Table 1

Ref 1	Ref 5
$\tilde{u} = u - u$	C
ϵ_ν	$D_T + D_M$
s	ω
Total drag	Mass or heat conservation

$x/d = 70$, $u_0/u = 0\ 9835$ The total drag can be evaluated from the profile data and Eq (2) used to calculate $L = 3\ 04 \times 10^3$ ft Finally, the eddy diffusivity constant K can be calculated from the asymptotic slope of $(\delta_2)^3$ vs x to be 0 136, which is somewhat larger than the value suggested in Ref 1 Figure 3 shows two sample profiles for comparison of the adjusted theory with experimental data

The linear theory seems to offer an excellent framework, but extension to three-dimensional cases remains uncertain As Ref 1 points out, Eq (38) for an eddy diffusivity in non-axisymmetric wakes is untested experimentally Furthermore, the Oseen approximation for the convective acceleration in the boundary-layer equations probably can only be justified for low local Reynolds number $Re_\delta[\equiv \tilde{u}\delta/\nu)]$ flow in the wake For the axisymmetric wake, Re_δ decreases as $x^{-1/3}$, thus assuring a low local value far downstream However, the two-dimensional wake has a constant Re_δ It would appear that x may systematically increase with decreasing eccentricity and thereby push the linear wake solution beyond the range of interest for highly elliptical cases

Where the linear solution for the wake is a valid approximation, the large literatuie on the analogous turbulent diffusion of heat and mass is directly applicable For example, Mickelsen[5] tabulates 63 solutions for a wide variety of initial wake shapes; his nomenclature is compared with that of Ref 1 in Table 1

Refeiences

[1] Steiger, M H and Bloom, M H, "Three-dimensional effects in viscous wakes," AIAA J 1, 776–782 (1963)

[2] Steiger, M H and Bloom, M H, "Three-dimensional viscous wakes,' J Fluid Mech 14, 233–240 (1962)

[3] Steiger, M H and Bloom, M H, "Three-dimensional effects in viscous wakes," General Applied Science Labs, Inc, TR 270 (January 1962)

[4] Cooper, R D and Lutzky, M, 'Exploratory investigation of turbulent wakes behind bluff bodies," David Taylor Model Basin Rept 963 (1955)

[5] Mickelsen, W R, ' Flow and mixing processes in combustion chambers," *Basic Considerations in Combustion of Hydrocarbon Fuels in Air,* NACA TR 1300 (1957), Chap II

Reply by Authors to Y -H Kuo and L V Baldwin

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In the preceding comments by Kuo and Baldwin on Ref 1, there are several statements concerning the boundary-layer growth, the validity of the Oseen approximation, and the problem per se which warrant further comment

The boundary-layer thickness δ, in the sense discussed by Steiger and Bloom,[1 2] signifies the shape of a line of constant velocity That is, it outlines a region within which nonuniformities are considered to be of interest and outside which they are deemed negligible A cutoff criterion must be associated with such a δ outline This can be expressed as $u = ku$,‡ where k was given a value of 0 99 for purposes of illustrative concreteness in Refs 1 and 2 In this definition, δ is meaningless beyond $u_0 = ku$

Kuo and Baldwin select for consideration an alternative region within which nonuniformities are compared with local peak nonuniformities $(u - u_0)$ This is perhaps more conventional Clearly, it has a different outline shape

Since each outline is related to a different question about the cutoff, there is no issue of correctness involved here but simply a matter of specific interest

The forementioned discussion is not related to the question of the laminar or turbulent nature of the flow but is general

Concerning the validity of the solutions, Kuo and Baldwin make a conjecture about the applicability of the Oseen approximation Unfortunately, we are not aware of a really rigorous evaluation of this approximation in the current context However, Bloom and Steiger have attempted to evaluate corrections for nonlinearity for the three-dimensional cases[2] Furthermore, in the two-coordinate (two-dimensional and axisymmetric) cases, they show in Ref 3 a reasonably good comparison between the linearized theory and a nonlinear integral method solution, whereas in Ref 4 the error incurred in the linearization process is discussed

Finally, Bloom and Steiger do not purport to give new solutions to the equation $\varphi = \varphi_{\eta\eta} + \varphi_{\sigma\sigma}$ but have applied these[5] to the physical problem at hand

References

[1] Steiger, M H and Bloom, M H, "Three-dimensional effects in viscous wakes," AIAA J 1, 776–782 (1963)

[2] Steiger, M H and Bloom, M H, "Three dimensional viscous wakes," J Fluid Mech 14, 233–240 (1962)

[3] Steiger, M H and Bloom, M H, "Integral method solutions of laminar viscous free-mixing," AIAA J 1, 1672–1674 (1963)

[4] Steiger, M H and Bloom, M H, ' Linearized viscous free mixing with streamwise pressure gradients," AIAA J 2, 263–266 (1964)

[5] Staff of the Bateman Manuscript Project, *Tables of Integral Transforms* (McGraw-Hill Book Co, Inc, New York, 1954)

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‡ The notation is defined in Ref 2

Addendum: "An Alternate Interpretation of Newton's Second Law"

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[AIAA J 1, 927–928 (1963)]

THE author has shown[1] that if the instantaneous linear momentum of an arbitrary time variable aggregate of mass is represented by the Stieltjes integral

$$\mathbf{G} = \int \mathbf{U}\, dm \tag{1}$$

in which **U** is the local absolute velocity of the mass, and in which the integral is summed over the mass, then the equation of motion of a variable mass system can be written in the classical Newtonian form

$$\Sigma\mathbf{F} = d\mathbf{G}/dt \tag{2}$$

In performing the differentiation it must be remembered that the boundaries of the volume of integration must have

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