Thus for given blow rate and unit Reynolds number these equations can be used to find c_f from measured values of y and u/U_∞, provided the points are within the sublayer. Simpson used the first measured point to find c_f, and also found that "In many cases, several consecutive y-stations produced the same value of $c_f/2$, lending credence to the method". Figure 5 shows the velocity profiles measured near the wall with zero blowing together with the sub-layer profile based on Simpson's sublayer skin friction. In general the measured points lie on lines which intersect the sublayer profile rather than blend into it. This suggests that the measured points do not lie in the sublayer, and the fact that Simpson gets sensible skin-frictions values probably implies some cancellation of errors. In particular it is easy to see that a displacement effect of 0·001 in. (0·1 times the height of the probe) could make the results blend into a sublayer profile with the right skin friction.

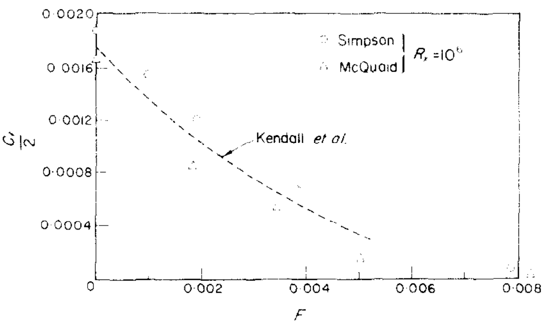

FIG. 6.

The skin friction results of the two sets of experiments are compared in Fig. 6 at a Reynolds number of $R_x = 10^6$. This figure also included the values obtained by Kendall *et al.* [6] from an extensive survey of all the measurements made at M.I.T. under H. S. Mickley. As will be seen Simpson's results are much higher than those of McQuaid with Kendall's results occupying a mean position.

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REPLY TO THE COMMENTS BY DR. Y. R. MAYHEW ON THEORETICAL STUDY OF LAMINAR FILM CONDENSATION OF FLOWING VAPOUR

IT WAS of great interest for us to read the comments [1] by Dr. Y. R. Mayhew from the University of Bristol on our paper [2].

It was shown in papers [2, 3] that a transverse mass flow across the vapour–liquid interface due to phase change is the dominant factor in the hydrodynamics of film condensation for vapour flowing longitudinally over a flat plate. Even at negligible rates of phase change the presence of the above-mentioned flow excludes the occurence of the turbulent boundary layer in the vapour flow, and for condensation processes it develops such a flow at which interfacial shear is mainly determined by the momentum transferred by the condensing vapour mass. In view of this papers [2, 3] have given solutions for some cases of film condensation of flowing vapour. The expression for the mean heat-transfer coefficient for condensation of flowing vapour on a vertical plate was also obtained (equation 20 [2]).

$$\bar{\alpha} = \frac{\sqrt{2}}{3}\sqrt{\left(\frac{\lambda^2 \rho U_\infty}{\mu \mathscr{L}}\right)} \frac{2 + \sqrt{\left(1 + \frac{16g\mathscr{L}}{U_\infty^2 N}\right)}}{\sqrt{\left(1 + \sqrt{\left[1 + \frac{16g\mathscr{L}}{U_\infty^2 N}\right]}\right)}}. \qquad (1)$$

For the state of weightlessness ($g = 0$) equation (1) gives

$$\bar{\alpha} = \sqrt{\frac{\lambda^2 \rho U_\infty}{\mu \mathscr{L}}}. \qquad (2)$$

For the case of stationary vapour ($U_\infty = 0$) equation (1) reduces to the known Nusselt result

$$\bar{\alpha} = \frac{4}{3}\sqrt[4]{\left(\frac{\rho^2 g r \lambda^3}{4\mu \mathscr{L}\,\Delta t}\right)}. \qquad (3)$$

While deriving expression (20) from equations (17) and boundary conditions (18) we have made in paper [2] a simplifying assumption $N + 1 \approx 1$ which holds for the cases of condensation of non-metallic liquids ($N \ll 1$). However, there is no reference to the assumption in our paper that has been noted by Dr. Mayhew.

Paper [4] treats the condensation problem of flowing vapour over a vertical plate by considering the body forces, the momentum transferred by the condensing mass and the so called forces of dry friction. Solutions are also given for various combinations of the above forces including the solution equivalent to equation (1). In this paper the value of dry friction is determined according to the law of dry turbulent friction

$$\tau = C_f^* \frac{\rho_v U_\infty^2}{2}. \qquad (4)$$

On the other hand, in accordance with [2, 3] for the condensation process, when a plate is in the infinite vapour flow, introduction of term (4) in the interfacial shear determination appears to be unsound. In his comments [1] Dr. Mayhew does not dispute this statement but he justifies the necessity of allowance for dry friction [4] because in his experiments vapour is fed to the condensation section as a preliminary fully developed turbulent flow. Further we will show that introduction of the dry turbulent friction term into the relation for full friction, as given in expression [4], does not prove its value for the case of a turbulent flow in the vapour phase (as if it occurred in spite of the laminarizing influence of the condensation process itself).

A momentum equation for the incompressible boundary layer with suction for the case of U_∞ = Const. may be expressed as follows [5]:

$$\frac{\tau_0}{\rho_v} = U_\infty^2 \frac{d\theta}{dx} - V_0 U_\infty \qquad (5)$$

As is known, equation (5) holds for both laminar and turbulent boundary layers. Suction of the boundary layer with the rates which occur in the actual cases of condensation leads not only to the appearance of the term $v_0 U_\infty$ in the momentum equation, but it limits rather sharply the boundary layer development across the flow width, i.e. decreases sharply the derivative $d\theta/dx$. At a sufficient distance from the beginning of the suction the velocity profile practically becomes stable. In this connection, from the very beginning of suction the term $U_\infty^2\, d\theta/dx$ decreases sharply irrespective of the condition of the flow, and with sufficiently high suction rates it becomes infinitesimal down the flow. Proceedings from the above, at the analysis of condensation process the determination of the term $U_\infty^2\, d\theta/dx$ according to the law of dry turbulent friction (4) is not justified even on the assumption of a turbulent flow in the vapour boundary layer.

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