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Hypersonic Turbulent Boundary-Layer and Free Shear Database

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Table of Contents

Abstract 1
Introduction 1
Database Subject Areas 2
Database Collection 3
  Boundary Layers in Pressure Gradients 4
  Compressible Turbulent Free Shear Layers 4
Database Assessment 5
  Boundary Layers in Pressure Gradients 5
  Compressible Turbulent Free Shear Layers 8
Results and Conclusions 9
Need for Further Experimentation 17
Text References 18
Appendix A: Database References
  Part A - Attached Boundary-Layers in Pressure Gradients 20
  Part B - Supersonic Turbulent Mixing Layers 23
Appendix B: Database Assessment 27
  Part A - Attached Boundary-Layers in Pressure Gradients 29
  Part B - Compressible Turbulent Mixing Layers 33
Appendix C: Data Tabulation 38

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Abstract

A critical assessment and compilation of data are presented on attached hypersonic turbulent boundary layers in pressure gradients and compressible turbulent mixing layers. Extensive searches were conducted to identify candidate experiments, which were subjected to a rigorous set of acceptance criteria. Accepted datasets are both tabulated and provided in machine-readable form. The purpose of this database effort is to make existing high-quality data available in detailed form for the turbulence-modeling and computational fluid dynamics communities. While significant recent data were found on the subject of compressible turbulent mixing, the available boundary-layer/pressure-gradient experiments are all older ones of which no acceptable data were found at hypersonic Mach numbers.

Introduction

In modern hypersonic projects such as the National Aerospace Plane (NASP), it has been recognized from the outset that Computational Fluid Dynamics (CFD) must play a major role. Indeed, the future of high-speed air and space transportation depends critically on our ability to predict solutions of those aerothermal problems which are too difficult or expensive to test in ground-based simulation facilities. Great strides have recently been made in the ability of CFD methods to do this, but it is clear that we still have a long way to go.

While not the only problem obstructing further advances in CFD, turbulence modeling is generally recognized to be a major one. A closed solution of the governing Navier-Stokes equations for turbulent flows of practical consequence is still far beyond our grasp. At the same time, the simplified models of turbulence which are used to achieve closure of the Navier-Stokes equations are known to be rigorously incorrect. While these models serve a definite purpose, they are inadequate for the general prediction of hypersonic viscous/inviscid interactions, mixing problems, transition, chemical nonequilibria, and a range of other phenomena which we must be able to predict in order to design a hypersonic vehicle computationally. For this reason turbulence modeling is a key issue in NASA's continued efforts to push forward the boundaries of knowledge of high-speed flight.

Due to the complexity of turbulence, useful new turbulence models are synthesized only when great expertise is brought to bear and considerable intellectual energy is expended. Although this process is fundamentally theoretical, crucial guidance may be gained from carefully-executed basic experiments. Following the birth of a new model, its testing and validation once again demand comparisons with data of unimpeachable quality. This report concerns these issues which arise from the experimental aspect of hypersonic turbulence modeling.

Prior to about 1970, hypersonics was a subject of considerable research in the USA and abroad. However, for a variety of social, economic, and political reasons, such research all but ceased in the USA for 15 years. This "gap" in hypersonic technology now hampers the NASP program and all other modern efforts related to hypersonic flight.

Further, during the "hypersonic gap" years, computer and laser technologies relevant to fluid-dynamic instrumentation matured considerably. Given these improvements, it is now possible to carry out far more meaningful and detailed hypersonic experiments than those of the pre-1970 period.

With this background, a High-Speed Turbulence Modeling Workshop was held at NASA-Ames Research Center during June 7-8, 1988. This workshop had the goal of identifying ways to improve turbulence modeling for hypersonic flows, with specific applicability to the NASP Program. Both theoretical and experimental issues were discussed in detail.

In the course of this discussion, questions arose about the quantity and quality of *existing* experimental data which bear upon the issue of hypersonic turbulence modeling. Specifically, it was pointed out that existing surveys of high-speed flows list several hundred experiments which have been carried out at hypersonic speeds. However, some attendees of the Workshop questioned whether or not any significant number of these existing experiments could meet the high standards presently required for CFD code validation and turbulence modeling.

Since this issue could not be resolved at the time, one of the conclusions of the Workshop was that the need existed to review critically the database of existing hypersonic experiments for its suitability to turbulence modeling and code validation. Accordingly, an effort was begun early in 1989 at the Penn State University Gas Dynamics Laboratory to perform this critical review and to assemble the required database. The effort was sponsored by the NASP Program through NASA-Ames Research Center, and is a part of an ongoing overall task to develop compressible turbulence models. The first phase of this effort was completed in 1991 and released to the public (Refs. 1 and 2). The present report represents the results of the second phase of this effort.

Database Subject Areas

In choosing the specific subject areas for this hypersonic database collection and assessment effort, some caution was exercised in favor of a few critical issues directly relevant to turbulence modeling. Our purpose in this effort is to define a database for the specific goal of the advancement of modern turbulence models with regard to these critical issues, not to conduct a broad-based survey of all previous work in the field of hypersonics.

Accordingly, discussions with NASA personnel have led to the following list of specific topics for the database:

1) shock wave/boundary-layer interactions
2) supersonic shear layer mixing
3) high-speed attached boundary layers with pressure gradients

The first-phase database collection and assessment effort (Refs. 1 and 2) considered only topic 1) above. Topics 2) and 3) were then approached by similar methods in the second phase of the effort, reported herein. Specifically, the coverage of the present phase of the database collection and assessment effort includes both supersonic ($M \sim 3$ and above) and hypersonic data on attached boundary layers in pressure gradients, both two-dimensional (2-D) and three-dimensional (3-D) data on this topic, and data on free turbulent mixing layers where the convective Mach number (defined as the Mach number of a large-scale turbulent structure with respect to the surrounding mixing streams) is greater than zero.

Database Collection

Our philosophy of collecting the necessary data for this study hinges around the following four strategies:

1) Take full advantage of pre-existing database reviews, surveys, and compilations.
2) Conduct machine searches to identify likely candidate studies cited in the literature.
3) Make use of NASA, NTIS, DTIC, AIAA, and other technical library resources to obtain data reports as necessary.
4) Contact investigators, both former and current, as necessary to obtain sufficient documentation of prime candidate studies.

During the initial phase of this effort we have studied a variety of prior reviews and surveys on turbulent boundary layers in pressure gradients and compressible free turbulent shear layers (eg Refs. 3-10). The library holdings of the Penn State Gas Dynamics Laboratory were also thoroughly reviewed. However, the major data collection effort took the form of computerized literature searches.

We have searched the AIAA Aerospace Database, which comprises file 108 of the Dialog computerized database system. The Aerospace Database covers publications and reports since 1962 on aerospace-related subjects, and includes both International Aerospace Abstracts, compiled by the AIAA, and Scientific and Technical Aerospace Reports, compiled by NASA. Considering the strong aerospace flavor of the present subject matter, it was felt that this database was an obvious choice and that searches of other science and engineering databases would be unlikely to reveal significant additional material of relevance.

Before beginning this search process, the NASA Thesaurus (Ref. 11) was consulted for appropriate keywords. A group of well-known references likely to be pertinent to the database was called up from the Aerospace Database to determine which keywords were used. The process, beginning at that point, is decribed separately below for the two subject areas of the present report.

Boundary Layers in Pressure Gradients

At the time the search was conducted, the Aerospace Database contained 32,313 references ("Set 1") indexed by one or the other of the two keywords COMPRESSIBLE and SUPERSONIC, 25,308 indexed by the keyword TURBULENT ("Set 2"), and 25,741 indexed by the keyword phrase BOUNDARY LAYER ("Set 3"). The intersection of Sets 1-3 contained 1,355 references which might be described as supersonic or compressible turbulent boundary layer studies ("Set 4"). A similar search strategy then yielded 16,568 references indexed by either HYPERSONIC or COMPRESSIBLE ("Set 5"). The intersection of Set 5 with Sets 2 and 3 contained 870 references which might be described as hypersonic or compressible turbulent boundary layer studies ("Set 6"). We next found that 1,794 references indexed in the Aerospace Database carried the descriptive keyword phrase PRESSURE GRADIENT ("Set 7"). The intersections of Sets 4 and 6 with Set 7 produced, respectively, 84 ("Set 8") and 69 ("Set 9") references, the combination of which might be described as "compressible or supersonic or hypersonic turbulent boundary layers with pressure gradients." Examination of these 153 references by abstract revealed a high percentage of useful entries for present purposes.

Every citation in Sets 8 and 9 was studied by either abstract or full paper in order to determine its relevance. This process depended heavily on our background and experience in order to identify likely candidate experiments. In all cases for which a decision could not be reached from the abstract alone, a hard copy of the full document was obtained and scanned. The result of this process was the final set ("Set 10"), which consisted of 39 distinct experimental studies of compressible turbulent boundary layers at Mach numbers of 3 or higher, presumably with pressure gradients imposed. Set 10 was subjected to the database assessment procedure described below.

Compressible Free Turbulent Shear Layers

At the outset, a number of references known to be highly pertinent to this topic were searched for and retrieved from the Aerospace Database and examined in order to determine the range of keyword descriptors involved. Unfortunately, a bewildering array of different keywords and keyword combinations was found to describe the general issue of compressible free turbulent mixing. For example, the concept of a "mixing layer" is variously categorized as SHEAR LAYER (1272), TURBULENT MIXING (1703), FREE FLOW (1127), SPREADING (49), CONVECTIVE FLOW (2826), or VORTEX SHEET (565), where the number following each keyword phrase is the number of references thus indexed. In all, 29,178 unique references were found to fit the general concept of a mixing layer, henceforth referred to as "Set A."

Similarly, compressibility was manifested in a variety of ways by the keywords MACH NUMBER (1161), COMPRESSIBLE FLOW (3176), SUPERSONIC OR HYPERSONIC FLOW (10,753), SUPERSONIC WIND TUNNEL (654), COMPRESSIBILITY EFFECT (501), and SCHLIEREN PHOTOGRAPHY (704). In all, 16,472 unique references were found to fit the general concept of compressibility, henceforth referred to as "Set B."

The intersection of Sets A and B yielded 1137 unique literature citations, "Set C," which appeared to contain a high percentage of the known pertinent references on compressible free turbulent mixing. Clearly, of course, it contained many extraneous citations as well. Attempts to reduce the size of this set by further restricting the search strategy failed because they caused pertinent references to be discarded. (In retrospect, the number might have been further reduced chronologically, since most of the pertinent references over the period 1962-present were found to be dated after 1984.)

All 1137 citations of Set C were then manually scanned for relevance by abstract or, if necessary, by complete hardcopy. This resulted in the final Set D, consisting of 45 references which appeared to qualify as turbulent mixing-layer experiments with a convective Mach number greater than zero. All of these were subjected to evaluation in terms of the acceptance criteria described in the next section.

Database Assessment

This was the critical step of the study, in which the decision was made as to which of the possible candidate experiments identified above actually merit inclusion in a database to be put forth as a standard for CFD code validation and turbulence model development. We drew guidance from a distinguished predecessor at this task (Ref. 12), who noted that those data turn out to be most useful in which only one factor is varied at a time, and that there appears to be a certain level above which measurements can be described as being of "professional quality."

Boundary Layers in Pressure Gradients

A special circumstance occurs in the case of compressible turbulent boundary layers with pressure gradients. This topic was covered in a previous database collection and assessment effort which resulted in 4 AGARD publications (Refs. 3-6) by Fernholz, Finley, and others. The scale of this effort, which covered about a decade, was at least an order of magnitude larger than that of the present effort. Profs. Fernholz and Finley have distinguished themselves by this massive undertaking and by the care with which they critiqued the available datasets.

We cannot pretend to second-guess the Fernholz/Finley effort, but only to update it. However, it must be noted that the aims of their assessment and our own are somewhat different. Fernholz and Finley stated at the outset that they felt the value of their database increased with each new addition, and they thus tabulated several cases which were sufficiently incomplete or confusing as to render them useless for code validation and turbulence modeling. Our philosophy, on the other hand, is that we are looking only for those few experimental studies of unimpeachable quality and direct pertinence to the subject at hand. We have thus accepted only a small subset of the entire Fernholz/Finley catalog.

We have subjected the 39 candidate studies of compressible-boundary-layers-with-pressure-gradients (Set 10 above) to a test based on rigorous criteria for this purpose. The criteria are grouped in two categories: "necessary" and "desirable." Candidate experiments were required to pass all the "necessary" criteria in order to be considered further. However, even then, failure to meet any of the "desirable" criteria might result in rejection of a candidate experiment for the database, on the basis that it fails to contribute anything truly useful to the goal of the database.

A list of the 8 necessary criteria we applied is given below, in the hierarchical order in which they were applied.

1) BASELINE APPLICABILITY

All candidate studies must be experiments involving turbulent flows in either the supersonic or the hypersonic Mach number range (ie M ~ 3 or higher). Further, these studies must address the subject area of boundary layers with pressure gradients.

2) SIMPLICITY

All candidate studies passing this criterion must involve experimental geometries sufficiently simple that they may be modeled by CFD methods without enormous difficulty. Flows through complex inlet scale-models or over the surfaces of complete 3-D flight configurations are rejected at this point, for example. Stated in other words, this criterion is a filter which passes only "building-block" experiments.

3) SPECIFIC APPLICABILITY

All candidate studies passing this criterion must be capable of providing some useful test of turbulence modeling. For example, any study which provides only a surface pressure distribution over an arbitrary surface in hypersonic flow is rejected as insufficient to further the goals of turbulence modeling. To be a useful test case, such a study would at least require additional data such as flowfield profiles or heat transfer/skin friction distributions. (Some experienced judgement was called for in the application of this criterion.)

4) WELL-DEFINED EXPERIMENTAL BOUNDARY CONDITIONS

This criterion was applied in a sense similar to that of CFD studies, where a rational solution cannot be had if the boundary conditions of the problem are inadequately defined. For high-speed experiments, this criterion requires at least that all incoming conditions (especially the state of the incoming boundary-layer) be carefully documented. For turbulent incoming boundary-layers, either known upstream transition conditions (to allow a boundary-layer calculation to be made) or else the documentation of both the mean and fluctuating character of the incoming profile must be provided. Similarly, all studies claiming "2-D" flow must show data which establish the extent of spanwise flow variations.

We recognized at the outset that this criterion alone might eliminate a large proportion of all past hypersonic studies from further consideration. However, without it, the resulting database would fail to be useful for its intended purpose. Once again, some experienced judgement was called for in the application of this criterion.

5) WELL-DEFINED EXPERIMENTAL ERROR BOUNDS

To pass this criterion, the experimenter him/her/self must have provided an analysis of the accuracy and repeatability of the data, or error bands on the data points themselves. Further, such accuracy indications or error bounds must be substantiated in some rational way beyond their mere statement. (Without this criterion, a proper code validation exercise cannot be conducted with the subject data.)

