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# LETTERS TO THE EDITORS

## DISCUSSION OF "APPLICATION OF A SECOND-MOMENT TURBULENCE CLOSURE TO HEAT AND MASS TRANSPORT IN THIN SHEAR FLOWS—I. TWO-DIMENSIONAL TRANSPORT"

LAUNDER and Samaraweera [1] have recently compared their calculation, which uses a transport equation for the turbulent heat flux, with measurements of Antonia *et al.* [2] obtained in a turbulent boundary layer downstream of a sudden increase in surface heat flux. They found generally satisfactory agreement between measured and calculated distributions of heat fluxes $\overline{vc}$ and $\overline{uc}$ (the notation used here is the same as in [1]) but less satisfactory agreement between measured and calculated mean temperature profiles. While it is true that the use of a transport equation for $\overline{vc}$ avoids the need to prescribe the turbulent Prandtl number $\sigma_t$ whose experimental uncertainty is relatively large, I should like to point out that mean temperature and heat flux profiles obtained by Antonia and Danh [3], using the calculation of Bradshaw and Unsworth [4] with $\sigma_t = 0.91$, are in generally satisfactory agreement with the measurements except for small values of $x/\delta_0$ where the assumption $\sigma_t =$ constant is not expected to be valid. The comparison between the calculations of [3] and the measurements of [2] is shown in Figs. 1 and 2. These figures can be directly compared with Figs. 16 and 17 of [1]. In the calculation of [4], the inner boundary condition on the temperature profile is given by $(C-C_w)/C_\tau = \kappa'^{-1} \ln (E_c y^+)$, with $\kappa' \simeq 0.45$ and $E_c = 4.41$. While measured values of $\sigma_t$ reported in [2] and also in Fig. 18 of [1] are larger than the value used in the calculation at $x/\delta_0 = 42.9$, measured values at $x/\delta_0 = 11.4$, 18.9, 25.7, are, on average, not too different from unity. Also, the mean temperature distribution in the inner layer at $x/\delta_0 = 42.9$ is consistent with $\kappa' = 0.41$.

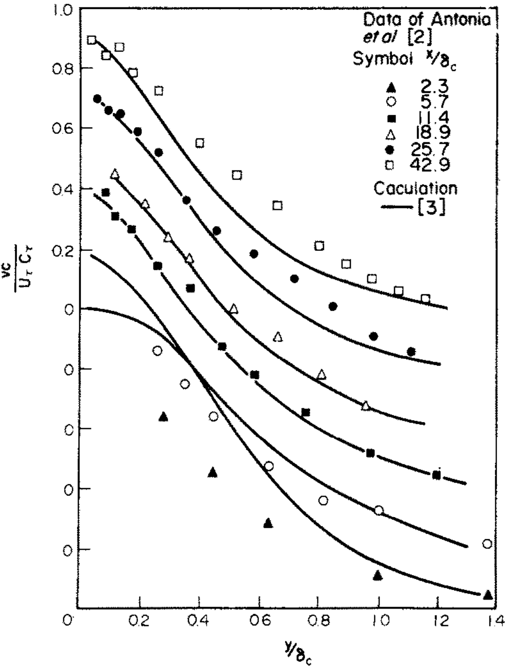

FIG. 1. Heat flux profiles downstream of a sudden increase in surface heat flux.

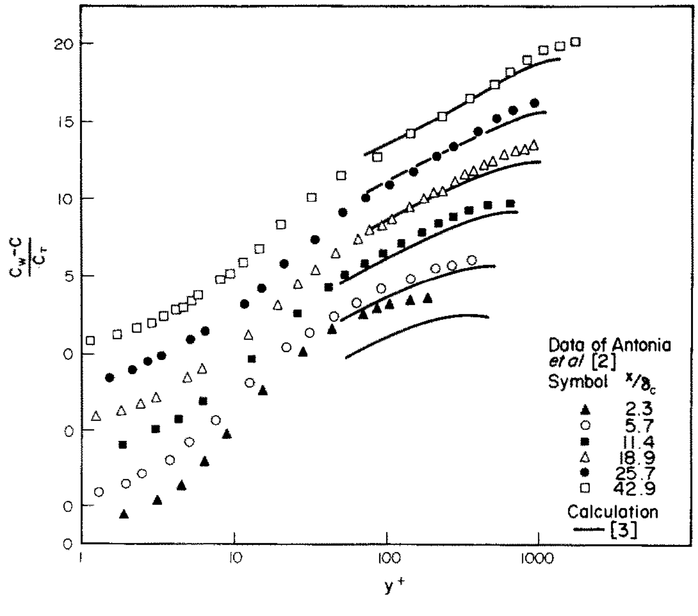

FIG. 2. Mean temperature profiles downstream of a sudden increase in surface heat flux.

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# AUTHOR'S RESPONSE TO 'DISCUSSION OF "APPLICATION OF SECOND-MOMENT TURBULENCE CLOSURE TO HEAT AND MASS TRANSPORT IN THIN SHEAR FLOWS"'

READERS of the Journal will be grateful to Professor Antonia for bringing to their attention the inaccessible conference paper by Dahn and himself [3]. If I correctly read between the lines of the discussion, Professor Antonia seems to be saying that *his* calculations succeed in achieving satisfactory agreement with both the mean temperature and heat flux fields whereas the results presented by Dr. Samaraweera and myself are only satisfactory for the heat flux profiles.

Here the point to emphasize is that the $y$-direction heat flux and the temperature distribution are not independent characteristics of the thermal boundary layer: prescription of one fixes the other through the enthalpy transport equation. In the Launder–Samaraweera calculations, $y$- (and $x$-) direction heat fluxes, beyond the initial region, were in nearly complete agreement with the experiments. The disparity between the measured and calculated temperature fields thus largely reflects an inconsistency between the measured temperature and heat flux distributions due, not to experimental error, but, as Samaraweera and I suggest in the paper, to a mild lack of two-dimensionality of the measured boundary layer. The calculations of [3] effectively "share out" the inconsistency between the two profiles, partly by adopting a larger turbulent Prandtl number over the outer region, which has the effect of reducing $\overline{vc}$ (worsening agreement with data) and steepening the slope of the temperature profile (improving it), and partly through using a larger coefficient $E_c$ in the thermal log law.

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