turbulence will change the characteristics of the boundary layer thus altering the heat transfer. This effect has never been discussed from a theoretical viewpoint. In some experimental studies, free stream turbulence was assumed to be very low and even sometimes it was totally neglected. Turbulence is inevitable for approaching flows in many heat transfer devices. Therefore, the study of free stream turbulence and its effects are important.

Several existing studies make a qualitative guess as to the increase in heat transfer caused by free stream turbulence. Few studies, however, have considered the quantitative effects. To the authors' knowledge, a study made by Commings *et al.* [1] for a cylinder in cross flow seems to be the only one giving such quantitative discussions.

The present study deals with heat transfer from a flat plate. Free stream turbulence is generated by means of a turbulence grid. The intention of this paper is to discuss the effect of free stream turbulence quantitatively. Therefore, measurements were made for the heat transfer coefficient as well as for turbulence.

2. EXPERIMENTAL APPARATUS AND PROCEDURE

2.1. *Experimental apparatus*

The experimental apparatus was the same as that described by Fig. 2 of the first report of the experimental study on heat transfer for the flat plate in a forced flow [2]. The present study incorporates a new device that can regulate the free stream turbulence as shown in Fig. 1. It is a type of turbulence grid S installed at the outlet of the contraction T (same as contraction E in Fig. 2 of the previous report) that induces free stream turbulence. The grid consists of rods with a circular cross section assembled in a rectangular configuration with the dimensions as shown in Table 1. The largest free stream turbulence was induced by grid A, while the smallest was induced by grid C.

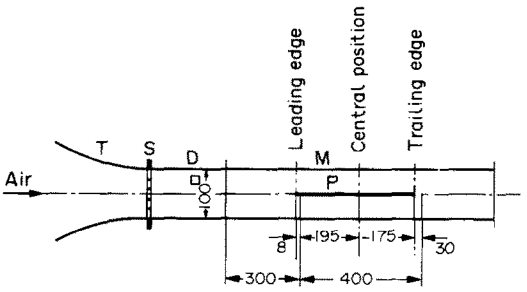

FIG. 1. Experimental apparatus.

The test section duct containing the measuring plate was located downstream from the grid. The turbulence level near the measuring plate was controlled by changing the distance between the grid and the measuring plate, since the turbulence intensity induced by the grid decreases with increasing

Table 1. Dimensions of grid (mm)

Symbol for grid	A	B	C
Rod diameter	6	3	1
Pitch	28	13	7

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† This paper is a translation of the paper presented at a meeting held in Japan on 19 October 1953 and published in *Trans. Japan Soc. Mech. Engrs* **19**(80), 18–25 (1953).

streamwise distance. Therefore, a variable length auxiliary duct D was installed as shown in Fig. 1.

Measurements were made using two types of ducts D, 50 and 10 cm in length, as well as without installation of the duct. Various levels of free stream turbulence intensity could be achieved by combining the different grid types with the different duct lengths D. To assure that measurements were made at a point where the turbulence distribution was cross-sectionally uniform, the plate was installed at a suitable distance downstream from the screen. This distance was determined from preliminary turbulence measurements.

2.2. *Measurement of the local heat transfer coefficient*

A brief outline of the measuring method for the local heat transfer coefficient is given here (a detailed description was given in the previous study [2]). The plate with constant temperature, previously heated by a flow of hot air, is cooled suddenly by drawing cold air over the plate. During the cooling process, the time-dependent change of the local temperature difference between the air flow and the plate was measured. The local heat transfer coefficient was calculated from

$$\alpha = Bc\gamma s/2 \tag{1}$$

where B is the index of the change in the temperature difference θ over a period of time t during the cooling process, c is the specific heat of the plate, γ the specific weight of the plate, and s the thickness of the plate. B is given by

$$\theta = A\,e^{-Bt}. \tag{2}$$

The plate used in this study was a tin-coated iron plate 1.32 mm thick. The front edge of the plate was smooth. The heat transfer coefficient was measured at twelve streamwise locations. The free stream velocity was about 14 m s^{-1}. Another measurement for a free stream velocity of 7 m s^{-1} was also made to examine the effect of the free stream velocity.

