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# Comment on "Effects of Freestream Disturbances on Boundary-Layer Transition"

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THE following comments are directed to the authors of Ref. 1. Reference 2 presents a rather comprehensive investigation of the effects of periodic disturbances of a single frequency on flat plate boundary-layer transition. In that work Miller and Fejer found that the transition Reynolds number was a function only of the disturbance amplitude, whereas the disturbance frequency dictated the transition length. Figures 1 and 2 summarize those results.

Although the minimum amplitude of disturbance investigated by Miller and Fejer was an order of magnitude greater than the maximum disturbance amplitude of Ref. 1, one would a priori expect the same phenomenological behavior at the lower amplitudes. As was predicted by Liepmann[3] in 1945, most data tend to indicate that the value of the maximum rate of shear occurring within the boundary layer dominates the transition mechanism. More recently, Greenspan and Benney[4] have confirmed this notion analytically. Thus, since one would expect the maximum instantaneous value of shear in the boundary layer to be proportional to the disturbance amplitude, one may conclude that the results reported in Ref. 2 are physically justifiable, whereas Spangler and Wells[1] offer no explanation in terms of fundamental phenomena for their rather surprising findings.

Further consideration of the experiment of Ref. 1 brings to mind that the real indicator of transition is the appearance of turbulent bursts in the late Tollmien-Schlichting flow, a phenomenon rather difficult to detect with the smoke filament technique described by Spangler and Wells. Indeed, it may well be that a careful hot-wire traverse of the transition regime will indicate results more in consonance with those previously reported. Moreover, detailed information on the distribution of the intermittency factor would be a valuable product of such an investigation.

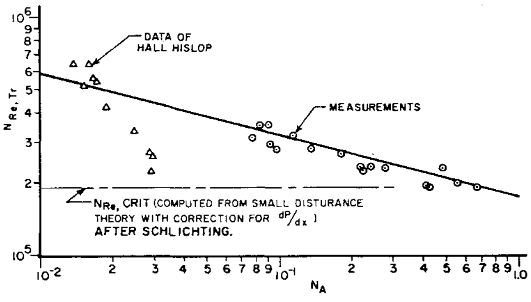


**Fig. 1 Effect of the amplitude parameter $\Delta U/U_\infty$ on the transition Reynolds number.**

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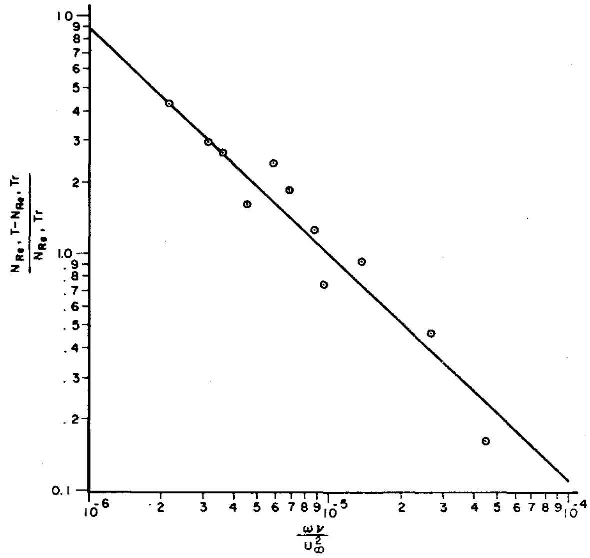


**Fig. 2 Effect of the frequency parameter $\omega\nu/U_\infty{}^2$ on the transition length.**

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# Reply by Authors to J. A. Miller

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THE authors are familiar with the investigations of Miller and Fejer[1] concerning boundary-layer transition induced by periodic disturbances. Although on the surface the two investigations appear similar, there is one important difference that we feel explains the disparity in results. That difference is the magnitude of the freestream disturbances that induced transition. Miller and Fejer studied the effects of sinusoidal freestream disturbances ranging in amplitude from 8.0 to 67.0% of the freestream velocity, whereas our disturbances ranged from 0.04 to 0.33% of freestream, some two orders of magnitude smaller.

Transition may indeed be a function of disturbance amplitude only and not of frequency, as was found by Miller and Fejer, when the freestream disturbance is large enough to impose directly on the boundary layer a rate of shear high enough to cause breakdown. The validity of the role of maximum shear rate in the transition process has been recognized by many. Liepmann,[2] van Driest and Blumer,[3] and Rouse,[4] among others, have all considered this point. Unfortunately, no one as yet has been able to predict correctly or to measure experimentally the value of the maximum shear rate preceding transition. Consequently the minimum value

