and from References 1, 2

$$\frac{\partial N}{\partial T} = \frac{(n-1)\,L}{\lambda_0\, T_s} \qquad [17]$$

$$\therefore \frac{dT}{dy} = \frac{\left.\frac{dN}{dy} - 2\,\frac{\partial N}{\partial x}\right]_{y,T} \tan\phi}{\frac{(n-1)\,L}{\lambda_0 T_s}} \qquad [18]$$

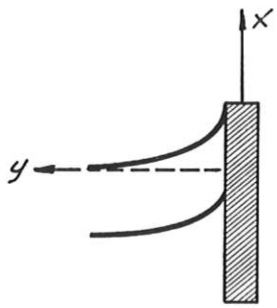

FIG. 17

Therefore, if fringes are perpendicular to plate, then $\Delta x/\Delta y = \tan\phi = 0$ and the equation reduces to the normal temperature-gradient equation for straight fringes

$$\frac{dT}{dy} = \frac{\frac{dN}{dy}}{\frac{(n-1)\,L}{\lambda_0\, T_s}} \qquad [19]$$

EQUATIONS USED IN ANALYSIS

1 Plate surface temperature, T_s

$$T_s - T_0 = \Delta T = \frac{\Delta N\; T_0}{\frac{(n-1)\,L}{\lambda_0} - \Delta N}, \text{ deg R or deg F}$$

(Equation derived in references 1 and 2)

2 Surface-temperature gradient, $\frac{dT}{dy}$

$$\frac{dT}{dy} = -\frac{\left.\frac{dN}{dy} - 2\,\frac{\partial N}{\partial x}\right]_{T,y} \tan\phi}{\frac{(n-1)\,L}{\lambda_0\, T_s}}, \text{ deg F per in.}$$

3 Local convective unit thermal conductance, h_{cx}

$$h_{cx} = -\frac{k_s\,\frac{dT}{dy}}{\Delta T}, \text{ Btu/hr sq ft deg F}$$

4 Heat balance

Heat input = heat lost by convection + heat lost by radiation + heat lost by conduction

(Note that heat loss by conduction is negligible.)

(*a*) Heat input, $Q_{in} = \frac{E^2}{R_e} \times 3.41$, Btu per hr

(*b*) Loss by convection, Q_c

$$Q_c = h_{c_{avg}}\, A\,(T_s - T_0), \text{ Btu per hr}$$

(*c*) Loss by radiation, Q_R

$$G = K\,(\text{mv}) + F\sigma\, T_H^4$$

where

G = irradiation on radiometer, Btu/hr sq ft
K = radiometer constant = 5.2
(mv) = radiometer reading, millivolts
F = shape factor of radiometer = 0.034
T_H = radiometer housing temperature, deg R
σ = Stefan-Boltzmann constant = 0.173×10^{-8}

$$Q_R = \frac{GA}{F}, \text{ Btu per hr}$$

Discussion

SIMON OSTRACH.[5] In the subject paper the treatment of the pressure-gradient terms for the inclined plate was the same as for the vertical plate. However, the second equation of motion (or momentum equation) for the inclined plate should be

$$\frac{\partial P}{\partial Y} = \rho g \sin\theta\, \frac{(T - T_\infty)}{T_\infty}$$

(which is different from the $\partial P/\partial Y = 0$ for the vertical plate) and hence it cannot be argued, as for the vertical plate, that the pressure-gradient term in the first equation of motion vanishes because there is no pressure variation across the boundary layer.

A pressure variation across the boundary layer does, in fact, exist for the inclined plate and is given by the foregoing equation. It can be seen from this expression that this variation is of the same order as the driving or buoyancy term for angles of plate inclination θ, whereby $\sin\theta \approx \cos\theta$. However, the pressure-gradient term in the first equation of motion can be shown to be negligible on the basis of the boundary-layer assumptions alone. It then should be kept in mind that as the plate inclination exceeds 30 deg a large pressure variation normal to the plate exists. Just what effect, if any, this has on the actual results or whether this could in some way explain the deviation of the theoretical from the experimental results should be discussed.

J. RUTKOWSKI[6] AND M. TRIBUS.[7] In Equations [2] and [2′] the symbols are not consistent with Fig. 1 and the nomenclature of the paper. The second term on the right in Equation [2′] should be zero if the nomenclature is to be followed.

The statement that $v <<< u$ in Equation [2′] is no longer true when the plate is tilted. The term $(\sin\theta)^{1/4}$ then enters the correct version of Equation [2′]; for example, at a 30-deg inclination $(\sin 30)^{1/4} = 0.84$ and the terms cannot be dropped on the basis proposed by the author.

The fact that the inclination angle enters Equation [2] as $(\cos\theta)^{1/4}$ means that in the range of angles studied this term varies only from 1 to 0.935.

It would have been desirable for the author to include a plot of data showing dimensionless temperature versus angle of inclination with the author's variable ξ as a parameter. The figures given seem to show that the data for different angles fall on one curve.

It would have been extremely interesting if the author had made probes of the velocity boundary layer to see how the angle of inclination affects the velocity distribution and the transition from laminar to turbulent flow.

The fact that the author could get the accuracy shown in Table

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[6] University of Michigan, Ann Arbor, Mich.

[7] University of Michigan. Jun. ASME.

1, despite the inferior plates in the inexpensive interferometer, is creditable. It seems, however, that the effects of inclining the plate are small and for this problem a repetition of the work using a better apparatus would be justified.

Author's Closure

The pressure gradient, $\partial P/\partial y$, discussed by Mr. Ostrach, is a point well taken. Unfortunately a pressure survey of the boundary layer was not made; therefore, no check could be made.

In reply to the comment of Messrs. Rutkowski and Tribus on the effect of the velocity component v, when the plate is inclined, the author concurs that the v component becomes significant especially at the top of the plate at the higher angles of inclination.

The author recommends that if further investigations were made, a boundary-layer survey illustrating the effect of pressure and velocity distribution with plate inclination be made.