2.3. *Measurement of the turbulent intensity*

2.3.1. *Characteristic frequency of the amplifier for the measurement of turbulence.* Turbulence was measured with a hot-wire anemometer. The biggest difficulty, when using the hot-wire anemometer to measure turbulence, arises from temperature fluctuation of the hot wire due to the heat capacity of the wire. This fluctuation leads to the electric voltage fluctuations being out of phase with the velocity fluctuation, decreasing the amplitude of the voltage fluctuation and its time lag. Additionally, the phase lag and the decreasing rate of amplitude increase with the frequency of the velocity fluctuations. According to Dryden and Kuethe [3], the amplitude decreases in proportion to $1/\sqrt{(1+(M\omega)^2)}$ and the phase lag increases in proportion to $\tan^{-1} M\omega$, where $\omega = 2\pi f$, f is the frequency of the velocity fluctuations, $M = 4.2\rho A^2 c(\bar{T}-T_0)/i^2 r$ and is a characteristic of the heat capacity of the hot wire, ρ the specific resistance of the wire, A the cross section of the wire, c the specific heat of the wire, r the resistance of the wire, $\bar{T}$ the mean temperature of the wire, T_0 the fluid temperature and i the electric current passing through the wire.

Therefore, compensation for the decrease in amplitude and the phase lag is needed for the situation when air flow turbulence fluctuates at various frequencies. The frequency characteristics of the amplifier should be completely opposite to the characteristic frequency of the hot wire so that the total characteristic is independent of frequency. Mock and Dryden [4] used principles of inductance and resistance to build an amplifier satisfying the requirements described above. However, they needed a very large inductance coil with an empty core in order to maintain good frequency sensitivity. Additionally, a large coil having negligibly small capacitance is very difficult to construct. Therefore, the compensation was achieved using negative feedback for this study. The negative feedback circuit is shown in Fig. 2. A single step voltage amplifier (6F6) was connected in series after a three-step voltage amplifier (6SH7–6SH7–6SH7).

Negative feedback was supplied from the plate V_3 to the cathode V_2. Denoting $\dot{G}$ as the amplification rate between V_2 and V_3, β the feedback rate, $\dot{E}_i$ the input voltage to V_2, and $\dot{E}_o$ as the output voltage from V_3, the following equation can be derived:

$$\dot{G}(\dot{E}_i+\dot{E}_o\beta) = \dot{E}_o$$

$$\dot{E}_o/\dot{E}_i = \dot{A} = \dot{G}(1-\beta\dot{G})$$

where $\dot{A}$ is the actual amplification rate when negative feedback is used and the dot above each sign indicates a vector quantity. If $|\dot{G}\beta| \gg 1$, the following relation can be derived:

$$\dot{A} \fallingdotseq -1/\beta. \tag{3}$$

In Fig. 2, the impedance $\dot{z}$ of R_1 and C_1 is

$$\dot{z} = R_1/(1+j\omega C_1 R_1)$$

where $j = \sqrt{-1}$. If each value is chosen such that $R_0 \gg |\dot{z}|$, the feedback rate can be given by

$$\beta = \dot{z}/(R_0+\dot{z}) = \dot{z}/R_0.$$

Using equation (3), the following equation is derived:

$$\dot{A} = -R_0/\dot{z} = -R_0(1+j\omega C_1 R_1)/R_1. \tag{4}$$

When C_1 and R_1 are chosen so as to satisfy equation (4) and $C_1R_1 = M$, the decreasing amplitude and phase lag of the voltage fluctuation of the hot wire can be compensated.

Because the characteristic frequency of the hot wire is completely compensated through negative feedback, it is necessary that the characteristic frequency without negative feedback of the condensers between the amplification steps and the cathode are made as large as possible, and the plate voltage was supplied by two different power sources for the first

