[10] Schlichting, H., *Boundary Layer Theory*, 6th ed., McGraw-Hill, New York, 1968.

[11] Hartree, D. R., "On an Equation Occurring in Falkner and Skan's Approximate Treatment of the Equations of the Boundary Layer," *Proceedings of the Cambridge Philosophical Society*, Vol. 33, 1937, pp. 223–239.

[12] Crabtree, L. F., Kuchemann, D., and Sowerby, L., "Three-Dimensional Boundary Layers," *Laminar Boundary Layers*, edited by L. Rosenhead, Oxford University Press, London, 1963, p. 427.

Comment on "Inner Region of Transpired Turbulent Boundary Layers"

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IN a recent Note, Stevenson[1] discussed several different inner region equations for transpired turbulent boundary layers. In a Comment on this Note, Dahm and Kendall[2] misinterpreted the experimental results of Simpson et al.[3] in stating that the second Rubesin hypothesis [Stevenson's Eq. (5)] correlated these data. In fact, the mixing length "law of the wall" result[3]

$$(2/V_w^+)\ [(1 + U^+V_w^+)^{1/2} - (1 + C_1V_w^+)^{1/2}] = (1/K)\ \ln|y^+/C_2|$$

with $C_1 = C_2 = 11$ and $K = 0.44$ fits the data of Simpson et al. in the inner region $30 < y^+ < 100$ for $-0.04 < V_w^+ < 0.6$ in the range $10^3 < Re_\theta < 10^4$. This equation is clearly not equivalent to any of the hypotheses discussed by Stevenson. In fact, neither Stevenson's equation (6) with B constant nor the second hypothesis of Rubesin [Stevenson's equation (5)] comes very close in correlating the U^+ vs y^+ and V_w^+ data of Simpson et al.[3,4]

Dahm and Kendall make a strong point about $C_f/2$ values obtained from the momentum integral equation being sensitive to small errors in $d\theta/dx$ and V_w/U_1 and hence that the different mathematical formulations of the behavior of the inner region possibly lie within the uncertainty of the experimental data using these $C_f/2$ values. (The momentum integral equation was the only independent means Stevenson[5] and McQuaid[6] used to obtain $C_f/2$ values.) Because of this sensitivity, $C_f/2$ values were obtained from velocity profiles in the sublayer as well as from the momentum integral equation for the data of Simpson et al. As pointed out in Refs. 3, 7, and 8, the results from these two independent methods are in close agreement. Because of this agreement, there is some confidence in the U^+ vs y^+ experimental results and "law of the wall" equation of Simpson et al.[3]

References

[1] Stevenson, T. N., "Inner Region of Transpired Turbulent Boundary Layers," *AIAA Journal*, Vol. 6, No. 3, March 1968, pp. 553–554.

[2] Dahm, T. J. and Kendall, R. M., "Comment on 'Inner Region of Transpired Turbulent Boundary Layers'," *AIAA Journal*, Vol. 6, No. 9, Sept. 1968, pp. 1822–1824.

[3] Simpson, R. L., Kays, W. M., and Moffat, R. J., "The Turbulent Boundary Layer on a Porous Plate: An Experimental Study of the Fluid Dynamics with Injection or Suction," Rept. HMT-2, Dec. 1967, Mechanical Engineering Department, Stanford Univ.; also Simpson, R. L., Ph.D. thesis, 1967, Stanford Univ., available from University Microfilms, Ann Arbor, Mich.

[4] Simpson, R. L., unpublished work.

[5] Stevenson, T. N., "Experiments on Injection into an Incompressible Turbulent Boundary Layer," Rept. 177, 1964, Cranfield College of Aeronautics.

[6] McQuaid, J., "Incompressible Turbulent Boundary Layers with Distributed Injection," Ph.D. thesis, 1966, Cambridge University.

[7] Simpson, R. L., Moffat, R. J., and Kays, W. M., "The Turbulent Boundary Layer on a Porous Plate: Experimental Skin Friction with Variable Injection and Suction," *International Journal of Heat Mass Transfer*, to be published.

[8] Simpson, R. L. and Whitten, D. G., "Preston Tubes in the Transpired Turbulent Boundary Layer," *AIAA Journal*, Vol. 6, No. 9, Sept. 1968, pp. 1776–1777.

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Hg^+ + Cs Charge Transfer with Comments on Ion Engine Neutralization

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THE operation of electric propulsion systems in space requires that equal numbers of positive and negative charged particles be ejected to maintain the electrical neutrality of the vehicle. Neutralization of a positive ion beam has been accomplished using a thermionic electron emitter immersed in the ion beam, but the lifetime of this type of emitter is limited by ion sputtering. An attractive alternative is the plasma bridge neutralizer located out of the beam, with ions, atoms, and electrons forming a conducting path between the emitter and the ion beam. This type of neutralizer was developed and tested using cesium[1] and has resulted in an efficient and

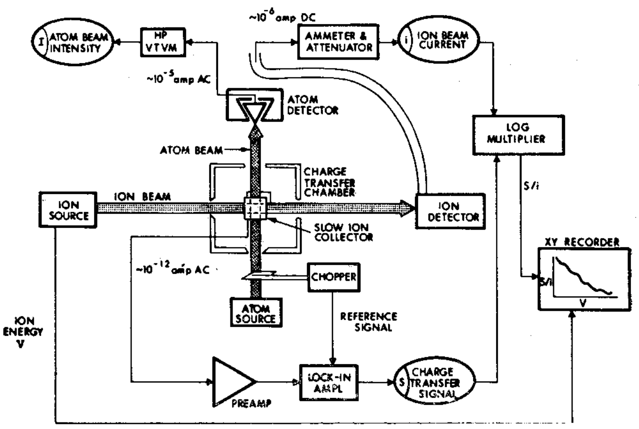

Fig. 1 Schematic diagram of the experiment to measure charge-transfer cross sections using a crossed beam technique. The slow ions that constitute the charge-transfer signal are formed in ion-atom collisions at the intersection of the beams.

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