

licated, but it may be different for air. Furthermore, the influence of other parameters on transition must also be assessed: classical freestream—wall temperature ratio and pressure gradient induced by the presence of the boundary layer, this last parameter being possibly non-negligible in tubes of moderate and small cross sections working at low initial pressures. Furthermore, for large values of Re^* , the transition occurs very close to the shock front; thus, from an experimental point of view, the mounting of gages must be carefully done, trying to avoid any discontinuity in the tube wall. Thus, taking into account these final remarks, new systematic experiments on transition in shock-tube boundary-layer flows are needed.

References

- 1Chaney, J. C. and Cook, W. J., "Further Experiments on Shock Tube Wall Boundary-Layer Transition," *AIAA Journal*, Vol. 21, July 1983, pp. 1046-1048.
- 2Thompson, W. P. and Emrich, R. J., "Turbulent Spots and Wall Roughness Effects in Shock Tube Boundary-Layer Transition," *Physics of Fluids*, Vol. 10, 1967, pp. 17-20.
- 3Brun, R., Auberger, P., and Nguyen, V. Q., "Shock Tube Study of Boundary-Layer Instability," *Acta Astronautica*, Vol. 5, 1978, pp. 1145-1152.
- 4Mark, H. and Mirtich, M., "Transition in Shock Tube Boundary-Layer," *Physics of Fluids*, Vol. 5, 1962, pp. 251-253.
- 5Boison, J. C., "Highly Cooled Boundary-Layer Transition Data in a Shock Tube," *Proceedings of the Tenth International Shock Tube Symposium*, Kyoto University, Japan, edited by G. Kamimoto, July 1975, pp. 415-421.
- 6Mirels, H., "Boundary-Layer Growth Effects in Shock Tubes," *Proceedings of the Eight International Shock Tube Symposium*, London Chapman and Hall (Edited by J. L. Stollery et al.), July 1971, pp. 6/1-6/30.
- 7Schubauer, G. B. and Klebanoff, P. S., "Contribution on the Mechanics of Boundary-Layer Transition," NACA Rept. 1289, 1956.

Reply by Authors to R. Brun

William J. Cook*

Iowa State University, Ames, Iowa
and

Michael J. Chaney†
Sverdrup Technology, Inc.
Arnold Air Force Station, Tennessee

REMARKS in the Comment suggest that a common feature of shock tube wall boundary-layer transition behavior is that at low unit Reynolds number Re_u the velocity U_T of the front corresponding to departure from laminar flow is less than the laboratory fluid particle velocity U_2 , and that with increasing Re_u , U_T progresses toward the shock velocity U_s . Our experimental data do not fully support this hypothesis. In Fig. 2 of Ref. 1 only the largest value of the transition Reynolds number Re_T observed at each T_w/T_e was shown. Examination of the complete data given in Ref. 2 allows some features of the transition path to be identified. These data are presented in Fig. 1, in which ex-

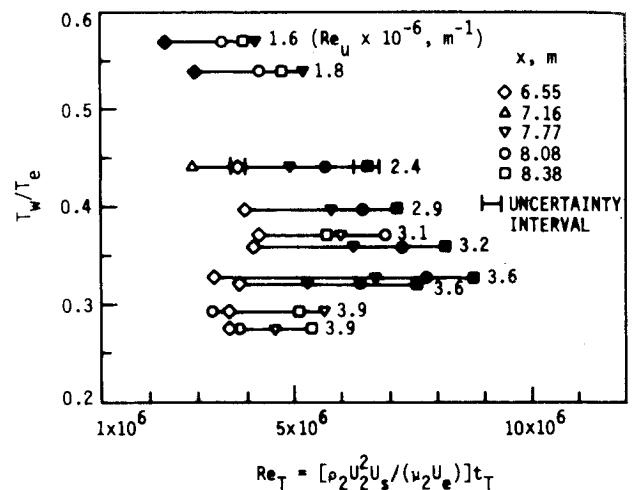


Fig. 1 Transition Reynolds number range for various wall-to-post-shock temperature ratios.

perimental Re_T values are shown for the various x stations for each T_w/T_e considered. Estimated uncertainties in Re_T are shown. At a given T_w/T_e (a given shock Mach number) Re_T is proportional to the transition time t_T , the time between the arrival of the shock and the transition front at a given x . Thus, if the transition front travels at a speed less than U_s , Re_T will increase with increasing x , and if $U_T = U_s$ the same value of Re_T would be obtained at all x stations.

Consider first the data in Fig. 1 in the range $2.4/m \leq Re_u \times 10^{-6} \leq 3.6/m$. These data exhibit Re_T values that vary with x . However, a clearly defined transition front velocity exists only for the data represented by the solid symbols; these data closely follow the transition path $U_T = U_2$. Data for five of the six runs in this range exhibit this characteristic, and only data from stations at the three largest values of x behave in this manner. Consider next the data in Fig. 1 at the two lowest values of Re_u . These data are in the range of unit Reynolds number which, according to Brun, should exhibit a transition front velocity less than U_2 and thus should exhibit a pattern of increasing Re_T with x similar to that for $U_T = U_2$ but with even larger increments of Re_T between the measurement stations. The results do not follow this pattern. The data at x stations 6.55 m and 7.77 m (solid symbols) lie very close to the transition path $U_T = U_2$, while the data for the remaining two x stations indicate that U_T is near U_s downstream of $x = 7.77$ m.