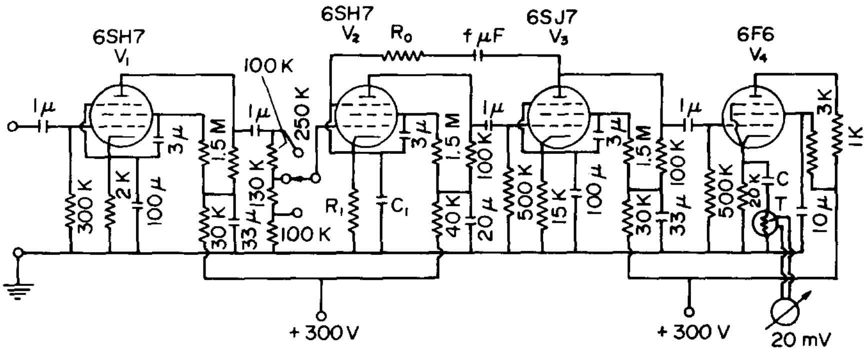

FIG. 2. Amplifying circuit: $C = 100\ \mu F$; $C_1 = 10\ \mu F$; $R_0 = 250\ k\Omega$; $R_1 = 2.3\ k\Omega$.

and second two amplification steps. This prevented oscillation and feedback through the impedance of the power source. Because the amplifier had a large amplification rate, source hum and voltage fluctuation of the power supply had to be reduced to a minimum. Thus, a filter was installed in the power supply line and the constancy of the voltage was maintained by using a voltage discharge tube.

In the output circuit, electric power amplification was made by V_4. Only the alternating component of the cathode current was passed through the hot wire of a vacuum thermocouple T using the filtering condenser C. The temperature of the hot wire was read from a millivoltmeter with a full scale of 20 mV. In this way, a value proportional to the effective value of the input voltage, or the relative value of the r.m.s. velocity fluctuation $\sqrt{(\overline{u^2})}$ was obtained because the heat generation in the vacuum thermocouple gave the effective value of the current fluctuation.

The hot wire used in the experiment was about 30 μm in diameter and 10 mm in length. A constant 300 mA current was supplied by a 6 V battery. For the situation when the mean flow velocity was 14 m s^{-1}, the mean temperature of the hot wire was estimated as about 170°C, and M was almost equal to 0.023 s.

The amplified output with no negative feedback from the hot wire is depicted by open circles in Fig. 3. The broken line indicates the value calculated from Dryden's relationship under the condition of $M = 0.023$. As shown in the figure, the sensitivity is good in the low frequency range, and worsens rapidly with increasing f.

The results of amplified hot-wire signals, after installation of the negative feedback loop, are shown by solid triangles in Fig. 3. The figure shows that the output value from the system is almost constant and is independent of the frequency up to 7000 Hz. In this experiment, the input to the hot wire was obtained by superimposing a small alternating current of any frequency on the direct current used in heating the hot wire. The small alternating current was obtained by changing the frequency of the oscillator, while keeping the r.m.s. output from the oscillator constant.

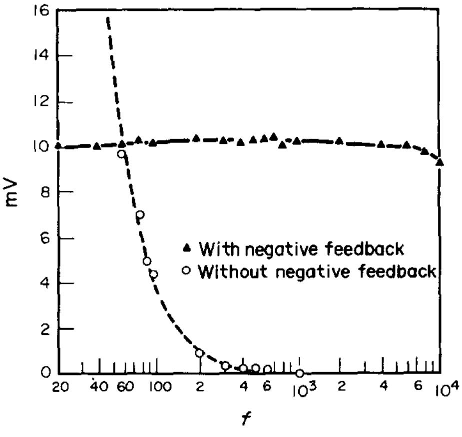

FIG. 3. Frequency characteristic.

The resistance change resulting from periodic heating due to the superimposed alternating current is similar to the periodic cooling obtained by mechanically vibrating the wire in the air flow if the resistance change is kept very small.

The periodic change of the resistance described above was obtained from the calibration circuit shown in Fig. 4, where R_1 is the resistance of the hot wire used in a constant flow with weaker turbulence. R_2 is a resistance having almost the same value as R_1. Resistances R_3 and R_4 are equal to each other. Resistances R_1, R_2 and R_3 correspond to the lowest possible temperature coefficients. R_2 was previously adjusted to balance the Wheatstone bridge so that the current passing through the amplifier was zero. By supplying an alternating current of constant amplitude from a low-frequency oscillator to R_2, and superimposing the alternating current on the direct current from the battery B, the resistance change resulting from the alternating current will occur only in R_1 and the alternating current will pass through the amplifier. A vacuum-tube voltmeter of type A was used to measure the output voltage of the low-frequency oscillator. The voltage was kept constant at all frequencies.