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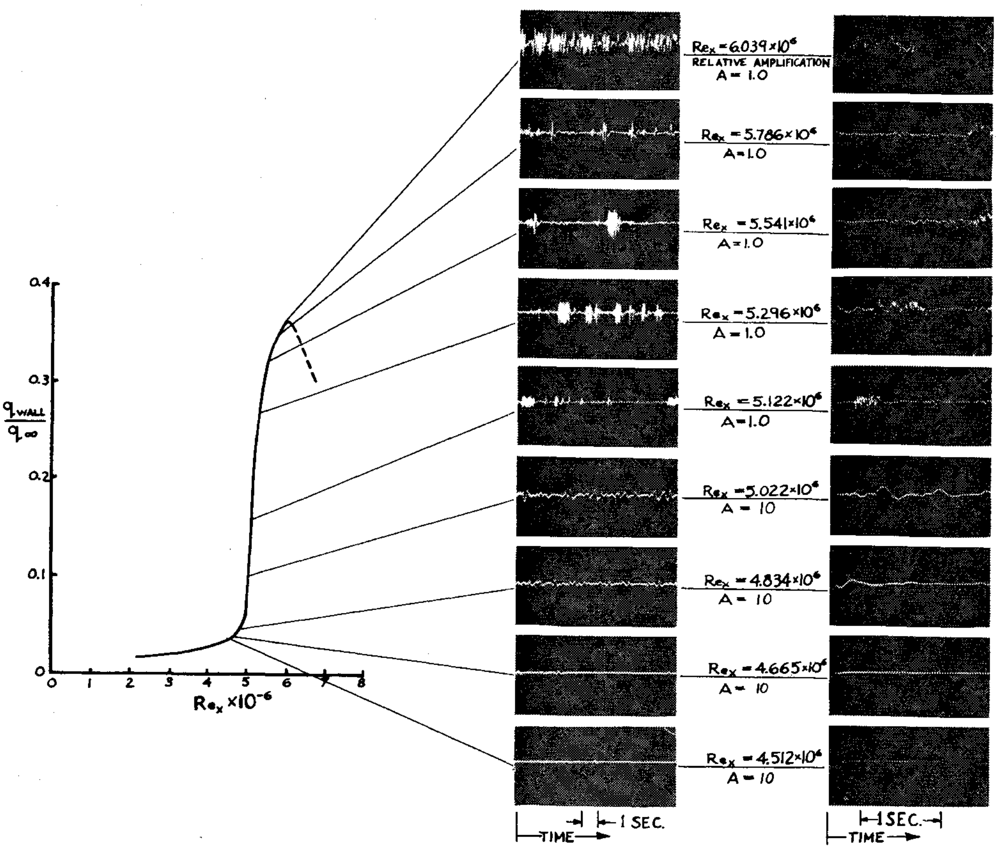


**Fig. 1 Velocity fluctuation measurements through the transition region at $y/\delta = 0.6$.**

of freestream disturbance which can directly induce transition is still uncertain. From the many different attempts that may be found in the literature to correlate transition Reynolds number with freestream disturbances and the widely varying results, the authors contend that transition cannot be treated as a simple function of a single parameter, regardless of isolated cases in which it appears to be so. Disturbance amplitude, frequency and waveform, facility noise level and resonance characteristics, entropy fluctuations, the presence of Tollmien-Schlichting amplification, and other possible parameters should be considered in attempting to correlate transition data. In the case of the subject article the authors feel that Tollmien-Schlichting amplification of the induced boundary-layer disturbances was controlling transition, thus explaining the frequency dependence of the results, whereas in Ref. 1 the gross superposition of the freestream disturbances on the boundary layer was responsible.

With regard to the reliability of the smoke filament technique in locating transition, the authors wish to point out that this has been checked thoroughly against the sudden rise in dynamic pressure at the wall associated with the onset of transition, a technique successfully employed by Klebanoff et al.[5] and Wells.[6,7] Measurements of the location of transition for various unit Reynolds numbers gave repeatable values of transition Reynolds number which agreed within 5%. The spatial relation of the transition point determined in this manner to the occurrence of turbulent bursts may be seen in Fig. 1, which is taken from Ref. 6. The transition Reynolds number is determined by the downward extrapolation of the steep dynamic pressure gradient. The hot-wire traces show that the turbulent bursts appear only beyond this point. Previous experience with hot-wire surveys of the transition region has shown this consistently.

The distribution of the intermittancy factor mentioned by Miller is an interesting point although it was not investigated in the subject article. The results of Ref. 1, which show a definite regularity in the intermittancy, are probably related to the nature of the experiments. It seems reasonable that the intermittancy should indeed become more regular when transition is caused by gross superposition of two-dimensional freestream disturbances instead of through the Tollmien-Schlichting amplification of small unstable disturbances. The large freestream disturbances impose a constraint on the boundary layer that causes the distribution of maximum shear rate also to be two-dimensional, leading to a more orderly transition process. The decrease in transition length with increasing disturbance frequency corresponds to the directly related increase in frequency of turbulent spot production, which in combination with the growth rate of the turbulent spots, leads to more rapid coalescence and the establishment of fully turbulent flow.

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