6) CONSISTENCY CRITERION

If, during the consideration of a candidate study, mutually inconsistent results were discovered, said study was eliminated from further consideration for the database. This criterion amounts to a special corollary of the previous criterion.

7) ADEQUATE DOCUMENTATION OF DATA

Candidate studies were examined to determine whether or not their data were documented sufficiently to allow quantitative results to be included in the database in tabulated and machine-readable form. Those failing this criterion were eliminated. This criterion applied in particular to studies whose documentation was available only in plotted form. If such plots were quantitatively unreadable within reasonable error bounds as mentioned above (taking note of the well-known scale distortions which often occur during publication), then the data could not be considered useful for present purposes.

8) ADEQUATE SPATIAL RESOLUTION OF DATA

To pass this criterion, experiments must present data of sufficiently high resolution, compared with the scale of the flow in question, that the key features of the flow are clearly resolved. Failure to do so results in data which are inadequate to provide a proper example or test for turbulence modeling.

In addition to the above-listed "necessary" criteria, the following "desirable" criteria also had an influence on which candidate experiments were finally included in the database:

1) TURBULENCE DATA

In addition to purely mean-flow measurements, data on fluctuating quantities such as Reynolds stresses and velocity or mass-flux fluctuations were considered highly desirable.

2) REALISTIC TEST CONDITIONS

Of those flows passing the necessary criteria, special preference was given to cases (if any) with Mach numbers in the hypersonic range, non-adiabatic wall conditions, real-gas effects, or related characteristics typical of actual hypersonic flight.

3) NON-INTRUSIVE INSTRUMENTATION

All other conditions being equal, preference was given to experiments (if any) wherein non-intrusive instrumentatation (*eg* optical measurements) were employed to acquire the data. This preference is based on the automatic satisfaction of some error and boundary-condition concerns which occurs when non-intrusive measurements are made. It is recognized, of course, that being non-intrusive is not a sufficient condition for a measurement to be considered accurate.

4) REDUNDANT MEASUREMENTS

Further preference was given to experiments (if any) in which redundant data were taken in order to establish the values of flow quantities by more than one method. This is considered to be a strong demonstration of the quality and error bounds of the data.

5) FLOW STRUCTURE AND PHYSICS

Finally, preference was also given to those experiments which, in addition to providing quantitative data, also reveal flow structures and physical mechanisms. The philosophy of this criterion was to allow higher-level CFD comparisons with the salient characteristics of the flows in question, rather than merely with unstructured flow profiles.

The 39 individual studies subjected to the above criteria are listed by bibliographic citation in Appendix A, Part A. Each of these studies was given a detailed assessment through examination of its source material. During the evaluation procedure a tabular evaluation matrix was kept of decisions in each assessment category for every studied considered. A form of this table is given as Appendix B, Part A. Other than an indication of whether or not each candidate met the criteria indicated, additional notes pertinent to the assessment are provided in some cases.

Compressible Free Turbulent Shear Layers

No equivalent of the Fernholz-Finley catalog exists in the case of compressible mixing layers. A tabulation of early data resulted from a NASA conference on the topic 20 years ago (Ref. 7), but the preponderance of work on this topic since 1985 has never been assembled into a database.

We have subjected the 45 candidate studies of compressible-free-turbulent-shear-layers (Set D above) to a test based on similar criteria to those detailed in the previous section. Both the "necessary" and "desirable" categories were once again used, and candidate experiments were required to pass all the "necessary" criteria in order to be considered further. Briefly, "Baseline Applicability" (Necessary Criterion 1) here requires the convective Mach number (defined as the Mach number of a large-scale turbulent structure with respect to the surrounding mixing streams) to be greater than zero. Otherwise the present criteria are essentially identical to those of the previous section. "Realistic Test Conditions" (Desirable Criterion 2) is here taken to mean conditions representative of those which might actually occur in a SCRAMJET combustor.

The 45 individual studies subjected to these criteria are listed by bibliographic citation in Appendix A, Part B. Each of these studies was given a detailed assessment through examination of its source material. During the evaluation procedure a tabular evaluation matrix was kept of decisions in each assessment category for every study considered. A form of this table is given as Appendix B, Part B. Other than an indication of whether or not each candidate met the criteria indicated, additional notes pertinent to the assessment are provided in some cases.

Results and Conclusions

Boundary Layers in Pressure Gradients

As shown in the evaluation tables of Appendix B, Part A, only 9 of the "finalists" in Database Collection Set 10 passed a sufficient number of the assessment criteria to be accepted into the database. All of these studies fell in the supersonic Mach number range of Mach 3 to 4; none were in the hypersonic range (above Mach 5). The studies accepted are listed in Table I below and additional information on each is included in Appendix C. Machine-readable data files for each accepted study are also given on the diskettes bound inside the back cover of this report.

The same *general* conclusion may be drawn from this study as from the previous phase of this database effort, which concerned shock/boundary-layer interactions: high-quality data on *hypersonic* boundary layers in pressure gradients, suitable for use in turbulence modeling efforts, are so scarce as to be nonexistent. The existing data, all in the supersonic range, do not begin to satisfy the current need. Thus the authors strongly suggest that new, detailed, carefully-planned experiments be funded and carried out. Suggestions for these experiments are listed in the next section.

This disappointing result is not due to the fact that hypersonic experiments on boundary layers in pressure gradients have never been conducted (see, eg, the evaluated studies cited in Appendix A, Part A, Refs. 2, 5, and 18, at Mach numbers up to 47). It is rather due to the fact that all these hypersonic experiments suffered fatal flaws which caused them to fail "Necessary Criterion" number 4 (having to do with properly-defined boundary conditions). Heavily-tripped boundary layers or boundary layers at marginal Reynolds number could not be taken as proper intial conditions for a benchmark pressure-gradient experiment. We have taken the position that transitional effects in the intial boundary-layer state are disqualifying for present purposes. Similarly, high-Mach-number nozzle-wall boundary layers suffer either or both of: 1) a strong favorable pressure gradient history, or 2) a highly-nonuniform heat transfer history. In either case, such boundary layers tend to be in a highly non-equilibrated state, which fails to form a proper initial condition for a benchmark study as previously noted.

Thus it is understandable that the acceptable data all lie below Mach 5. Only in this range can one *normally* obtain well-developed, equilibrium turbulent boundary layers. Suggestions on how to overcome this problem are given in the section on the Need for Future Experimentation.

Compressible Free Turbulent Shear Layers

As shown in the evaluation tables of Appendix B, Part B, only 3 of the "finalists" in Database Collection Set D passed a sufficient number of the assessment criteria to be accepted into the database. The studies accepted are listed in Table I below and additional information on each is included in Appendix C. Machine-readable data files for each accepted study are also given on the diskettes bound inside the back cover of this report.

Several reasons may be cited for the small number of acceptable experiments in this category, as follows:

1) A number of original experimenters in this subject area were solicited by mail and by direct contact for their pertinent datasets in machine-readable form early in 1992. Only 5 responses were received. It appears that a number of potentially-acceptable datasets have never been put into acceptable form for public release. For example, the experiment of Barre, et al. (Appendix A, Part B, Ref. 3) bears all appearances of being an acceptable and valuable dataset, but it is a very new experiment for which tabulated data are not yet available. This helps to explain the frequent occurrence of the comment "Data not available" in the evaluation table.

2) As already mentioned, a large number of studies (experimental, theoretical, and computational) of compressible turbulent mixing has been spawned by the NASP project since about 1985. Most of the experimental ones have been reviewed in the course of this database assessment. A significant proportion of these (including some work of the present authors) concerned the phenomenology of the compressibility effect on turbulence mixing. Such studies relied on flow visualization and other approaches which did not lead to detailed, quantitative, tabulated datasets. Only a very few experimental studies produced quantitative mean-flow and turbulence data of direct use in turbulence modeling and code validation. This helps to explain the frequent occurrence of the comment "No specific tabulated data" in the evaluation table.

3) Third, and of considerable importance, is the issue of the definition of boundary conditions. In order for a computational simulation of a given experiment to be carried out, a complete definition of the boundary conditions must be provided. Experiments, too, require complete boundary conditions, but not all these conditions may have been measured by the experimentalist. When some boundary conditions are unknown, the task of the computationalist is reduced to guesswork and the quality of the comparison between experiment and numerical simulation is compromised by this "least common denominator." Thus, proper definition of boundary conditions has been a recurrent theme in this database effort, and it is nowhere more important than in the case of compressible turbulent mixing.

Mixing layers, either planar or axisymmetric, originate from two dissimilar gas streams. At the point where these streams meet it is imperative that each stream be well-defined. For example, the "splitter plate" which joins the two streams always has two boundary layers on it in real viscous flow. Proper specification of boundary conditions requires that both the freestream conditions and the boundary layer of both mixing streams be adequately documented, though this has seldom been done in experimental practice. (Here we echo the earlier comments of Viegas and Rubesin, Refs. 10 and 13, concerning planar mixing layers and those of Lepicovsky, Ref. 14, and Donaldson and Snedeker, Ref. 15, concerning free jets.) This helps to explain the frequent rejection of candidate datasets on the basis of "Necessary Criterion 4" in the evaluation table.

Finally, the nature of the compressibility effect is to reduce turbulent mixing below its incompressible equivalent rate by one or more physical mechanisms which remain to be fully understood. It has become common practice to plot the compressible mixing-layer spreading rate, δ', normalized by its incompressible equivalent δ'_i, vs. the convective Mach number, M_c, which is conveniently defined as the total difference in velocity between the two mixing streams divided by the acoustic velocity. Many studies have generated data points on this plot which reveal a general decline in mixing rate with increasing M_c. The ability of a turbulence model to encompass compressibility effects is judged, to some extent, by its agreement with this body of data. (The standard k-ϵ model, for example, does not do well in this regard according to Ref. 10.)

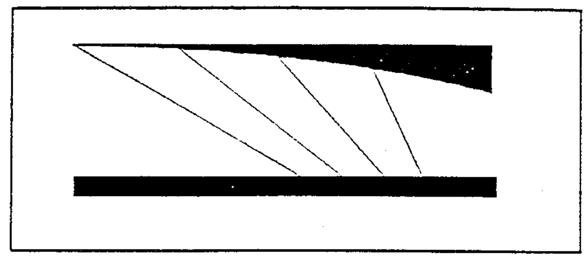
Thus the trend of δ'/δ'_i vs. M_c is important in code validation and turbulence modeling, and is reproduced here in Fig. 1. A collection of 38 data points is shown, which is supported by the tabulation given in Table II. The additional references from which these data come are listed as Text Refs. 16-23. Users of these data are cautioned by Viegas and Rubesin (Ref. 10) that compressibility effects are distinct from those of density *per se*, and that ignorance of this distinction in forming the ratio δ'/δ'_i can lead to serious errors.

TABLE I

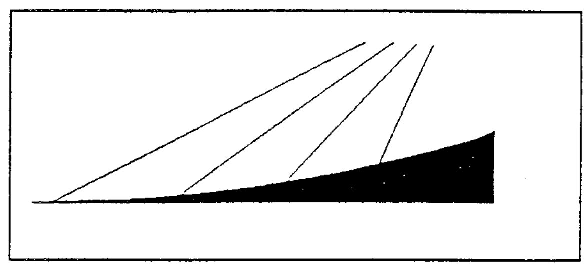
PART A - ATTACHED BOUNDARY-LAYERS IN PRESSURE GRADIENTS

ACCEPTED EXPERIMENTS

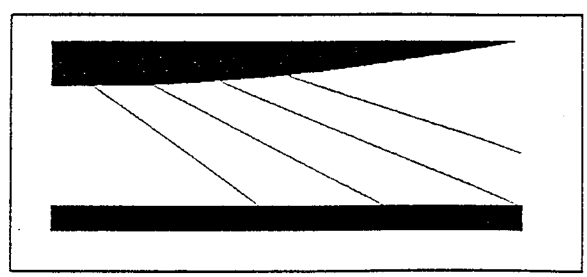
Author: Fernando & Smits (Ref. 10)
Geometry: Streamwise APG,
Flat Wall
Mach number: 3
Data: mean velocity & temperature
profiles, CTHWA turbulence
data



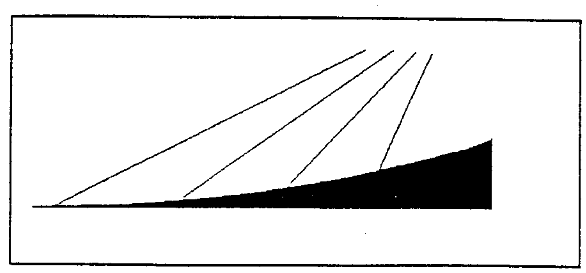
Author: Laderman (Ref. 20)
Geometry: Streamwise APG,
Curved Ramp
Mach number: 3
Data: mean velocity & temperature
profiles



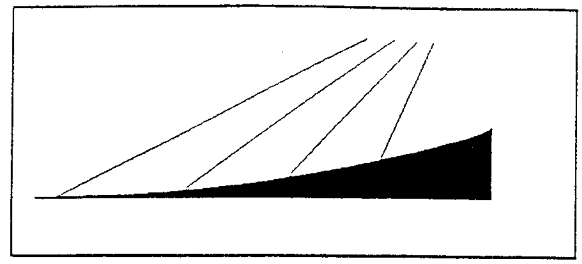
Author: Lewis, Gran, & Kubota (Ref. 22)
Geometry: Streamwise APG & FPG,
Flat Wall
Mach number: 4
Data: mean velocity & temperature
profiles



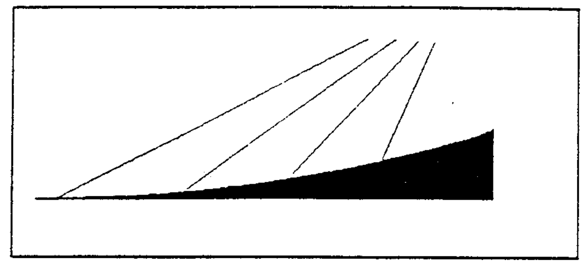
Author: Sturek (Ref. 28)
Geometry: Streamwise APG,
Curved Ramp
Mach number: 3.5
Data: mean velocity & temperature
profiles



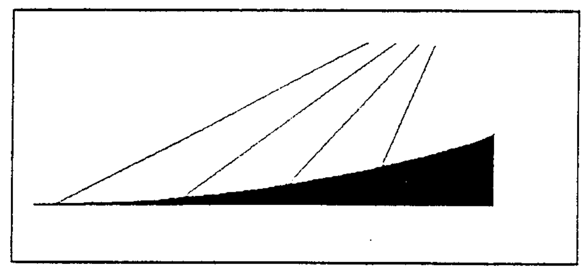
Author: Taylor (Ref. 29)
Geometry: Streamwise APG,
Curved Ramp
Mach number: 3
Data: mean velocity & temperature
profiles