The relative value of $\sqrt{(\overline{u^2})}$ was obtained by the method mentioned above regardless of frequency. In

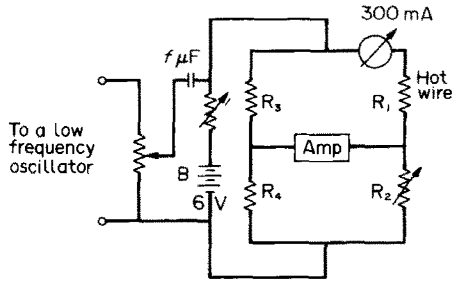

FIG. 4. Calibration circuit for characteristic frequency.

order to obtain a relation between the relative value and the absolute one, the hot wire was fixed to the oscillating part of a dynamic speaker and made to oscillate in constant velocity air flow with low turbulence. By changing the amplitude and frequency, the absolute value of $\sqrt{(\overline{u^2})}$ could be calculated using the amplitude and frequency for each condition. Thus, the relation between the absolute value and the value from the output meter could finally be determined. The amplitude of the hot-wire motion was measured using a microscope, and the accuracy of the frequency was confirmed by calibrating a 1000 cycle fork oscillator and a 60 cycle alternating current source checked by a frequency meter.

2.3.2. *Effect of mean velocity.* The mean velocity U was corrected by taking into account the relationship of the sensitivity change of the hot wire with U. The relation between the mean velocity U and the direct current voltage E of the hot wire is nonlinear, as shown in King's equation [6]. The actual relationship between U and E using the hot wire is shown in Fig. 5. The sensitivity of the hot wire to turbulence depends upon the change in mean velocity.

The sensitivity at the condition of the mean velocity U_1 is proportional to $\mathrm{d}E/\mathrm{d}U$ at U_1, that is, proportional to the tangent of the curve shown in Fig. 5 at $U = U_1$, but it changes with a change of U_1. Thus, by using the reciprocal value of $\mathrm{d}U/\mathrm{d}E$, it is necessary for the amplified output value to be corrected so as to correspond to the actual value at each level of mean velocity.

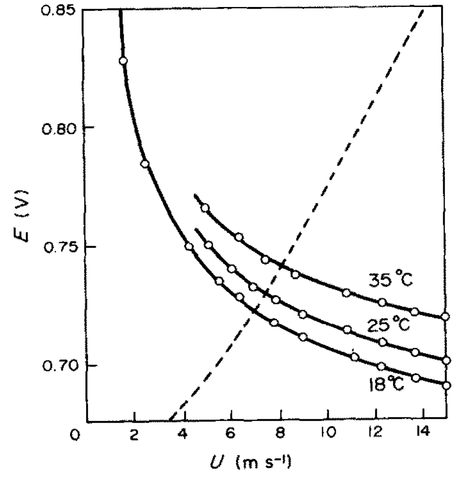

FIG. 5. Relation between mean velocity and voltage drop of the hot wire.

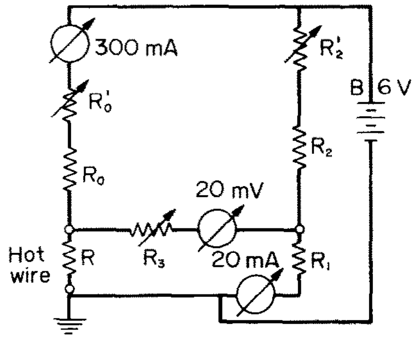

FIG. 6. Circuit for measuring mean velocity.

The broken line in Fig. 5 shows the curve representing the value $\mathrm{d}U/\mathrm{d}E$ obtained for a flow temperature of 18°C. As shown in the figure, the relation between U and E also depends on the flow temperature and a correction for this effect is desirable. However, the flow temperature does not seriously affect the value of $\mathrm{d}U/\mathrm{d}E$ because the curve seems to shift only in the vertical direction as the flow temperature increases.