The results in Fig. 1 for $Re_u = 3.9 \times 10^6/m$ do not exhibit a trend in Re_T that allows clear identification of a transition front velocity. However, both the mean values for Re_T and the Re_T range observed for these runs are smaller than those for the data in the range $2.4/m \leq Re_u \times 10^{-6} \leq 3.6/m$. The smaller spread in Re_T suggests a trend toward $U_T = U_s$, as observed by Brun at $Re_u = 4.1 \times 10^6/m$.

Brun associates transition front velocities less than U_2 at low Re_u with the presence of turbulent spots in an otherwise laminar flow. The existence of turbulent spots in the flow would possibly explain results in which measured values of Re_T first decrease and then increase with x . The results in Fig. 1 at $Re_u = 2.4 \times 10^6/m$ exhibit this variation with x . These data are from the study conducted to assess the influence of driver-created disturbances on transition (Fig. 1, Ref. 1). Data at this unit Reynolds number were obtained at five x stations for several runs. Mean values of Re_T at each x station are shown in Fig. 1. Turbulent spots are identified on heat flux gage response curves by an increase from the step-like laminar signal and a subsequent signal decrease indicating a return to laminar flow.³ Records of heat flux gage response for all of the data obtained in this study do not in-

Received May 23, 1985. Copyright © American Institute of Aeronautics and Astronautics, Inc., 1985. All rights reserved.

*Professor, Department of Mechanical Engineering. Member AIAA.

†Project Engineer.

dicating the presence of turbulent spots. Instead, they show an abrupt and complete transition from laminar to turbulent flow. Thus the transition pattern in Fig. 1 at $Re_u = 2.4 \times 10^6/m$ is not explained by the presence of turbulent spots.

Although our experimental results do not in all respects behave in the manner proposed by Brun, it is evident from the results in Fig. 1 that, as suggested by Brun, a multiplicity of measurement stations is necessary to obtain a complete description of shock tube wall boundary layer transition.

References

- ¹Chaney, M. J. and Cook, W. J., "Further Experiments on Shock Tube Wall Boundary Layer Transition," *AIAA Journal*, Vol. 21, July 1983, pp. 1046-1048.
- ²Chaney, M. J., "Effect of Driver Created Disturbances on Shock Tube Sidewall Boundary Layer Transition," M.S. Thesis, Iowa State University, Ames, 1977.
- ³Thompson, W. P. and Emrich, R. J., "Turbulent Spots and Wall Roughness Effects in Shock Tube Boundary-Layer Transition," *Physics of Fluids*, Vol. 10, 1967, pp. 17-20.

From the AIAA Progress in Astronautics and Aeronautics Series . . .

GASDYNAMICS OF DETONATIONS AND EXPLOSIONS—v. 75 and COMBUSTION IN REACTIVE SYSTEMS—v. 76

*Edited by J. Ray Bowen, University of Wisconsin,
N. Manson, Université de Poitiers,
A. K. Oppenheim, University of California,
and R. I. Soloukhin, BSSR Academy of Sciences*

The papers in Volumes 75 and 76 of this Series comprise, on a selective basis, the revised and edited manuscripts of the presentations made at the 7th International Colloquium on Gasdynamics of Explosions and Reactive Systems, held in Göttingen, Germany, in August 1979. In the general field of combustion and flames, the phenomena of explosions and detonations involve some of the most complex processes ever to challenge the combustion scientist or gasdynamicist, simply for the reason that *both* gasdynamics and chemical reaction kinetics occur in an interactive manner in a very short time.

It has been only in the past two decades or so that research in the field of explosion phenomena has made substantial progress, largely due to advances in fast-response solid-state instrumentation for diagnostic experimentation and high-capacity electronic digital computers for carrying out complex theoretical studies. As the pace of such explosion research quickened, it became evident to research scientists on a broad international scale that it would be desirable to hold a regular series of international conferences devoted specifically to this aspect of combustion science (which might equally be called a special aspect of fluid-mechanical science). As the series continued to develop over the years, the topics included such special phenomena as liquid- and solid-phase explosions, initiation and ignition, nonequilibrium processes, turbulence effects, propagation of explosive waves, the detailed gasdynamic structure of detonation waves, and so on. These topics, as well as others, are included in the present two volumes. Volume 75, *Gasdynamics of Detonations and Explosions*, covers wall and confinement effects, liquid- and solid-phase phenomena, and cellular structure of detonations; Volume 76, *Combustion in Reactive Systems*, covers nonequilibrium processes, ignition, turbulence, propagation phenomena, and detailed kinetic modeling. The two volumes are recommended to the attention not only of combustion scientists in general but also to those concerned with the evolving interdisciplinary field of reactive gasdynamics.

*Published in 1981, Volume 75—446 pp., 6×9, illus., \$35.00 Mem., \$55.00 List
Volume 76—656 pp., 6×9, illus., \$35.00 Mem., \$55.00 List*

TO ORDER WRITE: Publications Dept., AIAA, 1633 Broadway, New York, N.Y. 10019