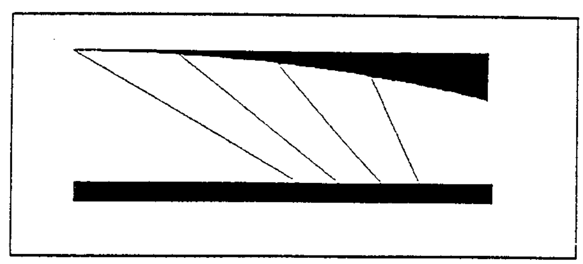
Author: Jayaram et al. (Ref. 17)
Geometry: Streamwise APG,
Curved Ramp
Mach number: 3
Data: CTHWA turbulence data



Author: Donovan (Ref. 9)
Geometry: Streamwise APG,
Curved Ramp
Mach number: 3
Data: CTHWA turbulence data



Author: Smith & Smits (Ref. 25)
Geometry: Streamwise APG,
Flat Wall
Mach number: 3
Data: mean velocity & temperature
profiles, CTHWA turbulence
data



Author: Zheltovodov et al. (Ref. 38)
Geometry: 8° Expansion Corner
Mach number: 2.9 and 3.7
Data: mean velocity profiles,
skin friction

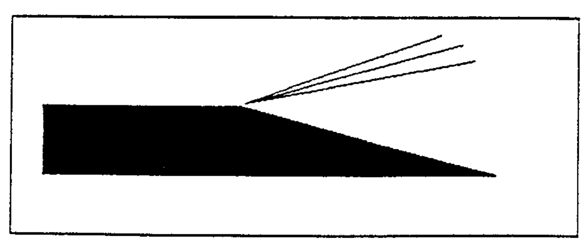
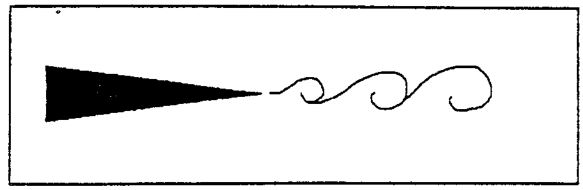


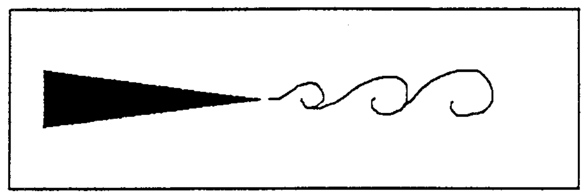
TABLE I

PART B - SUPERSONIC TURBULENT MIXING LAYERS
ACCEPTED EXPERIMENTS

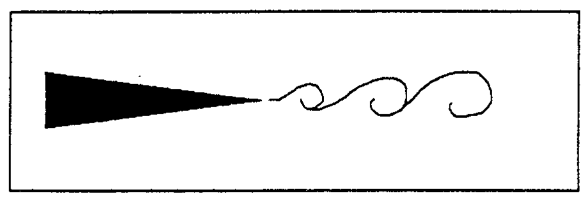
Author: Goebel (Ref. 17)
Geometry: 2-D Splitter Plate
Convective Mach Number: 0.2-0.99
Data: 2-D LDV (mean & fluctuating)



Author: Gruber, et al. (Ref. 18)
Geometry: 2-D Splitter Plate
Convective Mach Number: 0.8
Data: 3-D LDV (mean & fluctuating)



Author: Samimy & Elliot (Ref. 33)
Geometry: 2-D Splitter Plate
Convective Mach Number: 0.51-0.86
Data: 2-D LDV (mean & fluctuating)



Elliot and Samimy
AIAA-90-0705
vorticity thickness

Mc	δ'/δ'_i
0.5068128	0.9100622
0.6370569	0.7076751
0.8547651	0.5573491

Fourgette et al.
AIAA Journal
Vol. 29, No. 7
1991
Pitot thickness

Mc	δ'/δ'_i
0.7266265	0.3856538

Fourgette et al.
AIAA Journal
Vol. 29, No. 7
1991
Visual thickness

Mc	δ'/δ'_i
0.6867489	0.3097857

Bogdanoff Compilation
AIAA Journal
1983
Vol. 21, No. 6
vorticity thickness

Mc	δ'/δ'_i
0.0497425	0.9987765
0.4254258	0.998259
0.4657529	0.9765364
0.6324128	0.7495671
0.8268807	0.5987423
0.9302578	0.4631004
1.1174869	0.452314
1.3120048	0.419876
1.4400666	0.4296296

Papamoschou and Roshko
JFM
Vol 187
1988
visual thickness

Mc	δ'/δ'_i
0.2641428	0.9990381
0.3319724	0.7025797
0.3933234	0.711568
0.560031	0.5037233
0.6486326	0.2110421
0.9050897	0.2202974
1.062174	0.2850307
1.4522256	0.171235
1.8164714	0.2157946

Goebel & Dutton
AIAA Journal
Vol. 29 No. 4
vorticity thickness

Mc	δ'/δ'_i
0.2	1
0.46	0.81
0.69	0.56
0.72	0.63
0.86	0.46
0.99	0.4

Clemens & Mungal
AIAA Journal
April 1992
Vol. 30 No. 4
visual thickness

Mc	δ'/δ'_i
0.2842421	0.581756
0.6230616	0.4087488
0.7945345	0.3608398

Gruber et al.
AIAA-92-3544
vorticity thickness

Mc	δ'/δ'_i
0.8	0.5088548

Naughton et al.
AIAA Paper 93-0742
Concentration
Thickness

Mc	δ'/δ'_i
0.7	0.392
1.3	0.198
1.6	0.186
1.9	0.236

TABLE II
Tabulation of Normalized Mixing Layer Growth Rate vs. Convective Mach Number

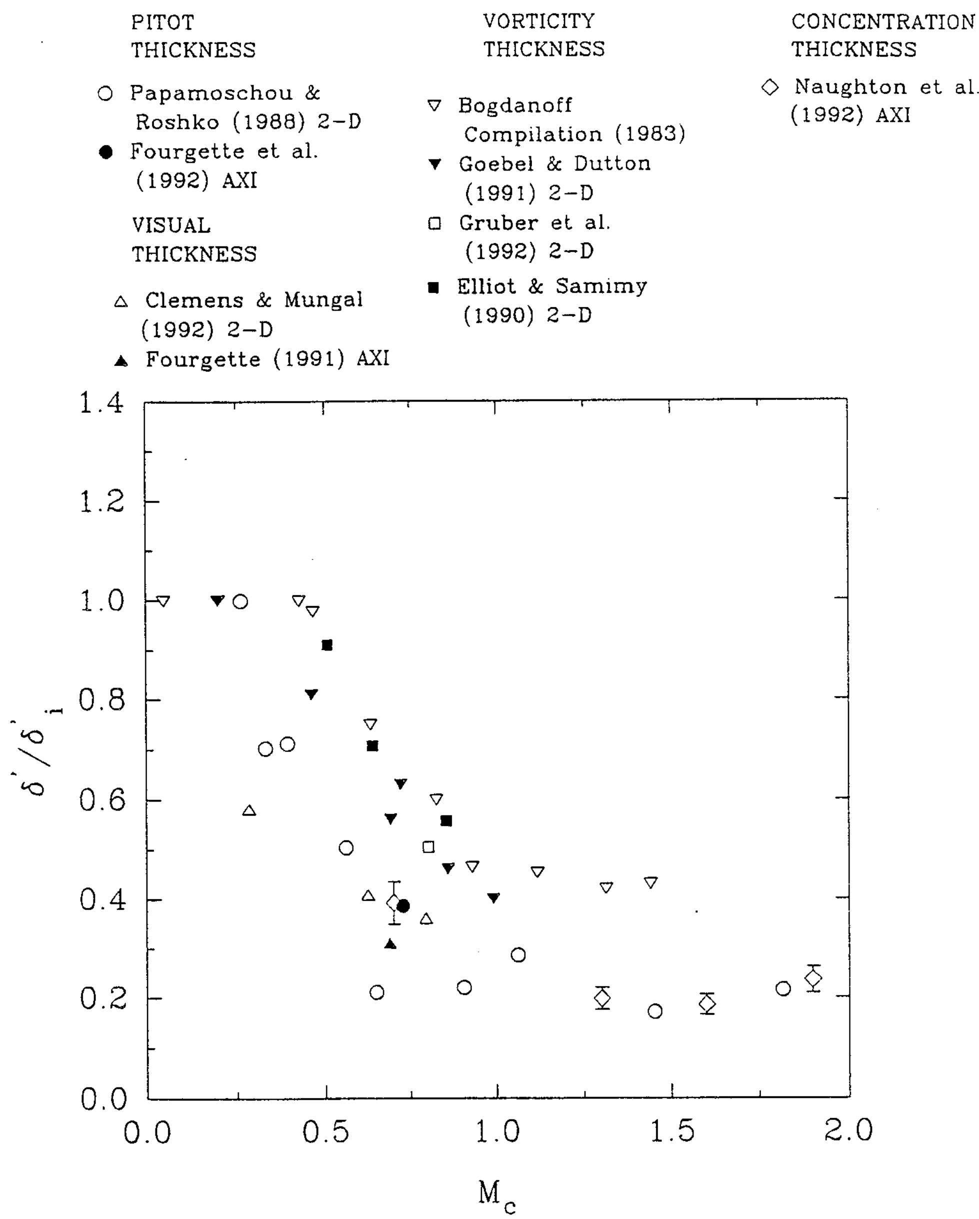


Fig. 1 - Plot of Normalized Mixing Layer Growth Rate vs. Convective Mach Number

Need for Further Experimentation

Based upon the results of this study, the following list conveys our recommendations for further experimentation.

Boundary Layers in Pressure Gradients

1) High-Reynolds-Number hypersonic experiments with well-defined initial turbulent boundary layers (data with any form of pressure gradient would be welcome).

2) Turbulence data for properly-defined hypersonic experiments as in item 1).

3) More data with either favorable or transverse pressure gradient, covering a broader parameter range than those of the accepted studies.

4) Non-intrusive flowfield data (mean as well as fluctuating)

5) "Measurements are needed in adverse pressure gradients with heat transfer for a cooled isothermal wall, and for all pressure gradients with wall temperature varied in a controlled manner," (as concluded by Fernholz and Finley in Text Ref. 4)

Compressible Free Turbulent Shear Layers

1) More detailed, quantitative, high-resolution, well-documented experimental data are seriously needed, since only three such studies have been found thus far.

2) Particular attention must be paid to the proper definition of boundary conditions, especially splitter-plate boundary-layers and entrained-flow properties in the case of free jets, if the data are to be useful for turbulence modeling and code validation.

3) Such data are especially needed in the case of coaxial jets, shrouded mixing layers, reacting mixing layers, swirling flows, and other geometries more sophisticated than simple planar two-stream mixing.

4) Data are needed for turbulence modeling, per Text Ref. 10, in which stagnation temperatures are adjusted to provide both matched densities at the splitter plate and mismatched densities more characteristic of potential SCRAMJET applications.

Acknowledgement

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Appendix A: Database References

Part A - Attached Boundary-Layers in Pressure Gradients

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Appendix B: Database Assessment

The following two tables list the 39 Boundary Layer Database References (Part A) and the 45 Compressible Mixing Database References (Part B) which were subjected to an evaluation based on the criteria described earlier in the Database Assessment section. These references are presented in a numerical order which implies alphabetical order based on the last name of the first author. The tables include an evaluation field for each of the 8 necessary and 5 desirable criteria as discussed earlier, followed by a field which indicates whether or not the reference was accepted into the database. The thirteen assessment criteria are indicated in the table only by numbers, the meaning of which is as follows:

NECESSARY CRITERIA

- #1 Baseline Applicability
- #2 Simplicity
- #3 Specific Applicability
- #4 Well-Defined Experimental Boundary Conditions
- #5 Well-Defined Experimental Error Bounds
- #6 Consistency Criterion
- #7 Adequate Documentation of Data
- #8 Adequate Spatial Resolution of Data

DESIRABLE CRITERIA

- #1 Turbulence Data
- #2 Realistic Test Conditions
- #3 Non-Intrusive Instrumentation
- #4 Redundant Measurements
- #5 Flow Structure and Physics

Each of these evaluation fields contains either a blank or one of three symbols:

- ✓ Acceptable
- X Not Acceptable
- ? No Determination Made

The question-mark symbol indicates that the necessary information to evaluate that category was lacking. In many cases, question marks or blanks in one or more evaluation fields also indicate that the evaluation was terminated after the candidate study failed one or more of the "necessary" criteria. Finally, a "comments" field provides additional information pertinent to the assessment.

Acronyms used in these tables and elsewhere in this report for brevity include:

APG - Adverse Pressure Gradient

CTHWA - Constant-Temperature Hot-Wire Anemometry

FPG - Favorable Pressure Gradient

LDV - Laser-Doppler Velocimeter

		NECESSARY CRITERIA								DESIRABLE CRITERIA					
REF NO	1st AUTHOR	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2	#3	#4	#5	ACCEPT?
1	Acharya	X													X
	Mach number too low.														
2	Beckwith	X			X										X
	Low-Re, transitional tunnel wall boundary layer.														
3	Boldman	✓	?		X										X
	Initial freestream conditions not well-defined (see FF Cat 6901).														
4	Brakmann (see Peake, et al)	✓	✓	✓	?	X	X	✓	✓						X
	See AGARDograph 253 Sec. 5.3.1 for discussion of inconsistencies.														
5	Bushnell	X			X										X
	Low-Re, transitional tunnel wall boundary layer.														
6	Chen							X							X
	Data not available.														
7	Delery	X													X
	Not a simple experimental geometry.														
8	Demetriades	✓	✓	✓	✓	X	✓	X	✓	?	X	X	?	✓	X
	No error analysis. Machine-readable data not available.														
9	Donovan	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X	X	✓	✓
10	Fernando	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X	X	X	✓

PART A - ATTACHED BOUNDARY-LAYERS IN PRESSURE GRADIENTS

		NECESSARY CRITERIA								DESIRABLE CRITERIA					
REF NO	1st AUTHOR	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2	#3	#4	#5	ACCEPT?
11	Fischer	X													X
	Low-Re, transitional tunnel wall boundary layer.														
12	Gootzait	✓	✓	✓	?	X	?	X	✓	✓	X	X	X	X	X
	Experiment does not meet present standards. Low Re, data not available.														
13	Hopkins	X													X
	Zero-pressure-gradient data.														
14	Horstman	X													X
	Mach number too low.														
15	Horstman	X													X
	Zero-pressure-gradient data.														
16	Hoydysh	✓	✓	✓	?	X	?	X	✓	X	X	X	X	X	X
	Experiment does not meet present standards. Data not available.														
17	Jayaram	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X	X	✓	✓
18	Kemp	X			X										X
	Low-Re, transitional tunnel wall boundary layer.														
19	Krestianinova							X							X
	Data not available.														
20	Laderman	✓	✓	✓	✓	✓	✓	✓	✓	X	X	X	X	X	✓

			NECESSARY CRITERIA							DESIRABLE CRITERIA					
REF NO	1st AUTHOR	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2	#3	#4	#5	ACCEPT?
21	Laderman	X													X
	Zero-pressure-gradient data.														
22	Lewis	✓	✓	✓	✓	✓	✓	✓	✓	X	X	X	X	X	✓
23	Nagamatsu							X							X
	Data not available.														
24	Rotta	X						X							X
	Data not applicable nor available.														
25	Smith	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X	X	✓	✓
26	Spina	X	✓		✓			✓		✓	X	✓		✓	X
	Zero-pressure-gradient data.														
27	Stroud	✓	✓	✓	X	X	?	✓	✓	X	X	X	X	X	X
	See Ferholz&Finley Cat 6503 for discussion of inconsistencies.														
28	Sturek	✓	✓	✓	✓	✓	✓	✓	✓	X	X	X	X	X	✓
29	Taylor	✓	✓	✓	✓	✓	✓	✓	✓	X	X	X	X	✓	✓
30	Thomann	?	✓	X	X	?	✓	✓	✓	X	X				X
	Heat transfer data only.														