The circuit for measuring the mean velocity is shown in Fig. 6. It is based on the constant current method, and the heating condition of the hot wire is the same as that for measuring turbulence. The circuit is similar to an electrical bridge where the difference between the hot-wire resistance R and that of R_1 was detected by a 20 mV voltmeter. Inaccuracy of the measured current can be reduced by setting R_0 to a value much larger than R. Also the magnification of the voltmeter can be adjusted by changing R_3 so that the measuring range can be controlled. The current passing through R_1 was adjusted in order to change the lowest measurable mean velocity.

By compensating the frequency and correcting the mean velocity effect as mentioned above, the turbulence intensity $\sqrt{(\overline{u^2})}/U$ can be obtained.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1. *Distributions of turbulence intensity and mean velocity in the boundary layer*

Two examples of the measured distribution of turbulence intensity are shown in Figs. 7 and 8. Figure 7 is an example of low free stream turbulence intensity obtained when the auxiliary duct D and the grid are not used. Figure 8 is an example of the large turbulence intensity obtained when grid A is used without the auxiliary duct. The abscissa indicates the distance y in mm from the plate. The broken lines in these figures express the percentage turbulence $\sqrt{(\overline{u^2})}$

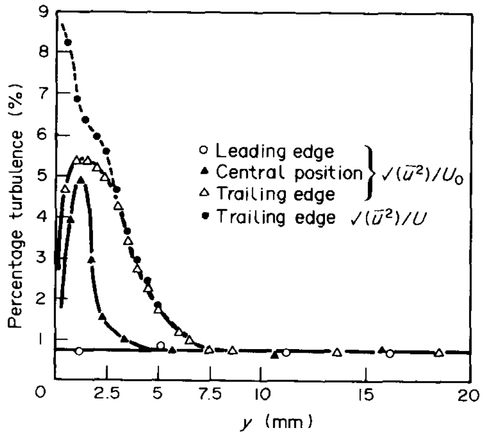

FIG. 7. Turbulence distribution in the turbulent boundary layer (no duct and no grid).

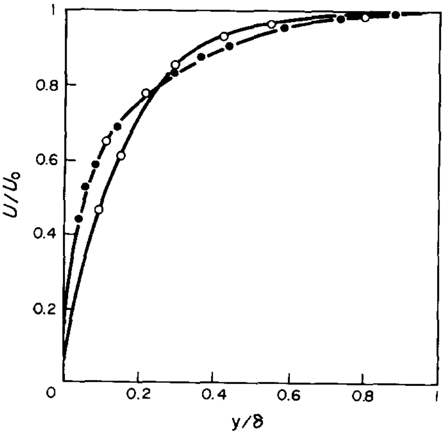

FIG. 9. Velocity distribution (central position of the plate): ○, no duct and no grid; ●, no duct and grid A.

divided by the local velocity U and were obtained at the trailing edge of the plate. The other three solid lines express the percentage turbulence $\sqrt{(u^2)}$ divided by the free stream velocity U_0. The value of U_0 was about 14 m s^{-1} in Fig. 7 and about 12 m s^{-1} in Fig. 8. The leading edge, the central position and the trailing edge of the plate described in the two figures correspond to those shown in Fig. 1. The turbulent boundary layer was found to occur at the central location and the trailing edge in Figs. 7 and 8. At the leading edge of the plate, the turbulence intensity was uniformly distributed in the transverse direction in each figure, about 0.74% in Fig. 7 and 7.27% in Fig. 8. The value of $\sqrt{(u^2)}/U$ increases with a decrease of y in each case, while $\sqrt{(u^2)}/U_0$ attains a maximum value at a distance from the plate of 1/3 or 1/4 of the boundary layer thickness. The maximum value is larger and the thickness of the turbulence region in the turbulent boundary layer increases remarkably for the case of large free stream turbulence. The turbulence intensity near the plate also increases.

Considering only the longitudinal turbulence intensity, a comparison of these two figures shows that the free stream turbulence intensity of the mean flow causes larger turbulence in the turbulent boundary layer and makes the laminar sublayer thinner.

