DISCUSSION

R. C. Dean, Jr.[3]

The authors are to be complimented on carrying out a very careful and perceptive investigation of skewed turbulent boundary layers. Their thorough review of past work, with a comparison between the results generated by several authors, is a critical review very useful to anyone active in this field.

The authors' data were intended to add significantly to the meager supply of reliable measurements of the skewed turbulent boundary layer. They made careful measurements with acceptable accuracy. From their data, they draw several important conclusions which can have a great influence on both theoretical and experimental research on this matter.

We feel that it is unfortunate indeed, in light of the great care and understanding which has been given to this effort, that their experimental situation has been greatly complicated by the sliding of the concave outer wall boundary layer onto the floor of the bend where measurements were made. We are afraid that their data in the bend cannot be interpreted as representative of a skewed boundary layer flow free of edge complications. Since the three-dimensional boundary layer is by itself a complicated and unresolved problem, to further complicate it with corner and edge effects causes the problem to be so difficult as to defy solution today. The actual situation tested appears not to have yielded data of great utility in advancing theoretical understanding.

We would suggest in the future that a flat plate fitted at midspan in the bend, but with sufficient clearance from the curved walls to prevent end wall fluid from flowing onto the plate, would form a better experimental situation. True, this arrangement will make a boundary layer with a leading edge, but it is only a three-dimensional version of the flat plate. Essentially this would be a flat plate having a superimposed curving potential flow. Of course, the Reynolds number and the flow over the plate would have to be such to cause early enough transition to provide an adequate area of turbulent flow. On the other hand, the new boundary layer forming from the curved edge, if the plate were fed with a well-developed turbulent profile as in the present work, would only gradually displace the original turbulent boundary layer so that for a considerable region downstream from the entrance to the bend, a skewing turbulent flow would be available for study.

Other approaches to the generation of a skewed turbulent boundary layer without corner effects are found in the symmetrical scheme of Johnston and similar arrangements. To us it seems that such experimental arrangements have probably produced more useful data than the present work. Nevertheless, the authors' discussion of the problem and past work and their revelation that side wall contamination markedly alters turbulence distribution are all important and welcome contributions.

[3] Professor of Engineering, Thayer School of Engineering, Dartmouth College, Hanover, N. H., and President, Creare, Inc., Hanover, N. H.

Authors' Closure

The authors wish to thank Professor Dean for his discussion. As indicated in the introduction, this study is concerned with the flow of the skewed turbulent boundary layer on the floor of curved channels. As such, it is strongly influenced by the boundary layer on the outer concave wall which subsequently flows onto the end wall or floor of the curved channel. This influence is discussed by the authors, using the results shown in Figs. 16, 17, and 18. The authors did not intend that their results should be extended in a quantitative manner to other flow geometries. The geometry used by both Johnston and Hornung and Joubert is influenced by strong pressure gradients and the ensuing three-dimensional separation. Hence it also represents a special case. Nevertheless, there is a certain amount of practical interest in specific geometries even though the applications are restricted.

Professor Dean suggests a geometry which he feels will provide a more general set of data. Such data would be an important contribution to the understanding of the skewed turbulent boundary layer. The authors would like to offer their opinions about the proposed geometry. Several preliminary tests were conducted prior to the selection of the 60-deg circular channels used in this work. The key areas investigated were free-stream flow direction, boundary-layer separation and vortex formation, and free-stream and boundary-layer interaction. The choice of the test geometry used here was determined from the results of these preliminary tests. These tests also showed that large unsteady regions can occur when the side walls and end walls do not meet. Based on these observations, as well as other works on curved channel flows, the authors feel that the geometry suggested by Professor Dean may not yield data which could be regarded as general. Rather, they feel that Bradshaw's[4] recent suggestion of an infinite swept wing or, in the practical sense, a long yawed plate, or long swept wing would yield more general results.

[4] Bradshaw, P., "Boundary Layer Problems of 1966," NPL Aero Report 1203, 1966.