		NECESSARY CRITERIA								DESIRABLE CRITERIA					
REF NO	1st AUTHOR	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2	#3	#4	#5	ACCEPT?
31	Thomas	X													X
	Mach number too low. 3-D effects ill-defined.														
32	Voisinet	X													X
	Transitional boundary layer.														
33	Voisinet		X				X								X
	Wall cooling rate overrides pressure gradient effects.														
34	Waltrup	X													X
	Mach number too low.														
35	Wang				?	X		X							X
	No error analysis. Data not available.														
36	Zakkay	✓	✓	✓	X	X	X	✓							X
	Experiment does not meet present standards														
37	Zakkay	✓	X												X
	Film-cooling experiment, not a simple-enough flow for present purposes.														
38	Zheltovodov	✓	✓	✓	✓	✓	✓	✓	✓	X	X	X	✓	✓	✓
	8-degree expansion corner at Mach 2.9 and 3.7. New data.														
39	Zwarts		✓	✓	X	X	?	?	✓	✓					X
	3-D effects ill-defined.														

		NECESSARY CRITERIA								DESIRABLE CRITERIA					
REF NO	1st AUTHOR	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2	#3	#4	#5	ACCEPT?
1	Abu-Hijleh	✓		X											X
	Backstep flow														
2	Alekseev	✓						X							X
	Data Not Available														
3	Barre	✓	✓	✓	✓	?	✓	X	✓	✓	X	X	X	✓	X
	Otherwise acceptable but data not available														
4	Bowman	✓	✓	✓	X	?	?	X	✓						X
	Insufficient data documentation available														
5	Chow	X													X
	Theoretical Study														
6	Chriss	✓		X											X
	Experiment does not meet current standards														
7	Clemens	✓		X											X
	No specific tabluated data														
8	Cohen	✓				X		X							X
	Data not available														
9	DeSocio	✓	✓	?				X							X
	Data and documentation not available														

PART B - SUPERSONIC TURBULENT MIXING LAYERS

		NECESSARY CRITERIA								DESIRABLE CRITERIA					
REF NO	1st AUTHOR	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2	#3	#4	#5	ACCEPT?
10	Dimotakis	✓		X											X
	No specific tabulated data														
11	Dolling	✓		X											X
	No specific tabulated data														
12	Durand	✓	X	X											X
	Base flow														
13	Eggers	✓	✓					X							X
	Data not available														
14	Eggers	✓	✓		X	X									X
	Experiment does not meet current standards														
15	Evans	✓	?	✓	?	?		X							X
	Data not available														
16	Fourgette	✓	✓	X											X
	No specific tabulated data														
17	Goebel	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	X	✓	✓
18	Gruber	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	X	✓	✓

		NECESSARY CRITERIA								DESIRABLE CRITERIA					
REF NO	1st AUTHOR	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2	#3	#4	#5	ACCEPT?
19	Harvey	✓		✓	?			X		✓	✓	✓	✓		X
	Data not available														
20	Hill	✓		X											X
	No specific tabulated data														
21	Ikawa	✓	✓	✓	✓	?	✓	X	✓						X
	Data not available														
22	Jarrett	✓	✓	✓	?	?	?	X	✓						X
	Data not available														
23	Jenkins	✓						X							X
	Data not available														
24	Kozlov	✓						X							X
	Data Not available														
25	Lau	✓	✓	X											X
	No specific tabulated data														
26	Maydew	✓	✓					X		X					X
	Data not available														
27	McIntyre	✓	✓	X											X
	No specific tabulated data														

		NECESSARY CRITERIA								DESIRABLE CRITERIA					
REF NO	1st AUTHOR	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2	#3	#4	#5	ACCEPT?
28	Murakami	✓						X							X
	Data not available														
29	Naughton	✓	✓	X											X
	No specific tabulated data														
30	Padova	✓	✓	✓	X										X
	Experiment does not meet current standards														
31	Papamoschou	✓	✓	?	✓	?	✓	X	✓	X	X	✓	?	✓	X
	Data not available														
32	Samimy	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	X	✓	✓
33	Samimy	✓													X
	No applicable data; see previous reference														
34	Schadow	✓	✓	X	X	?	?	X							X
	No applicable data available														
35	Sirieix	✓	✓	X											X
	No specific tabulated data														
36	Smoot	X													X
	Correlation based on previous data														

		NECESSARY CRITERIA								DESIRABLE CRITERIA					
REF NO	1st AUTHOR	#1	#2	#3	#4	#5	#6	#7	#8	#1	#2	#3	#4	#5	ACCEPT?
37	Sullins	✓			X			X							X
	Experiment not well-enough defined for present purposes														
38	Swanson	✓		✓	X	X		X							X
	Swirling flow not adequately defined														
39	Thomas	X													X
	Review of previous data														
40	Wagner	✓						X	✓	✓					X
	Data not available														
41	Walsh	X													X
	Not a simple mixing layer														
42	Wantuck	✓						X							X
	Data not available														
43	Woolley	✓						X							X
	Data not available														
44	Xu	✓						X							X
	Data not available														
45	Yu	✓	✓	✓	X	?		X	✓						X
	Sufficient data documentation not available														

Appendix C: Data Tabulation

There follows a tabulation of samples of the pertinent data from the 9 Part A and 3 Part B studies which make up the database. The standard format of these tabulations includes a brief summary of pertinent information with an "icon" sketch of the test geometry, a citation of one or more pertinent literature references, an abstract from the literature reference describing the study, and detailed notes on the such matters as the uniqueness of the experiment, contents of the data files, nomenclature, and assumptions inherent in the data reduction. This is followed by "sample output pages" which typically show the first printed page of each of the various types of data files provided. Some explanation of this approach is required, as follows.

It was once standard procedure to provide detailed printed tabulations of all the data in such a database for the benefit of the user who might have access only to the paper copy of the database report. In the present case such a tabulation is impractical, in that it would occupy several hundred pages. It is also unnecessary, in that machine-readable ASCII files of the entire database are included on two diskettes at the back of this report. Since such diskettes are easily readable and the data are directly usable by most current desktop microcomputers, we cannot imagine that anyone would wish to re-enter any significant portion of the present database by hand keying. The lengthy tabulation has thus been omitted.

The two 3.5" high-density diskettes bound with this report contain 12 subdirectories named for the first author of each of the 12 studies which make up the database. A complete listing of the subdirectories and the ASCII-format data files they contain is given below. Users of these data are urged to consult the original publications describing the database experiments for additional information beyond that which is provided here.

DATA FILE NAMES

DISKETTE "DATABASE_1"

Subdirectory DONOVAN

AGM.4SP	AGM.4-1	AGM.401	AGM.403
AGM.4CF	AGM.400	AGM.402	AGM.404
AGM.405	AGM.406	AGM.407	AGM.408
AGM.409	AGM.410	AGM4-.1HW	AGM40.6HW
AGM1.0HW	M4C.W-1	M4C.W04	M4C.W06
M4C.W08			

Subdirectory FERNANDO

NEWAGAR.DF1	NEWAGAR.DF2	NEWAGAR.DF3	NEW2AGAR.DF4
NEW2AGAR.DF5	NEW2AGAR.DF6	NEW2AGAR.DF7	NEW2AGAR.DF8

Subdirectory JAYARAM

JAYARAM1.DAT JAYARAM2.DAT JAYARAM3.DAT JAYARAM4.DAT

Subdirectory LADERMAN

LADERMAN.DAT

Subdirectory LEWIS

LEWIS.DAT

Subdirectory SMITH

AGFPM.401 AGFPM.402 AGFPM.403 AGFPM.404

Subdirectory STUREK

STUREK.DAT

DISKETTE "DATABASE_2"

Subdirectory TAYLOR

TAYLOR1.DAT	TAYLOR2.DAT	TAYLOR3.DAT	TAYLOR4.DAT

Subdirectory ZHELT

ZHELT2.DAT

Subdirectory DUTTON

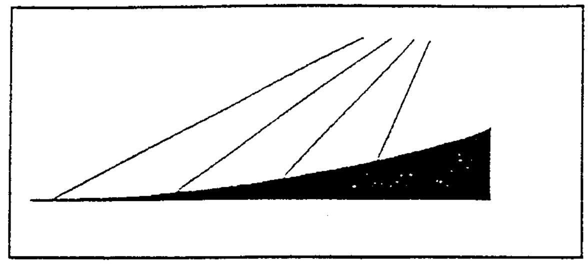
CASE.1	CASE.1D	CASE.2	CASE.3
CASE.3R	CASE.4	CASE.5	CASE.6

Subdirectory SAMIMY

MEANFLOW.PRN	ALLMCAVG.PRN	BLM2.PRN	BLM3.PRN
M5X60.PRN	M5X120.PRN	M5X150.PRN	M5X180.PRN
M5X210.PRN	M6X120.PRN	M6X150.PRN	M6X165.PRN
M6X180.PRN	M8X180.PRN	M8X210.PRN	M8X250.PRN

****

Ref.: 9
Authors: Donovan et al.
Geometry: Streamwise APG, curved ramp
Mach number: 3
Data: p_{wall}, c_f, mean-flow surveys,
CTHWA turbulence data
(normal & crossed wires)



Donovan, J. F., Ph.D. Thesis, Princeton University, Mechanical and Aerospace Engrg. Dept., 1989.

Donovan, J. F., Spina, E. F., and Smits, A. J., "The Structure of Supersonic Turbulent Boundary Layers Subjected to Concave Surface Curvature," to be published in *Journal of Fluid Mechanics*, 1993.

Donovan's data are too recent in the series of Princeton experiments to have been included in any of the previous AGARD tabulations. However, the experiments follow a logical path from the previously-reported work. Donovan's test model had the same 16° curved-ramp total turning angle as Taylor's (Ref. 29) Model 3, but a larger radius of curvature (0.35m vs. 0.127m). Donovan's results thus provide an additional test case, with both mean-flow and turbulence data, which is distinct from the earlier work of either Taylor or Jayaram (Ref. 17).

The following notes were provided with the data:

```
WIND TUNNEL:     8" x 8" supersonic blowdown wind tunnel. Upstream of the
                 interaction, the rms frestream mass-flow fluctuation level
                 is 1% of the mean freestream mass-flow rate. Details may
                 be found in "A Preliminary Report on the Princeton
                 University High-Reynolds Number 8" x 8" Supersonic Tunnel";
                 Internal Memo # 39, Gas Dynamics Laboratory, Department of
                 Aeronautical & Mechanical Sciences, Princeton University,
                 1971.

TEST MODEL:      The curved model was placed in the tunnel floor of second
                 section after nozzle. The model was 6" wide, allowing a 1"
                 gap on either side for the passage of the tunnel side-wall
                 boundary layer.  The model was fitted with fences to retain
                 two-dimensionality of the flow over the model.  The radius
                 of the curve was 0.35 meters giving a R/delta0 = 0.075.

UNITS:           All units are in SI ( kg, m, s, K ), except where indicated.

COORDINATE SYSTEM:  X, Y & Z form a Right Handed Coordinate system,
                    where:-
                      X is the streamwise coordinate, measured from the
                         start of curvature.
                        The maximum error in X is  +/-  0.0005
                      Y is measured normal to the test surface, with zero,
                        being on the test surface.
                        The maximum error in Y is  +/-  0.00012
                      Z is the spanwise co-ordinate, measured from the
                        tunnel center line. Z is measured positive to the
```

right, when looking downstream.
The maximum error in Z is +/- 0.0005

FILENAME	NOTES
AGM.4SP	-Surface pressure data from a SCANIVALVE survey. Note: X and Z cordinates are in inches, all other data is in SI units.
AGM.4CF	-Raw and reduced Preston tube data; Utau values from velocity profile fits to the log law using van Driest and Carvin et al. compressibility transformations. Preston tube diameter was 0.0016 meters.
AGM.4-1, AGM.400 to AGM.410	-Mean flow surveys taken along the centerline of the model. All surveys were performed normal to the model surface.

The static pressure is linearly interpolated to give the static pressure at each Y location of the pitot probe.

Total temperature is assumed to increase linearly by 4% towards the wall, across the boundary layer.

Pitot probe is built of flattened 0.000635 dia tubing. Probe tip height was0.00033 and the width was 0.00074. The opening was 0.00048 * 0.00008

Pwall was found from Pw/P0 taken from a previous SCANIVALVE survey of the surface pressures, and P0 during the pitot survey.

Tauw is from Preston probe pressure reduced using the Hopkins-Keener scheme.

Mref was found from the stagnation chamber pressure and the surface pressure one inch upstream of the start of curvature. 2.87 is used throughout this data compilation.

Uref is found for each survey using Mref, and T0 for the particular survey.

NOTE: The plots of the mean velocity profiles in semi-log coordinates reveal the presence of a systematic offset error in the original Y-position data. The Y coordinate measurements are believed to have an incorrect zero position. The changes that should be made to the values of the Y coordinates for each file are listed below. The data files as given do not have this correction. The values for Utau have been determined from the plots. All units are in SI.

FILE	CHANGE IN Y COORDINATES	Utau
AGM.4-1	- 0.0013	22.89
AGM.400	- 0.0013	22.30
AGM.401	- 0.0013	20.90
AGM.402	- 0.0013	18.97
AGM.403	- 0.0013	17.00
AGM.404	- 0.0007	16.40
AGM.405	- 0.0013	17.20
AGM.406	- 0.0013	17.80
AGM.407	- 0.0013	18.60
AGM.408	- 0.0013	18.70
AGM.409	- 0.0013	19.20
AGM.410	- 0.0013	19.20

Even after correcting for the Y coordinate error, the mean velocity profiles for some of the data files look questionable. The data points show unexpected deviations from the log-law near the wall. The data files in question are AGM.400, AGM.403, AGM.405, AGM.406 and AGM.410.