It should be noted that radiation effects must be considered when measuring the turbulence intensity and the velocity near the plate with hot-wire anemometry. Assuming that the temperature of the hot wire is about 170°C and the flow temperature is about 20°C, the temperature difference between the plate and the hot wire is 150°C. According to Schubauer [7], the correction for the effect of the wall is not necessary when the temperature difference is below 150°C. Therefore, the error is expected to be small. However, to assure the accuracy in the measurements, the experiments [2] were carried out while noting the variation of the voltage drop of the hot wire when the distance between the wire and the plate was changed. It was found that the radiation effect on the output was smaller than the measuring error when the distance from the wire to the plate was over 0.1 mm.

The velocity distributions in the boundary layer at the central location and at the trailing edge of the flat

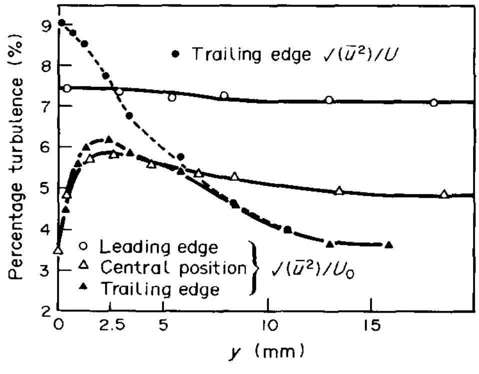

FIG. 8. Turbulence distribution in the turbulent boundary layer (no duct and grid A).

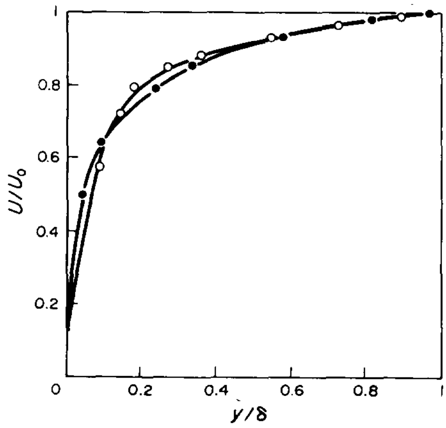

FIG. 10. Velocity distribution (trailing edge of the plate): ○, no duct and no grid; ●, no duct and grid A.

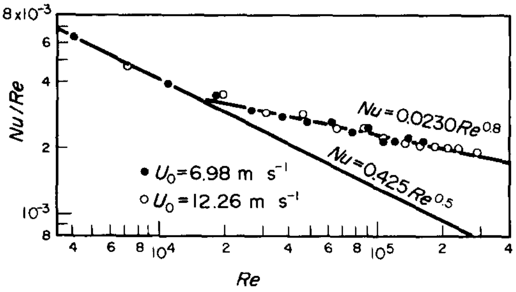

FIG. 11. Relation between *Nu*/*Re* and *Re* (50 cm duct and grid A).

plate are shown in Figs. 9 and 10, respectively. The open circles in these figures correspond to the small initial turbulence case shown in Fig. 7, while the solid circles indicate the larger initial turbulence case shown in Fig. 8. The abscissa is the value y/δ, where δ is the boundary layer thickness and is determined by the position where the average velocity is 99.5% of the main flow velocity. The steep gradient in the velocity occurs nearer to the plate as the free stream turbulence increases. This suggests that an increase in free stream turbulence results in a more uniform velocity distribution in the main part of the boundary and a thinner viscous sublayer.

3.2. *Results of heat transfer experiments*

A linear relationship between the logarithmic value of the Nusselt number and that of the Reynolds number was reported in ref. [2] for both laminar and turbulent heat transfer in the case of small free stream turbulence intensity. In this study, a similar relationship was found for larger free stream turbulence intensity. Typical examples of experimental results with various degrees of free stream turbulence are shown in Figs. 11 and 12. Here, the Nusselt number and Reynolds number are defined as

$$Nu = \alpha x/\lambda, \quad Re = U_0 x/\nu$$

where x is the streamwise distance from the leading edge of the flat plate, λ the thermal conductivity, and ν the kinematic viscosity of air.

