Int. J. Heat Mass Transfer. Vol. 5, pp. 559–560. Pergamon Press 1962. Printed in Great Britain.

LETTERS TO THE EDITOR

ON THE TRANSFER OF RADIANT ENERGY

H. C. Hottel in his note "Radiation as a diffusion process" [1] compares an exact solution to the problem of radiant energy transfer in a plane layer of grey medium with the solutions given in my paper "On the regularities of composite heat transfer". Comparison is made on the assumption that $l \gg l_s$, but it is then postulated that K is small, i.e. that the relation $K = 1/l_s$ is invalid.

Under these conditions, from formula (23), we obtain formula (26) with which an exact solution should be compared. If such a comparison is made, one may be convinced of a negligible divergence between both solutions.

Hottel states that the equations I proposed do not permit of a distinction between T_r and T; this is not so. The solution of equation (55) gives the relation $T = \varphi(x)$ whilst from equation (54) a relation between T_r and T is obtained. Solutions for equations (54) and (55) were not given in my paper.

One cannot agree with Hottel that in the expression for D_r the coefficient $\frac{1}{3}$ should be used instead of $\frac{1}{4}$. As is known, the coefficient $\frac{1}{3}$ relates to radiation which is isotropic over the whole space. The radiation considered in my paper (Fig. 1) is different and the coefficient $\frac{1}{3}$ is not, therefore, appropriate.

Finally, in my paper I did not make use of the concept of the effective thermal conductivity. Therefore the solutions obtained on the basis of it should not be identified with my solutions.

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REPLY TO COMMENTS BY ROGERS AND MAYHEW ON THE SHORTER COMMUNICATION "APPLICATION OF THE DEFECT LAW TO THE DETERMINATION OF THE AVERAGE VELOCITY AND TEMPERATURE IN TURBULENT PIPE FLOW" BY W. SQUIRE*

I must agree that the importance of the distinction between the average and bulk average temperatures was underestimated in my note [1]. However, since the average is always less than the bulk average, a basic discrepancy remains, primarily in the liquid metal range.

As Rogers and Mayhew point out in their letter, according to the conventional theories of turbulent heat transfer, the temperature distribution approaches the laminar form at sufficiently low Prandtl number, while the velocity distribution retains its turbulent form. The reason for this is that in the conventional analysis the ratio of eddy viscosity is found as a function of position by differentiation of the velocity profile. Then the eddy diffusivity is related to the eddy viscosity. As a result, the eddy diffusivity is a multiple of the molecular viscosity, and becomes negligible compared to the molecular conductivity at sufficiently small Prandtl number.

On the other hand, the assumption of a temperature defect profile, such as I made, implies that the temperature profile will retain a turbulent character at low Prandtl number.

In Fig. 1 I have plotted the temperature distribution

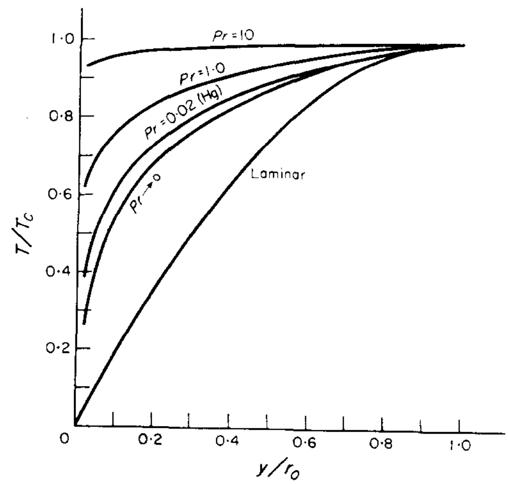

Fig. 1. Theoretical temperature distribution at $Re = 10^6$.

* *Received* 15 *February* 1962.

predicted by my analysis at a Reynolds number of 10^6 for several Prandtl numbers. The principal cause in the variation in the profile with Prandtl number is the change in the apparent wall temperature which is given by

$$\frac{T_\delta}{T_\tau} = 5{\cdot}25\, Pr \log_{10} Re \times 10^{-3}.$$

The fact that my analysis does give [2] a satisfactory heat transfer law in the low Prandtl number range is not particularly strong evidence that it is based on a correct temperature distribution. It is quite possible counter-balancing errors are involved. It would be desirable to have a direct experimental test. However, as the theory is based on the assumption that the thickness of the laminar sublayer is negligible, the comparison must be made at a reasonably high Reynolds number and therefore at a lower Prandtl number than liquid mercury.† Unfortunately, there do not seem to be any temperature traverses available for alkali metals.

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2. W. SQUIRE, *Proceedings Sixth Midwestern Conference on Fluid Mechanics*, p. 16, Austin (1959).

† A comparison which includes liquid mercury traverses is given in Ref. 2, Fig. 2.