AGM4.1HW to AGM41.0HW	- Reduced data, from streamwise constant temperature normal hot-wire surveys & corresponding mean flow data. The hot wires had an active length of 0.0008 - 0.001, a wire diameter of 0.000005, a frequency response of 120 kHz and were operated at an overheat ratio of 0.8 . Data acquisition & reduction for hot-wires are reviewed in : Princeton University MAE reports #1619, 1620 ,1642 & in "Constant Temperature Hot-wire Anemometer practice in Supersonic Flows. Part I - The normal wire"; Experiments in Fluids, Vol. 1, 1983 pp 83-92.

All surveys were performed perpendicular to the model surface.

Hotwire data was reduced using the mean flow survey taken at the same location. The strong reynolds analogy was used with the density-velocity correlation = 0.8.

Mref is the same as in the mean surveys.

The reference density was calculated using Mref and the average PO and TO for the survey.

Tauw is from Preston probe pressure reduced using the Hopkins-Keener scheme.

Uref is found for each survey from Mref, and TO for the particular survey.

The data points of file AGM4.1HW are from channel 1 from 1.98mm to 26.3mm and then from channel 2 from 27.5mm to 29.5mm, however, all data points are from the same survey. This patchwork was done to extend the range of data in the Y direction.

M4C.W-1 M4C.W04 M4C.W06 M4C.W08	Reduced data from constant--temperature crossed--wire surveys. Each file contains 3 parts, streamwise, normal, and shear quantities.

Crossed--wire data was reduced as described in Donovan & Spina to be published in Physics of Fluids and is also described in Donovan's PhD thesis, Princeton University.

Physical wire characteristics are the same as those described for the normal wire studies.

High frequency symmetrical bridges were used for these surveys (DISA 55M12). Frequency responses were in the range of 130 kHz to 160 kHz (-3dB point).

NOMENCLATURE IN FILES:

P wall, PW	-- wall static pressure
TAU wall, TAUWALL	-- wall friction obtained from Preston surveys
PS, Ps	-- local static pressure
PT	-- local pitot pressure
U	-- local flow speed
M	-- local mach number
M ref	-- upstream freestream mach number
UREF	-- upstream freestream speed
RHO	-- local density
RHO ref	-- upstream freestream density
RHOU	-- local mass flux
<(rhou)">	-- rms of fluctuating mass flux
<u">	-- rms of fluctuating streamwise velocity
PO	-- tunnel stagnation pressure
TO	-- tunnel stagnation temperature
PREST	-- measured preston pressure
CF	-- skin friction coefficient

```
************************************
FILE AGM.4SP      DONOVAN & SMITS
************************************

SURFACE PRESSURE DATA
NO. OF POINTS =  36
PO = 0.6876E+06 275.8
3-JUL-86350MM RADIUS 16 DEG. MODEL
X               Z           PW
-1.000     0.0000E+000.2269E+05
-.5000     0.0000E+000.2253E+05
0.0000E+000.0000E+000.2296E+05
0.2500     0.0000E+000.2370E+05
0.5000     0.0000E+000.2490E+05
0.7500     0.0000E+000.2642E+05
 1.000     0.0000E+000.2818E+05
 1.250     0.0000E+000.2989E+05
 1.500     0.0000E+000.3169E+05
 1.750     0.0000E+000.3379E+05
 2.000     0.0000E+000.3662E+05
 2.250     0.0000E+000.3895E+05
 2.500     0.0000E+000.4161E+05
 2.750     0.0000E+000.4463E+05
 3.000     0.0000E+000.4781E+05
 3.250     0.0000E+000.5108E+05
 3.500     0.0000E+000.5583E+05
 3.750     0.0000E+000.5892E+05
 4.000     0.0000E+000.6133E+05
 4.250     0.0000E+000.6198E+05
 4.500     0.0000E+000.6333E+05
 4.750     0.0000E+000.6443E+05
 5.000     0.0000E+000.6451E+05
 5.250     0.0000E+000.6545E+05
 5.500     0.0000E+000.6503E+05
 5.750     0.0000E+000.6544E+05
 6.000     0.0000E+000.6557E+05
 6.500     0.0000E+000.6672E+05
 7.000     0.0000E+000.6767E+05
 7.500     0.0000E+000.6846E+05
 8.000     0.0000E+000.6857E+05
 8.500     0.0000E+000.6890E+05
 9.000     0.0000E+000.7035E+05
 9.500     0.0000E+000.6868E+05
 10.00     0.0000E+000.6801E+05
 10.50     0.0000E+000.6648E+05
```

****
FILE AGM.4CF DONOVAN & SMITS
****

STREAMWISE PRESTON PROBE DATA FOR MODEL 4

X(m)	Z	DIA	P0	T0	PREST	PWALL
-.2540E-01	0.0000E+00	0.1600E-02	0.6880E+06	281.1	0.7453E+05	0.2260E+05
0.0000E+00	0.0000E+00	0.1600E-02	0.6881E+06	278.7	0.7598E+05	0.2290E+05
0.2540E-01	0.0000E+00	0.1600E-02	0.6892E+06	279.3	0.8249E+05	0.2820E+05
0.5080E-01	0.0000E+00	0.1600E-02	0.6890E+06	280.9	0.9389E+05	0.3690E+05
0.7620E-01	0.0000E+00	0.1600E-02	0.6890E+06	282.5	0.1107E+06	0.4820E+05
0.1016	0.0000E+00	0.1600E-02	0.6885E+06	282.3	0.1378E+06	0.6180E+05
0.1270	0.0000E+00	0.1600E-02	0.6880E+06	283.0	0.1601E+06	0.6540E+05
0.1778	0.0000E+00	0.1600E-02	0.6883E+06	283.0	0.1855E+06	0.6720E+05
0.2032	0.0000E+00	0.1600E-02	0.6887E+06	285.3	0.1965E+06	0.6850E+05
0.2286	0.0000E+00	0.1600E-02	0.6763E+06	284.2	0.2023E+06	0.6900E+05

REDUCED STREAMWISE PRESTON TUBE DATA FOR MODEL 4
Bradshaw-Unsworth & Hopkins-Keener Preston probe calibration scheme

X(m)	Z	B-U-Tauw	H-K-T'-Tauw	H-K-Tw-Tauw	B-U-Utau	B-U-Cfref
-.2540E-01	0.0000E+00	145.4	155.3	170.0	23.24	0.1107E-02
0.0000E+00	0.0000E+00	147.4	157.7	172.7	23.15	0.1122E-02
0.2540E-01	0.0000E+00	156.4	161.0	175.7	21.51	0.1188E-02
0.5080E-01	0.0000E+00	170.6	169.6	184.1	19.69	0.1296E-02
0.7620E-01	0.0000E+00	188.1	184.4	199.1	18.15	0.1429E-02
0.1016	0.0000E+00	223.1	215.0	231.0	17.45	0.1697E-02
0.1270	0.0000E+00	262.8	252.4	270.9	18.43	0.2000E-02
0.1778	0.0000E+00	302.8	295.7	317.1	19.52	0.2303E-02
0.2032	0.0000E+00	319.4	315.3	337.9	19.93	0.2428E-02
0.2286	0.0000E+00	327.1	324.1	347.2	20.06	0.2532E-02

MODEL 4 STREAMWISE SKIN FRICTION VALUES FROM VANDRIEST TRANSFORM

X(IN)	TAUW	UTAU	rhoe ue**2/2
-1.0	147.0	22.9	1.28E+05
0.0	141.3	22.1	1.29E+05
1.0	148.4	20.6	1.28E+05
2.0	162.2	18.9	1.29E+05
3.0	169.2	16.9	1.50E+05
4.0	204.4	16.4	1.84E+05
5.0	229.9	17.0	2.14E+05
6.0	256.0	17.65	2.17E+05
7.0	278.9	18.4	2.18E+05
8.0	287.1	18.45	2.19E+05
9.0	308.1	18.95	2.21E+05
10.0	299.4	19.05	2.23E+05

MODEL 4 STREAMWISE SKIN FRICTION VALUES FROM CARVIN/SMITS TRANSFORM

X(IN)	TAUW	UTAU	rhoe ue**2/2
-1.0	140.6	22.4	1.28E 05
0.0	136.9	21.75	1.29E 05
1.0	147.0	20.5	1.28E 05
2.0	158.8	18.7	1.29E 05
3.0	165.3	16.7	1.50E 05
4.0	202.0	16.3	1.84E 05
5.0	227.2	16.9	2.14E 05
6.0	251.6	17.5	2.17E 05
7.0	272.9	18.2	2.18E 05
8.0	280.9	18.25	2.19E 05
9.0	301.6	18.75	2.21E 05
10.0	293.1	18.85	2.23E 05

****
FILE AGM.4-1   DONOVAN & SMITS
****

MEAN PROFILE TABULATION
CONCAVE CURVATURE MODEL 4, TURNING ANGLE = 16.0 DEG, RADIUS = .350 M

```
 X                     = -.2540E-01
 Z                     = 0.0000E+00
 Stagnation Pressure   = 0.6912E+06
 Stagnation Temperature=  273.4
 M ref                 =  2.870
 U ref                 =  584.9
 P wall                = 0.2289E+05
 TAU wall              =  146.9
```

Y	PT/PWALL	PS/PWALL	U/UREF	M
0.1800E-03	1.603	0.9882	0.4642	0.8604
0.4178E-03	2.122	0.9882	0.5723	1.104
0.6594E-03	2.720	0.9882	0.6545	1.313
0.9020E-03	3.097	0.9838	0.6949	1.427
0.1139E-02	3.323	0.9860	0.7152	1.487
0.1387E-02	3.532	0.9834	0.7349	1.547
0.1629E-02	3.689	0.9821	0.7482	1.589
0.1863E-02	3.826	0.9803	0.7590	1.625
0.2111E-02	3.986	0.9786	0.7706	1.664
0.2352E-02	4.112	0.9790	0.7800	1.696
0.2582E-02	4.249	0.9803	0.7881	1.724
0.3085E-02	4.439	0.9860	0.7988	1.763
0.3572E-02	4.657	0.9865	0.8117	1.811
0.4058E-02	4.806	0.9795	0.8228	1.853
0.4543E-02	4.989	0.9725	0.8335	1.896
0.5022E-02	5.151	0.9677	0.8440	1.938
0.5497E-02	5.308	0.9637	0.8525	1.974
0.5977E-02	5.439	0.9616	0.8590	2.002
0.6460E-02	5.561	0.9602	0.8653	2.030
0.6941E-02	5.745	0.9589	0.8734	2.066
0.7429E-02	5.841	0.9581	0.8778	2.087
0.8391E-02	6.173	0.9559	0.8913	2.151
0.9383E-02	6.479	0.9559	0.9042	2.214
0.1034E-01	6.763	0.9559	0.9136	2.264
0.1129E-01	7.064	0.9572	0.9228	2.313
0.1226E-01	7.383	0.9598	0.9315	2.363
0.1324E-01	7.720	0.9629	0.9413	2.420
0.1421E-01	8.056	0.9659	0.9495	2.469
0.1518E-01	8.292	0.9685	0.9549	2.505
0.1613E-01	8.615	0.9694	0.9626	2.554
0.1710E-01	8.973	0.9699	0.9710	2.611
0.1808E-01	9.257	0.9685	0.9770	2.653
0.1904E-01	9.528	0.9659	0.9838	2.703
0.2001E-01	9.799	0.9633	0.9895	2.745
0.2098E-01	10.00	0.9598	0.9937	2.781
0.2196E-01	10.20	0.9567	0.9980	2.816
0.2293E-01	10.37	0.9546	1.001	2.844
0.2388E-01	10.50	0.9524	1.003	2.866
0.2484E-01	10.60	0.9515	1.005	2.880
0.2578E-01	10.65	0.9506	1.005	2.887
0.2675E-01	10.69	0.9498	1.005	2.894
0.2869E-01	10.75	0.9463	1.006	2.908
0.3064E-01	10.74	0.9436	1.005	2.908
0.3257E-01	10.76	0.9441	1.006	2.915

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FILE AGM4.1HW DONOVAN & SMITS
****

NORMAL WIRE PROFILE TABULATION, SURVEYS ARE PERPENDICULAR TO THE MODEL SURF
CONCAVE CURVATURE MODEL 4, TURNING ANGLE = 16.0 DEG, RADIUS = .350 M

X	= -.6350E-01
Z	= 0.0000E+00
M ref	= 2.870
U ref hw	= 578.1
RHO ref hw	= 0.7892
TAU wall preston	= 146.9
P wall mean flow	= 0.2289E+05

Y	<(rhou)"> RHOU	U Uref	M	Ps Pwall	<u">**2 U**2	RHO<u">**2 RHOref Uref**2
0.1980E-02	0.1995	0.7645	1.643	0.9795	0.1022E-01	0.3284E-02
0.2747E-02	0.1608	0.7916	1.737	0.9822	0.5895E-02	0.2122E-02
0.3693E-02	0.1565	0.8145	1.821	0.9848	0.5014E-02	0.1994E-02
0.4546E-02	0.1574	0.8336	1.896	0.9725	0.4613E-02	0.1965E-02
0.5135E-02	0.1554	0.8460	1.947	0.9667	0.4220E-02	0.1882E-02
0.5508E-02	0.1524	0.8526	1.975	0.9637	0.3918E-02	0.1792E-02
0.6164E-02	0.1469	0.8614	2.013	0.9611	0.3470E-02	0.1645E-02
0.6594E-02	0.1511	0.8676	2.040	0.9598	0.3548E-02	0.1725E-02
0.7452E-02	0.1478	0.8781	2.089	0.9580	0.3196E-02	0.1628E-02
0.7887E-02	0.1481	0.8842	2.117	0.9571	0.3095E-02	0.1619E-02
0.8331E-02	0.1471	0.8905	2.147	0.9560	0.2944E-02	0.1581E-02
0.9327E-02	0.1472	0.9035	2.210	0.9559	0.2727E-02	0.1547E-02
0.1013E-01	0.1449	0.9115	2.253	0.9559	0.2508E-02	0.1476E-02
0.1100E-01	0.1473	0.9200	2.298	0.9568	0.2454E-02	0.1504E-02
0.1181E-01	0.1453	0.9275	2.340	0.9586	0.2270E-02	0.1442E-02
0.1251E-01	0.1479	0.9340	2.378	0.9606	0.2248E-02	0.1473E-02
0.1339E-01	0.1472	0.9426	2.428	0.9634	0.2098E-02	0.1436E-02
0.1440E-01	0.1442	0.9506	2.476	0.9664	0.1901E-02	0.1355E-02
0.1535E-01	0.1404	0.9563	2.514	0.9687	0.1724E-02	0.1266E-02
0.1637E-01	0.1396	0.9647	2.568	0.9695	0.1600E-02	0.1226E-02
0.1739E-01	0.1367	0.9728	2.623	0.9695	0.1439E-02	0.1149E-02
0.1840E-01	0.1326	0.9793	2.670	0.9676	0.1284E-02	0.1059E-02
0.1935E-01	0.1241	0.9856	2.716	0.9651	0.1067E-02	0.9067E-03
0.2029E-01	0.1193	0.9907	2.755	0.9623	0.9437E-03	0.8213E-03
0.2130E-01	0.1069	0.9951	2.792	0.9588	0.7270E-03	0.6467E-03
0.2233E-01	0.1008	0.9991	2.827	0.9559	0.6223E-03	0.5651E-03
0.2328E-01	0.8084E-01	1.002	2.852	0.9538	0.3891E-03	0.3583E-03
0.2430E-01	0.7629E-01	1.004	2.872	0.9520	0.3390E-03	0.3157E-03
0.2531E-01	0.6215E-01	1.005	2.884	0.9510	0.2222E-03	0.2079E-03
0.2632E-01	0.5666E-01	1.005	2.891	0.9502	0.1832E-03	0.1715E-03
0.2748E-01	0.3784E-01	1.005	2.899	0.9485	0.8097E-04	0.7653E-04
0.2849E-01	0.2697E-01	1.006	2.907	0.9467	0.4080E-04	0.3861E-04
0.2950E-01	0.2412E-01	1.006	2.908	0.9452	0.3259E-04	0.3071E-04