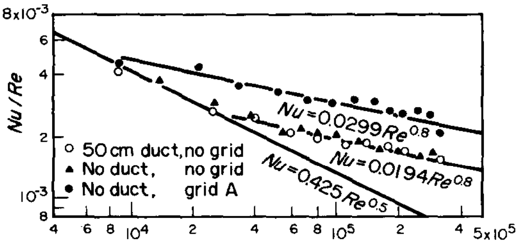

FIG. 12. Relation between *Nu*/*Re* and *Re*.

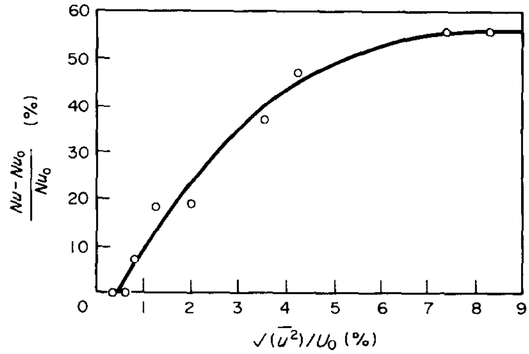

FIG. 13. Increasing rate of *Nu* as a function of percentage turbulence.

Figure 11 shows the results using the auxiliary duct of 50 cm and grid A. The same relationship can be found regardless of the value of U_0 as found in the case of low free stream turbulence. The temperature of the flat plate is not uniform. The $Nu = 0.425Re^{0.5}$ relation in the figure indicates experimental results for laminar flow heat transfer [2]. For any level of turbulence intensity, the relationship in the laminar regime does not change, but the transition Reynolds number from laminar to turbulent flow decreases. The line of smaller slope shows the heat transfer in the turbulent boundary layer regime. The fact that Nu is proportional to $Re^{0.8}$ is similar to the case of low level free stream turbulence. This is shown more clearly in Fig. 12. As seen in Figs. 11 and 12, the lines describing the turbulent heat transfer have the same slope and Nu is found to increase with the free stream turbulence level. These figures yield the following relationship valid in the turbulent heat transfer regime:

$$Nu = K Re^{0.8} \tag{5}$$

where the value of K increases with free stream turbulence intensity. The relation between an increase of turbulence intensity and that of Nu is shown in Fig. 13. The ordinate indicates

$$(Nu - Nu_0)/Nu_0$$

where Nu_0 is the Nusselt number obtained at the smallest level of turbulence intensity (percentage turbulence 0.37%) and is given by [2]

$$Nu_0 = 0.0194 Re^{0.8}. \tag{6}$$

The abscissa indicates the percentage turbulence in the main flow around the leading edge of the plate. Since the free stream turbulence decreases downstream along the plate, it is difficult to select a representative value for the turbulence. The free stream turbulence around the transition region may be suitable as a representative value, since the value of Nu is affected by the free stream turbulence only in the transition and turbulent regimes. However, since the leading edge of the plate used in this study was flat, transition occurred near the leading edge. Therefore, the free stream turbulence around the leading edge was used as the representative value of the turbulence. The typical behavior of the decrease of free stream turbulence in the streamwise direction along the plate is shown in Table 2. The difference between

Table 2. Percentage turbulence of free stream (precise locations of 'leading edge', 'central position' and 'trailing edge' are shown in Fig. 1)

Auxiliary duct length (cm) Grid symbol	— —	— A	50 A	— B
Leading edge (%)	0.72	7.42	2.05	3.54
Central position (%)	0.72	4.85	1.53	2.68
Trailing edge (%)	0.75	3.58	1.32	1.78

the representative value and the value around the transition point is small. According to Fig. 13, *Nu* increases with the intensity of free stream turbulence. The increasing slope is large in the small turbulence range but gradually becomes smaller as turbulence increases. The increase in *Nu* levels off in the turbulence region of 7–8%, and heat transfer is no longer enhanced with increasing free stream turbulence. At this point, the value of *Nu* is about 55% higher than that for very small free stream turbulence. This tendency is similar to the experimental results of Commings *et al.* for a cylinder in a cross flow. In their experiment, the heat transfer coefficient did not change remarkably in the range of turbulence intensity from 7 to 22%. However, experimental results by Commings *et al.* were only for a cylinder, and included the laminar flow heat transfer region. Therefore, a quantitative comparison between their data and the present data is not possible.