****
FILE M4C.W-1   DONOVAN & SMITS
****

(SAMPLE OUTPUT PAGE)

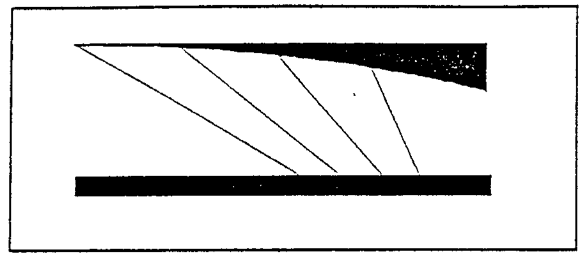
CROSSED-WIRE PROFILE TABULATION
DATA TABULATION FOR 350MM R CURVED MODEL 16 DEGREE TURNING

X	= -.0254E+00
Z	= 0.0000E+00
M ref	= 2.860
U ref hw	= 568.9
RHO ref hw	= 0.8164
TAU wall preston	=
P wall mean flow	= 0.2269E+05

Y	<(rhou)"> RHOU	U Uref	M	Ps Pwall	<u">**2 U**2	RHO<u">**2 RHOref Uref**2
0.1980E-02	0.1254	0.7655	1.643	0.9526	0.4037E-02	0.1285E-02
0.3080E-02	0.1540	0.7998	1.763	0.9601	0.5232E-02	0.1929E-02
0.4420E-02	0.1653	0.8319	1.885	0.9503	0.5161E-02	0.2150E-02
0.5764E-02	0.1617	0.8573	1.990	0.9406	0.4329E-02	0.1985E-02
0.7103E-02	0.1562	0.8760	2.073	0.9384	0.3639E-02	0.1804E-02
0.8467E-02	0.1544	0.8935	2.156	0.9374	0.3208E-02	0.1715E-02
0.9834E-02	0.1573	0.9098	2.238	0.9391	0.3012E-02	0.1735E-02
0.1116E-01	0.1569	0.9227	2.306	0.9420	0.2756E-02	0.1690E-02
0.1249E-01	0.1535	0.9350	2.376	0.9470	0.2425E-02	0.1583E-02
0.1381E-01	0.1464	0.9473	2.449	0.9527	0.2024E-02	0.1409E-02
0.1519E-01	0.1400	0.9563	2.506	0.9580	0.1731E-02	0.1267E-02
0.1654E-01	0.1398	0.9674	2.578	0.9610	0.1586E-02	0.1231E-02
0.1791E-01	0.1307	0.9772	2.646	0.9620	0.1283E-02	0.1047E-02
0.1926E-01	0.1194	0.9864	2.713	0.9599	0.9920E-03	0.8480E-03
0.2062E-01	0.1069	0.9935	2.768	0.9573	0.7474E-03	0.6621E-03
0.2200E-01	0.1043	0.9995	2.817	0.9550	0.6733E-03	0.6154E-03
0.2337E-01	0.8397E-01	1.004	2.854	0.9535	0.4189E-03	0.3917E-03
0.2470E-01	0.6774E-01	1.006	2.878	0.9531	0.2656E-03	0.2519E-03
0.2606E-01	0.5288E-01	1.006	2.889	0.9536	0.1599E-03	0.1527E-03
0.2744E-01	0.4897E-01	1.007	2.899	0.9537	0.1356E-03	0.1302E-03
0.2882E-01	0.3445E-01	1.007	2.908	0.9530	0.6647E-04	0.6404E-04
0.3019E-01	0.1775E-01	1.007	2.908	0.9522	0.1765E-04	0.1697E-04
0.3155E-01	0.1402E-01	1.007	2.911	0.9522	0.1097E-04	0.1057E-04
0.3291E-01	0.1096E-01	1.007	2.915	0.9523	0.6677E-05	0.6448E-05
0.3418E-01	0.1100E-01	1.007	2.915	0.9523	0.6726E-05	0.6495E-05
0.3548E-01	0.9119E-02	1.007	2.915	0.9523	0.4622E-05	0.4464E-05
0.3679E-01	0.1055E-01	1.007	2.915	0.9523	0.6187E-05	0.5975E-05
0.3807E-01	0.8835E-02	1.007	2.915	0.9523	0.4339E-05	0.4190E-05
0.3917E-01	0.9298E-02	1.007	2.915	0.9523	0.4805E-05	0.4641E-05
0.3919E-01	0.8861E-02	1.007	2.915	0.9523	0.4364E-05	0.4215E-05

Y	<v"> U	U Uref	M	Ps Pwall	<v">**2 U**2	RHO<v">**2 RHOref Uref**2
0.1980E-02	0.3629E-01	0.7655	1.643	0.9526	0.1317E-02	0.4193E-03
0.3080E-02	0.3745E-01	0.7998	1.763	0.9601	0.1403E-02	0.5171E-03
0.4420E-02	0.3731E-01	0.8319	1.885	0.9503	0.1392E-02	0.5800E-03
0.5764E-02	0.3677E-01	0.8573	1.990	0.9406	0.1352E-02	0.6201E-03
0.7103E-02	0.3599E-01	0.8760	2.073	0.9384	0.1295E-02	0.6422E-03
0.8467E-02	0.3498E-01	0.8935	2.156	0.9374	0.1224E-02	0.6542E-03
0.9834E-02	0.3510E-01	0.9098	2.238	0.9391	0.1232E-02	0.7097E-03
0.1116E-01	0.3334E-01	0.9227	2.306	0.9420	0.1112E-02	0.6813E-03
0.1249E-01	0.3350E-01	0.9350	2.376	0.9470	0.1122E-02	0.7327E-03
0.1381E-01	0.3196E-01	0.9473	2.449	0.9527	0.1021E-02	0.7113E-03
0.1519E-01	0.3026E-01	0.9563	2.506	0.9580	0.9157E-03	0.6700E-03
0.1654E-01	0.2840E-01	0.9674	2.578	0.9610	0.8066E-03	0.6258E-03
0.1791E-01	0.2779E-01	0.9772	2.646	0.9620	0.7723E-03	0.6306E-03
0.1926E-01	0.2462E-01	0.9864	2.713	0.9599	0.6061E-03	0.5181E-03
0.2062E-01	0.2288E-01	0.9935	2.768	0.9573	0.5235E-03	0.4638E-03
0.2200E-01	0.2177E-01	0.9995	2.817	0.9550	0.4739E-03	0.4332E-03
0.2337E-01	0.1756E-01	1.004	2.854	0.9535	0.3084E-03	0.2883E-03
0.2470E-01	0.1418E-01	1.006	2.878	0.9531	0.2011E-03	0.1907E-03

Ref.: 10
Authors: Fernando and Smits
Geometry: Streamwise APG, flat test surface
Mach number: 3
Data: p_{wall}, c_f, mean-flow profiles,
CTHWA turbulence data



Fernando, E. M. and Smits, A. J., "A Supersonic Turbulent Boundary Layer in an Adverse Pressure Gradient," *Journal of Fluid Mechanics*, 1990, Vol. 211, pp. 285-307.

ABSTRACT (from Ref. 10) This investigation describes the effects of an adverse pressure gradient on a flat plate supersonic turbulent boundary layer. Single normal hot wires and crossed wires were used to study the Reynolds stress behavior, and the features of the large-scale structures in the boundary layer were investigated by measuring space-time correlations in the normal and spanwise directions. Both the mean flow and the turbulence were strongly affected by the pressure gradient. However, the turbulent stress ratios showed much less variation than the stresses, and the essential nature of the large-scale structures was unaffected by the pressure gradient. The addition of streamline curvature affects the turbulence strongly, although its infuence on the mean velocity field is less pronounced and the modifications to the skin-friction distribution seem to follow the empirical correlations developed by Bradshaw.

This dataset is thoroughly documented in AGARDograph 315 under catalog entry 8601T. Users are directed to that reference for further details concerning the dataset. In addition, the following brief description of the experiment and the data files was provided by D. R. Smith of the Princeton University Gas Dynamics Laboratory:

```
WIND TUNNEL:      8" x 8" supersonic blowdown wind tunnel. Upstream of the
                  pressure gradient, the rms frestream mass-flow fluctuation
                  level is 2% of the mean freestream mass-flow rate. Details may
                  be found in "A Preliminary Report on the Princeton
                  University High-Reynolds Number 8" x 8" Supersonic Tunnel";
                  Internal Memo # 39, Gas Dynamics Laboratory, Department of
                  Aeronautical & Mechanical Sciences, Princeton University,
                  1971.

TEST MODEL:       Tunnel floor of second section after nozzle. An adverse
                  pressure gradient is imposed on the tunnel floor b/l by a
                  contoured plate in the freestream. The plate spans the
                  entire width of the tunnel.

UNITS:            All units are in SI ( kg, m, s, K ).

COORDINATE SYSTEM:   X, Y & Z form a Right Handed Coordinate system,
                     where:-
                        X is the streamwise coordinate, measured from the
                          nozzle exit.
                          The maximum error in X is  +/-  0.0005
```

Y is measured normal to the test surface, with zero being on the test surface.
The maximum error in Y is +/- 0.00012
Z is the spanwise co-ordinate, measured from the tunnel center line. Z is measured positive to the right, when looking downstream.
The maximum error in Z is +/- 0.0005

FILENAME	NOTES
NEWAGAR.DF1-	Tunnel floor static pressure distribution. 3 separate data sets are given
NEWAGAR.DF2-	Streamwise vertical total temperature surveys on tunnel center line, using an exposed thermocouple junction. The recovery factor varied between 0.9230 & 0.9180, the exact value being chosen so that stagnation temperature is reached in the freestream.
NEWAGAR.DF3	Streamwise & Spanwise vertical static pressure surveys. Probe diameter is 0.00084. It has a conical tip & two diametrically opposite holes (0.00015 dia) 0.0079 downstream of the tip, as static pressure orifices.
NEW2AGAR.DF4-	Streamwise & Spanwise vertical pitot pressure surveys. Also contains reduced mean flow data from pitot, static pressure & assumed total temperature distribution in boundary layer. The static pressure is linearly interpolated to give the static pressure at each Y of the pitot probe. Total temperature is assumed to increase linearly by 4% towards the wall, across the boundary layer. This seems reasonable, based on the data in file NEWAGARDF2 . Pitot probe is built of flattened 0.000635 dia tubing. Probe tip height was0.00033 and the width was 0.00074. The opening was 0.00048 * 0.00008
NEW2AGAR.DF5-	Reduced data, from streamwise vertical constant temperature normal hot-wire surveys & corresponding mean flow data. Further details may be found in "Supersonic turbulent boundary layer in an adverse pressure gradient," by E. M. Fernando. Ph.D. thesis, MAE dept., Princeton University.
NEW2AGAR.DF6-	Streamwise & spanwise preston probe measurements & reduced data. Preston probe diameter is 0.001651 .
NEW2AGAR.DF7-	Reduced data, from streamwise vertical constant temperature crossed-wire surveys & corresponding mean flow data. Further details may be found in "Supersonic turbulent boundary layer in an adverse pressure gradient," by E. M. Fernando. Ph.D. thesis, MAE dept., Princeton University.
NEW2AGAR.DF8-	Boundary layer integral parameters and wall friction from Clauser chart methods. Further details may be found in "Supersonic turbulent boundary layer in an adverse pressure gradient," by E. M. Fernando. Ph.D. thesis, MAE dept., Princeton University.

NOMENCLATURE IN FILES:

P wall, PW	-- wall static pressure
TAU wall, TAUWALL	-- wall friction obtained from Preston surveys
PS, Ps	-- local static pressure
PT	-- local pitot pressure
U	-- local flow speed
M	-- local mach number
M ref	-- upstream freestream mach number
UREF	-- upstream freestream speed

RHO	-- local density
RHO ref	-- upstream freestream density
RHOU	-- local mass flux
<(rhou)">	-- rms of fluctuating mass flux
<u">	-- rms of fluctuating streamwise velocity
P0	-- tunnel stagnation pressure
T0	-- tunnel stagnation temperature
PREST	-- measured preston pressure
CF	-- skin friction coefficient

COMMENTS:

1) For the pitot surveys, static pressure surveys, preston surveys & hot wire surveys the wall pressure was not obtained during the data runs. Instead the wall pressure from previously conducted SCANNIVALVE surveys (in NEWAGARDF1) was directly used.

2) The hot wire data was reduced using the mean flow profile at the closest x,z location. Where the distance between these 2 surveys was judged to be too large the hot-wire data was not reduced using the mean flow profile. There is one such data set (x=1.145).

3) To calculate 'RHO ref hw' for the hot-wire data sets, P0 is required. This P0 was taken to be 0.69E+06 (nominal tunnel stagnation pressure) This together with MREF and measured 'T0 hw' was used to determine 'RHO ref hw'.

4) MREF was taken to be 2.916, based on upstream wall pressure and tunnel stagnation pressure.

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FILE NEWAGAR.DF1       FERNANDO & SMITS
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(SAMPLE PRINTOUT PAGE)

SURFACE PRESSURE DISTRIBUTION ON TUNNEL FLOOR
AVERAGE STAGNATION PRESSURE = 0.6884E+06
AVERAGE STAGNATION TEMPERATURE = 278.3
NUMBER OF DATA POINTS = 187

X	Z	Wall Static Pressure
0.9431	0.2540E-01	0.2145E+05
0.9987	0.2540E-01	0.2240E+05
1.011	0.2540E-01	0.2215E+05
1.024	0.2540E-01	0.2232E+05
1.037	0.2540E-01	0.2279E+05
1.043	0.2540E-01	0.2252E+05
1.049	0.2540E-01	0.2481E+05
1.056	0.2540E-01	0.2593E+05
1.062	0.2540E-01	0.2606E+05
1.068	0.2540E-01	0.2663E+05
1.075	0.2540E-01	0.2561E+05
1.081	0.2540E-01	0.2578E+05
1.088	0.2540E-01	0.2631E+05
1.094	0.2540E-01	0.2643E+05
1.100	0.2540E-01	0.2758E+05
1.107	0.2540E-01	0.2790E+05
1.113	0.2540E-01	0.2813E+05
1.119	0.2540E-01	0.2853E+05
1.126	0.2540E-01	0.2940E+05
1.131	0.2540E-01	0.2945E+05
1.136	0.2540E-01	0.3067E+05
1.141	0.2540E-01	0.3079E+05
1.146	0.2540E-01	0.3132E+05
1.151	0.2540E-01	0.3104E+05
1.159	0.2540E-01	0.3179E+05
1.165	0.2540E-01	0.3291E+05
1.172	0.2540E-01	0.3259E+05
1.178	0.2540E-01	0.3314E+05
1.184	0.2540E-01	0.3488E+05
1.191	0.2540E-01	0.3583E+05
1.197	0.2540E-01	0.3732E+05
1.203	0.2540E-01	0.3852E+05
1.210	0.2540E-01	0.3770E+05
1.216	0.2540E-01	0.3812E+05
1.222	0.2540E-01	0.4084E+05
1.229	0.2540E-01	0.4251E+05
1.242	0.2540E-01	0.4553E+05
1.254	0.2540E-01	0.4381E+05
1.273	0.2540E-01	0.4291E+05
1.292	0.2540E-01	0.4341E+05
1.311	0.2540E-01	0.4376E+05
1.432	0.0000E+00	0.3997E+05
1.413	0.0000E+00	0.4049E+05
1.394	0.0000E+00	0.4029E+05
1.375	0.0000E+00	0.4161E+05
1.356	0.0000E+00	0.3947E+05
1.337	0.0000E+00	0.4004E+05
1.318	0.0000E+00	0.4156E+05
1.305	0.0000E+00	0.4133E+05
1.292	0.0000E+00	0.4366E+05
1.286	0.0000E+00	0.4305E+05
1.280	0.0000E+00	0.4382E+05
1.273	0.0000E+00	0.4380E+05
1.267	0.0000E+00	0.4157E+05
1.261	0.0000E+00	0.4243E+05
1.254	0.0000E+00	0.4294E+05
1.248	0.0000E+00	0.4296E+05
1.229	0.0000E+00	0.4113E+05
1.222	0.0000E+00	0.3940E+05
1.216	0.0000E+00	0.3775E+05
1.210	0.0000E+00	0.3735E+05
1.197	0.0000E+00	0.3598E+05