4. CONCLUSIONS

The effect of free stream turbulence on heat transfer from a flat plate was studied. Both the heat transfer coefficient and turbulence intensity were measured for various levels of increased free stream turbulence obtained by using turbulence grids at different pitches. The experiments suggested several conclusions.

(1) With an increase of free stream turbulence intensity, the laminar-to-turbulent transition Reynolds number decreases.

(2) With an increase of free stream turbulence intensity, turbulence in the boundary layer is intensified. This leads to a thickening of the turbulent boundary layer and a thinning of the laminar sublayer. Mainly because of the larger effect of the latter, heat transfer is enhanced.

(3) Heat transfer in the laminar regime is not affected by free stream turbulence; however, heat transfer increases in the turbulent regime. Even in the case of enhanced turbulent heat transfer, the proportionality of the Nusselt number to the 0.8 power of the Reynolds number is not affected.

(4) The Nusselt number in the turbulent heat transfer regime increases rather steeply with an increase of the free stream turbulence level for the low turbulence intensity range. The rate of increasing *Nu* becomes less for a higher range of free stream turbulence intensity. The Nusselt number does not increase any higher when the free stream turbulence level is increased by about 7–8%. The maximum enhanced heat transfer rate was about 55% higher than that for the smallest level of free stream turbulence.

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EFFET DE LA TURBULENCE D'ECOULEMENT LIBRE SUR LE TRANSFERT THERMIQUE D'UNE PLAQUE PLANE

Résumé—On étudie pour une plaque plane l'effet de la turbulence de l'écoulement libre sur le transfert thermique. Cette turbulence est obtenue à l'aide d'une grille. L'intensité de turbulence est mesurée par un anémomètre à fil chaud dans la couche limite et dans l'écoulement libre. Dans ces conditions, le coefficient de transfert local à la surface est mesuré en utilisant une méthode instationnaire. Le coefficient de transfert augmente avec le niveau de turbulence, rapidement dans le domaine de niveau faible et lentement pour les niveaux élevés. Pour un niveau de turbulence de 7–8%, le coefficient de convection s'élève à 55% au dessus de la valeur atteinte pour une très petite turbulence d'écoulement libre.

EINFLUSS DER TURBULENZ EINER FREIEN STRÖMUNG AUF DEN WÄRMEÜBERGANG AN EINER EBENEN PLATTE

Zusammenfassung—Der Einfluß der Turbulenz einer freien Strömung auf den Wärmeübergang an einer glatten ebenen Platte wurde untersucht. Die Turbulenz der freien Strömung wurde durch ein Turbulenzgitter erzeugt. Der Turbulenzgrad in der Grenzschicht und in der Hauptströmung wurde mit einem Hitzdrahtanemometer gemessen. Der örtliche Wärmeübergangskoeffizient an der Plattenoberfläche wurde unter denselben Bedingungen mit Hilfe einer instationären Methode gemessen. Es zeigt sich, daß der Wärmeübergangskoeffizient mit zunehmenden Turbulenzgrad ansteigt und zwar stärker bei kleinerem und geringer bei höherem Turbulenzgrad. Für Turbulenzgrade von 7–8% ist der Wärmeübergangskoeffizient etwa 55% größer als der Wert, der für sehr geringe Turbulenzgrade bestimmt wurde.

ВЛИЯНИЕ ТУРБУЛЕНТНОСТИ ОСНОВНОГО ПОТОКА НА ТЕПЛООБМЕН ПЛОСКОЙ ПЛАСТИНЫ

Аннотация—Проведено исследование влияния турбулентности основного потока на теплообмен поверхности гладкой плоской пластины. Турбулентность основного потока создавалась турбулизирующей решеткой. Интенсивность турбулентности измерялась термоанемометром как в пограничном слое, так и в основном потоке. При тех же условиях нестационарным методом измерялся локальный коэффициент теплообмена на поверхности плоской пластины. Найдено, что коэффициент теплообмена увеличивается с увеличением уровня турбулентности, причем это увеличение происходит быстро в области с небольшой турбулентностью и медленно с высокой. При уровне турбулентности в 7–8% коэффициент теплообмена примерно на 55% превышает значение, полученное при очень малой турбулентности основного потока.