****
FILE NEWAGAR.DF2   FERNANDO & SMITS
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(SAMPLE PRINTOUT PAGE)

```
TOTAL TEMPERATURE SURVEYS
X                              = 1.147
Z                              = 0.0000E+00
AVERAGE STAGNATION PRESSURE    = 0.6885E+06
AVERAGE STAGNATION TEMPERATURE =  266.9
NUMBER OF DATA POINTS          =         52
     Y         Total Temperature/Stagnation Temperature
0.8255E-03      1.047
0.1009E-02      1.047
0.1249E-02      1.046
0.1385E-02      1.044
0.1609E-02      1.044
0.1809E-02      1.042
0.2033E-02      1.044
0.2257E-02      1.042
0.2449E-02      1.043
0.2641E-02      1.042
0.2833E-02      1.043
0.3185E-02      1.041
0.3576E-02      1.041
0.4120E-02      1.038
0.4488E-02      1.037
0.4856E-02      1.036
0.5160E-02      1.036
0.5608E-02      1.036
0.6072E-02      1.034
0.6447E-02      1.032
0.6839E-02      1.033
0.7663E-02      1.032
0.8367E-02      1.031
0.9278E-02      1.029
0.1001E-01      1.029
0.1088E-01      1.028
0.1170E-01      1.027
0.1240E-01      1.027
0.1332E-01      1.025
0.1402E-01      1.024
0.1488E-01      1.023
0.1576E-01      1.021
0.1639E-01      1.023
0.1729E-01      1.018
0.1800E-01      1.019
0.1887E-01      1.017
0.1971E-01      1.013
0.2047E-01      1.016
0.2134E-01      1.013
0.2203E-01      1.011
0.2293E-01      1.008
0.2445E-01      1.010
0.2618E-01      1.005
0.2766E-01      1.005
0.2926E-01      1.004
0.3079E-01      1.002
0.3230E-01      1.003
0.3395E-01      1.004
0.3548E-01      1.001
0.3712E-01      1.002
0.3881E-01      1.002
0.4031E-01      1.000
TOTAL TEMPERATURE SURVEYS
X                              = 1.147
Z                              = 0.0000E+00
AVERAGE STAGNATION PRESSURE    = 0.6881E+06
AVERAGE STAGNATION TEMPERATURE =  262.0
NUMBER OF DATA POINTS          =         51
     Y         Total Temperature/Stagnation Temperature
0.8255E-03      1.052
0.1073E-02      1.051
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*****************************************
FILE NEWAGAR.DF3     FERNANDO & SMITS
*****************************************
                                                (SAMPLE PRINTOUT PAGE)

 STATIC PRESSURE SURVEYS
 X                              = 1.149
 Z                              = 0.0000E+00
 AVERAGE STAGNATION PRESSURE    = 0.6889E+06
 AVERAGE STAGNATION TEMPERATURE =  261.7
 NUMBER OF DATA POINTS          =           52
      Y          Static Pressure
 0.1313E-02      0.3050E+05
 0.1489E-02      0.3038E+05
 0.1858E-02      0.3021E+05
 0.1874E-02      0.3022E+05
 0.2170E-02      0.3003E+05
 0.2386E-02      0.2982E+05
 0.2474E-02      0.2954E+05
 0.2875E-02      0.2924E+05
 0.2835E-02      0.2917E+05
 0.3203E-02      0.2884E+05
 0.3371E-02      0.2862E+05
 0.3836E-02      0.2854E+05
 0.4228E-02      0.2865E+05
 0.4509E-02      0.2882E+05
 0.4885E-02      0.2907E+05
 0.5350E-02      0.2932E+05
 0.5846E-02      0.2958E+05
 0.6223E-02      0.2976E+05
 0.6631E-02      0.2992E+05
 0.6983E-02      0.3013E+05
 0.7288E-02      0.3021E+05
 0.8217E-02      0.3030E+05
 0.8898E-02      0.3056E+05
 0.9747E-02      0.3062E+05
 0.1065E-01      0.3054E+05
 0.1126E-01      0.3051E+05
 0.1223E-01      0.3054E+05
 0.1295E-01      0.3055E+05
 0.1380E-01      0.3049E+05
 0.1468E-01      0.3034E+05
 0.1531E-01      0.3046E+05
 0.1627E-01      0.3045E+05
 0.1699E-01      0.3051E+05
 0.1778E-01      0.3049E+05
 0.1849E-01      0.3057E+05
 0.1941E-01      0.3049E+05
 0.2031E-01      0.3073E+05
 0.2099E-01      0.3079E+05
 0.2178E-01      0.3097E+05
 0.2258E-01      0.3106E+05
 0.2350E-01      0.3103E+05
 0.2509E-01      0.3108E+05
 0.2672E-01      0.3158E+05
 0.2829E-01      0.3176E+05
 0.2992E-01      0.3254E+05
 0.3132E-01      0.3314E+05
 0.3301E-01      0.3367E+05
 0.3461E-01      0.3389E+05
 0.3617E-01      0.3351E+05
 0.3776E-01      0.3323E+05
 0.3937E-01      0.3343E+05
 0.4096E-01      0.3338E+05
 STATIC PRESSURE SURVEYS
 X                              = 1.172
 Z                              = 0.0000E+00
 AVERAGE STAGNATION PRESSURE    = 0.6883E+06
 AVERAGE STAGNATION TEMPERATURE =  263.8
 NUMBER OF DATA POINTS          =           52
      Y          Static Pressure
 0.1413E-02      0.3229E+05
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*****************************************
FILE NEWA2GAR.DF4     FERNANDO & SMITS
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(SAMPLE PRINTOUT PAGE)

MEAN PROFILE TABULATION
PITOT SURVEY DATA

X		= 1.000
Z		= 0.0000E+00
Stagnation Pressure	pitot	= 0.6917E+06
Stagnation Temperature	pitot	= 270.6
M ref		= 2.916
U ref	pitot	= 585.3
P wall		= 0.2192E+05
TAU wall	Preston	= 133.3

Y	PT/PWALL	PS/PWALL	U/UREF	M
0.5950E-03	3.006	1.000	0.6774	1.388
0.7726E-03	3.041	0.9983	0.6810	1.398
0.9719E-03	3.222	0.9983	0.6993	1.451
0.1215E-02	3.379	0.9992	0.7121	1.490
0.1400E-02	3.578	0.9992	0.7293	1.543
0.1519E-02	3.659	0.9992	0.7360	1.565
0.1773E-02	3.777	0.9983	0.7449	1.593
0.1987E-02	3.954	0.9973	0.7587	1.639
0.2121E-02	4.057	0.9926	0.7671	1.667
0.2306E-02	4.186	0.9945	0.7753	1.696
0.2450E-02	4.336	0.9945	0.7854	1.731
0.2900E-02	4.421	0.9992	0.7891	1.745
0.3288E-02	4.561	1.004	0.7973	1.775
0.3733E-02	4.763	1.000	0.8088	1.818
0.4103E-02	4.895	0.9992	0.8160	1.846
0.4462E-02	5.041	0.9983	0.8250	1.881
0.4853E-02	5.196	0.9954	0.8337	1.917
0.5252E-02	5.424	0.9935	0.8459	1.966
0.5611E-02	5.511	0.9945	0.8491	1.981
0.6027E-02	5.680	0.9916	0.8571	2.016
0.6383E-02	5.721	0.9907	0.8587	2.023
0.7194E-02	6.127	0.9916	0.8759	2.101
0.7915E-02	6.232	0.9897	0.8802	2.122
0.8680E-02	6.574	0.9868	0.8949	2.193
0.9456E-02	6.784	0.9849	0.9017	2.228
0.1023E-01	7.021	0.9821	0.9111	2.278
0.1103E-01	7.281	0.9811	0.9188	2.320
0.1182E-01	7.568	0.9811	0.9277	2.370
0.1253E-01	7.801	0.9783	0.9349	2.412
0.1332E-01	8.107	0.9792	0.9432	2.462
0.1410E-01	8.367	0.9764	0.9499	2.505
0.1490E-01	8.631	0.9754	0.9566	2.547
0.1562E-01	8.796	0.9754	0.9607	2.575
0.1638E-01	9.128	0.9735	0.9690	2.632
0.1714E-01	9.385	0.9716	0.9750	2.674
0.1799E-01	9.564	0.9716	0.9776	2.696
0.1875E-01	9.926	0.9726	0.9854	2.752
0.1950E-01	10.24	0.9735	0.9909	2.795
0.2026E-01	10.24	0.9764	0.9894	2.788
0.2099E-01	10.51	0.9783	0.9938	2.823
0.2181E-01	10.61	0.9830	0.9941	2.830
0.2335E-01	10.78	0.9821	0.9969	2.859
0.2483E-01	10.96	0.9821	0.9988	2.880
0.2639E-01	11.05	0.9830	0.9996	2.894
0.2796E-01	11.17	0.9821	1.000	2.908
0.2950E-01	11.15	0.9802	0.9993	2.908
0.3100E-01	11.19	0.9830	0.9989	2.908
0.3253E-01	11.15	0.9859	0.9981	2.901
0.3408E-01	11.15	0.9840	0.9989	2.908

MEAN PROFILE TABULATION
PITOT SURVEY DATA

X	= 1.064
Z	= 0.0000E+00

****
FILE NEWA2GAR.DF5 FERNANDO & SMITS
****

(SAMPLE PRINTOUT PAGE)

NORMAL WIRE PROFILE TABULATION
X = 1.000
Z = 0.0000E+00
M ref = 2.916
U ref hw = 586.9
RHO ref hw = 0.7366
TAU wall preston = 133.3
P wall mean flow = 0.2192E+05

Y	<(rhou)"> RHOU	U Uref	M	Ps Pwall	<u">**2 U**2	RHO<u">**2 RHOref Uref**2
0.6900E-03	0.2249	0.6793	1.393	0.9992	0.1778E-01	0.4170E-02
0.1366E-02	0.1972	0.7261	1.533	0.9992	0.1148E-01	0.3260E-02
0.2197E-02	0.1689	0.7705	1.679	0.9935	0.7000E-02	0.2370E-02
0.3024E-02	0.1570	0.7917	1.755	1.001	0.5494E-02	0.2047E-02
0.3851E-02	0.1524	0.8111	1.827	1.000	0.4722E-02	0.1906E-02
0.4674E-02	0.1553	0.8297	1.901	0.9964	0.4467E-02	0.1945E-02
0.5501E-02	0.1479	0.8481	1.976	0.9945	0.3682E-02	0.1729E-02
0.6335E-02	0.1498	0.8585	2.022	0.9907	0.3567E-02	0.1747E-02
0.7154E-02	0.1462	0.8751	2.097	0.9916	0.3093E-02	0.1631E-02
0.7974E-02	0.1409	0.8813	2.127	0.9897	0.2767E-02	0.1499E-02
0.8786E-02	0.1482	0.8958	2.198	0.9868	0.2807E-02	0.1618E-02
0.9616E-02	0.1473	0.9036	2.238	0.9840	0.2639E-02	0.1574E-02
0.1043E-01	0.1468	0.9130	2.289	0.9821	0.2466E-02	0.1533E-02
0.1125E-01	0.1414	0.9213	2.334	0.9811	0.2165E-02	0.1399E-02
0.1206E-01	0.1437	0.9301	2.384	0.9802	0.2105E-02	0.1419E-02
0.1288E-01	0.1389	0.9386	2.434	0.9783	0.1853E-02	0.1300E-02
0.1370E-01	0.1355	0.9465	2.483	0.9783	0.1665E-02	0.1214E-02
0.1453E-01	0.1353	0.9535	2.528	0.9754	0.1576E-02	0.1188E-02
0.1537E-01	0.1338	0.9593	2.565	0.9754	0.1475E-02	0.1145E-02
0.1616E-01	0.1293	0.9666	2.615	0.9745	0.1299E-02	0.1047E-02
0.1698E-01	0.1266	0.9737	2.665	0.9716	0.1177E-02	0.9826E-03
0.1782E-01	0.1174	0.9771	2.692	0.9716	0.9821E-03	0.8360E-03
0.1864E-01	0.1142	0.9843	2.744	0.9726	0.8760E-03	0.7756E-03
0.1946E-01	0.1082	0.9906	2.793	0.9735	0.7445E-03	0.6836E-03
0.2029E-01	0.9780E-01	0.9896	2.789	0.9764	0.6105E-03	0.5609E-03
0.2108E-01	0.9178E-01	0.9938	2.824	0.9792	0.5176E-03	0.4885E-03
0.2190E-01	0.7849E-01	0.9943	2.832	0.9830	0.3752E-03	0.3576E-03
0.2272E-01	0.6582E-01	0.9958	2.847	0.9821	0.2594E-03	0.2498E-03
0.2353E-01	0.5535E-01	0.9971	2.862	0.9821	0.1805E-03	0.1756E-03
0.2436E-01	0.4444E-01	0.9982	2.873	0.9821	0.1149E-03	0.1126E-03
0.2518E-01	0.4605E-01	0.9990	2.883	0.9821	0.1220E-03	0.1205E-03
0.2599E-01	0.3465E-01	0.9994	2.890	0.9830	0.6855E-04	0.6807E-04
0.2682E-01	0.2883E-01	0.9997	2.898	0.9830	0.4707E-04	0.4698E-04
0.2764E-01	0.2611E-01	0.9999	2.905	0.9821	0.3830E-04	0.3840E-04
0.2846E-01	0.2328E-01	0.9998	2.908	0.9811	0.3035E-04	0.3047E-04

NORMAL WIRE PROFILE TABULATION
X = 1.145
Z = 0.0000E+00
M ref = 2.916
U ref hw = 562.5
RHO ref hw = 0.8020
TAU wall preston =
P wall mean flow = 0.2982E+05

Y	<(rhou)"> RHOU	U Uref	M	Ps Pwall	<u">**2 U**2	RHO<u">**2 RHOref Uref**2

****
FILE NEWA2GAR.DF6   FERNANDO & SMITS
****

Preston probe data reduced according to Bradshaw & Unsworth [1974], and Hopkins & Keener [1966] calibration schemes
Preston probe diameter = 1.651mm

X	Z	PO	TO	PRESTON	PWALL	B-U-Tauw	H-K-T"-Tauw	H-K-Tw-Tauw
1.000	0.0000E+00	0.6957E+06	265.3	0.6552E+05	0.2192E+05	133.3	133.0	145.9
1.000	0.0000E+00	0.6961E+06	262.3	0.6542E+05	0.2192E+05	132.7	131.9	144.7
1.149	0.0000E+00	0.6881E+06	267.0	0.8138E+05	0.2997E+05	155.9	151.7	165.4
1.172	0.0000E+00	0.6890E+06	267.0	0.8458E+05	0.3136E+05	160.5	156.3	170.3
1.197	0.8000E-03	0.6871E+06	267.9	0.8743E+05	0.3580E+05	160.6	153.9	167.2
1.197	0.0000E+00	0.6871E+06	266.5	0.8825E+05	0.3580E+05	162.1	156.0	169.5
1.222	0.0000E+00	0.6882E+06	266.5	0.9258E+05	0.3969E+05	165.3	157.9	171.3
1.248	0.0000E+00	0.6870E+06	267.3	0.9812E+05	0.4278E+05	172.2	163.9	177.5
1.273	0.0000E+00	0.6878E+06	265.7	0.1018E+06	0.4365E+05	178.2	169.7	183.7
1.299	0.0000E+00	0.6873E+06	265.2	0.1048E+06	0.4246E+05	185.8	177.6	192.4
1.324	0.0000E+00	0.6897E+06	266.2	0.1058E+06	0.4100E+05	189.8	181.9	197.2
1.349	0.0000E+00	0.6869E+06	267.0	0.1055E+06	0.3963E+05	191.0	184.5	200.1
1.362	-0.3175E-02	0.6901E+06	265.8	0.1062E+06	0.4031E+05	191.3	183.9	199.5
1.362	-0.3175E-02	0.6913E+06	262.3	0.1058E+06	0.4031E+05	189.9	182.2	197.7
1.324	0.5080E-01	0.6876E+06	267.8	0.1098E+06	0.4103E+05	197.6	190.6	206.6
1.324	0.3810E-01	0.6867E+06	266.8	0.1080E+06	0.4100E+05	194.1	186.6	202.3
1.324	0.2580E-01	0.6889E+06	270.7	0.1091E+06	0.4100E+05	196.9	190.2	206.2
1.324	0.1070E-01	0.6892E+06	270.5	0.1064E+06	0.4100E+05	191.7	184.7	200.2
1.324	-0.1270E-01	0.6888E+06	269.8	0.1053E+06	0.4108E+05	189.4	182.1	197.4
1.324	-0.2660E-01	0.6892E+06	269.7	0.1068E+06	0.4220E+05	190.9	183.2	198.4
1.324	-0.3970E-01	0.6890E+06	270.1	0.1057E+06	0.4268E+05	188.2	180.3	195.2
1.324	-0.5080E-01	0.6885E+06	270.3	0.1067E+06	0.4310E+05	189.6	181.7	196.7

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FILE NEWA2GAR.DF7   FERNANDO & SMITS

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(SAMPLE PRINTOUT PAGE)

CROSSED-WIRE PROFILE TABULATION

X	= 1.000
Z	= 0.0000E+00
M ref	= 2.916
U ref hw	= 582.2
RHO ref hw	= 0.7486
TAU wall preston	= 133.3
P wall mean flow	= 0.2192E+05

Y	<(rhou)"> RHOU	U Uref	M	Ps Pwall	<u">**2 U**2	RHO<u">**2 RHOref Uref**2
0.2200E-02	0.1366	0.7706	1.679	0.9935	0.4576E-02	0.1550E-02
0.2848E-02	0.1404	0.7887	1.743	0.9983	0.4456E-02	0.1636E-02
0.3684E-02	0.1534	0.8075	1.813	1.000	0.4868E-02	0.1937E-02
0.4496E-02	0.1521	0.8258	1.884	0.9983	0.4375E-02	0.1874E-02
0.5328E-02	0.1593	0.8466	1.969	0.9935	0.4310E-02	0.2008E-02
0.6162E-02	0.1547	0.8577	2.019	0.9916	0.3820E-02	0.1866E-02
0.6970E-02	0.1583	0.8711	2.079	0.9916	0.3707E-02	0.1922E-02
0.7784E-02	0.1561	0.8794	2.118	0.9897	0.3436E-02	0.1846E-02
0.8613E-02	0.1536	0.8936	2.187	0.9868	0.3056E-02	0.1745E-02
0.9442E-02	0.1577	0.9016	2.227	0.9849	0.3065E-02	0.1811E-02
0.1028E-01	0.1560	0.9116	2.281	0.9821	0.2811E-02	0.1736E-02
0.1111E-01	0.1490	0.9197	2.325	0.9811	0.2430E-02	0.1559E-02
0.1192E-01	0.1473	0.9287	2.376	0.9811	0.2234E-02	0.1496E-02
0.1275E-01	0.1481	0.9372	2.426	0.9783	0.2128E-02	0.1482E-02
0.1358E-01	0.1384	0.9454	2.476	0.9783	0.1751E-02	0.1270E-02
0.1441E-01	0.1378	0.9525	2.521	0.9764	0.1646E-02	0.1235E-02
0.1524E-01	0.1392	0.9585	2.560	0.9754	0.1605E-02	0.1241E-02
0.1605E-01	0.1367	0.9654	2.607	0.9745	0.1466E-02	0.1174E-02
0.1688E-01	0.1318	0.9729	2.660	0.9726	0.1284E-02	0.1068E-02
0.1772E-01	0.1272	0.9768	2.689	0.9716	0.1156E-02	0.9824E-03
0.1855E-01	0.1176	0.9833	2.737	0.9726	0.9359E-03	0.8245E-03
0.1937E-01	0.1127	0.9899	2.788	0.9735	0.8124E-03	0.7431E-03
0.2020E-01	0.1046	0.9895	2.789	0.9764	0.6991E-03	0.6417E-03
0.2100E-01	0.9638E-01	0.9938	2.823	0.9783	0.5712E-03	0.5386E-03
0.2183E-01	0.8469E-01	0.9941	2.830	0.9830	0.4375E-03	0.4166E-03
0.2265E-01	0.8246E-01	0.9956	2.846	0.9821	0.4077E-03	0.3923E-03
0.2346E-01	0.5735E-01	0.9970	2.861	0.9821	0.1940E-03	0.1886E-03
0.2429E-01	0.6009E-01	0.9981	2.872	0.9821	0.2103E-03	0.2060E-03
0.2510E-01	0.4647E-01	0.9989	2.882	0.9821	0.1244E-03	0.1227E-03
0.2592E-01	0.5136E-01	0.9994	2.890	0.9830	0.1507E-03	0.1496E-03
0.2674E-01	0.3511E-01	0.9997	2.897	0.9830	0.6987E-04	0.6970E-04
0.2756E-01	0.2361E-01	0.9999	2.904	0.9821	0.3134E-04	0.3141E-04
0.2838E-01	0.1959E-01	0.9998	2.908	0.9811	0.2149E-04	0.2158E-04
0.2919E-01	0.1977E-01	0.9994	2.908	0.9802	0.2189E-04	0.2195E-04
0.3000E-01	0.1802E-01	0.9992	2.908	0.9811	0.1819E-04	0.1825E-04

Y	<v"> U	U Uref	M	Ps Pwall	<v">**2 U**2	RHO<v">**2 RHOref Uref**2
0.2200E-02	0.4326E-01	0.7706	1.679	0.9935	0.1871E-02	0.6340E-03
0.2848E-02	0.4348E-01	0.7887	1.743	0.9983	0.1891E-02	0.6939E-03
0.3684E-02	0.4258E-01	0.8075	1.813	1.000	0.1813E-02	0.7213E-03
0.4496E-02	0.4168E-01	0.8258	1.884	0.9983	0.1737E-02	0.7443E-03

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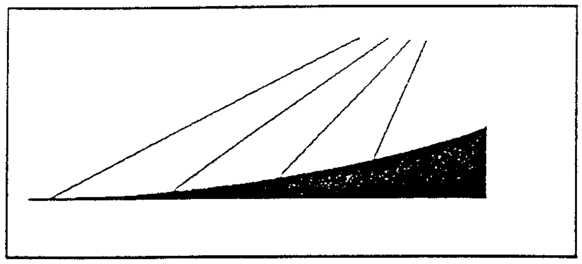
FILE NEWA2GAR.DF8   FERNANDO & SMITS
****

X	Z	DELTA	DELTA*	THETA	tauw_Carv	tauw_vD	0.5rU2 @ delta
1.000	0.0000E+00	0.2639E-01	0.7178E-02	0.1208E-02	136.1	137.3	0.1263E+06
1.064	0.0000E+00	0.2456E-01	0.6805E-02	0.1179E-02	140.8	144.8	0.1371E+06
1.127	0.0000E+00	0.2524E-01	0.6674E-02	0.1168E-02	149.8	154.4	0.1525E+06
1.151	0.0000E+00	0.2402E-01	0.7061E-02	0.1296E-02	161.3	164.5	0.1529E+06
1.172	-.1524E-02	0.2405E-01	0.6867E-02	0.1310E-02	161.3	164.5	0.1556E+06
1.197	-.7620E-03	0.2406E-01	0.6791E-02	0.1364E-02	164.9	164.9	0.1624E+06
1.222	-.7620E-03	0.2558E-01	0.6609E-02	0.1412E-02	169.8	173.5	0.1667E+06
1.248	0.1270E-02	0.2408E-01	0.6758E-02	0.1465E-02	168.7	172.6	0.1739E+06
1.254	0.0000E+00	0.2375E-01	0.6971E-02	0.1424E-02	176.7	178.7	0.1769E+06
1.273	0.0000E+00	0.2248E-01	0.6869E-02	0.1454E-02	176.1	178.1	0.1803E+06
1.299	-.5080E-03	0.2404E-01	0.6874E-02	0.1464E-02	182.4	186.4	0.1762E+06
1.324	0.7620E-03	0.2408E-01	0.7009E-02	0.1492E-02	190.8	196.8	0.1737E+06
1.349	0.1270E-02	0.2081E-01	0.7723E-02	0.1706E-02	192.1	198.0	0.1688E+06
1.361	-.1524E-02	0.2367E-01	0.6691E-02	0.1361E-02	198.0	202.0	0.1764E+06
1.381	0.0000E+00	0.2607E-01	0.7040E-02	0.1496E-02	187.0	193.0	0.1728E+06
1.324	0.4724E-01	0.1979E-01	0.6606E-02	0.1458E-02	197.6	199.6	0.1694E+06
1.325	0.3810E-01	0.1967E-01	0.6443E-02	0.1395E-02	200.8	204.8	0.1714E+06
1.324	0.2540E-01	0.2002E-01	0.6535E-02	0.1420E-02	195.9	197.9	0.1687E+06
1.324	0.1270E-01	0.1978E-01	0.7070E-02	0.1574E-02	193.3	201.3	0.1695E+06
1.324	-.1194E-01	0.2373E-01	0.6510E-02	0.1339E-02	190.1	194.2	0.1786E+06
1.324	-.2540E-01	0.2122E-01	0.6121E-02	0.1265E-02	198.6	207.1	0.1765E+06
1.324	-.2667E-01	0.2216E-01	0.6318E-02	0.1328E-02	194.5	200.6	0.1754E+06
1.324	-.3810E-01	0.2234E-01	0.6409E-02	0.1328E-02	189.2	193.3	0.1777E+06
1.325	-.5029E-01	0.2067E-01	0.6067E-02	0.1258E-02	189.0	189.0	0.1758E+06

X	Z	STREAMLINE HEIGHTS							
1.000	0.0000E+00	0.5380E-02	0.8000E-02	0.1076E-01	0.1345E-01	0.1600E-01	0.2152E-01	0.2400E-01	0.3200E-01
1.064	0.0000E+00	0.4961E-02	0.7380E-02	0.9936E-02	0.1246E-01	0.1489E-01	0.2012E-01	0.2241E-01	0.2970E-01
1.127	0.0000E+00	0.4697E-02	0.6995E-02	0.9426E-02	0.1181E-01	0.1408E-01	0.1896E-01	0.2108E-01	0.2763E-01
1.151	0.0000E+00	0.4485E-02	0.6781E-02	0.9156E-02	0.1147E-01	0.1367E-01	0.1840E-01	0.2046E-01	0.2688E-01
1.172	-.1524E-02	0.4368E-02	0.6582E-02	0.8892E-02	0.1115E-01	0.1329E-01	0.1794E-01	0.1994E-01	0.2619E-01
1.197	-.7620E-03	0.4178E-02	0.6285E-02	0.8515E-02	0.1067E-01	0.1274E-01	0.1721E-01	0.1912E-01	0.2514E-01
1.222	-.7620E-03	0.3941E-02	0.5950E-02	0.8076E-02	0.1014E-01	0.1207E-01	0.1623E-01	0.1806E-01	0.2385E-01
1.248	0.1270E-02	0.3891E-02	0.5855E-02	0.7918E-02	0.9926E-02	0.1183E-01	0.1594E-01	0.1774E-01	0.2334E-01
1.254	0.0000E+00	0.3995E-02	0.6000E-02	0.8105E-02	0.1014E-01	0.1205E-01	0.1613E-01	0.1789E-01	0.2334E-01
1.273	0.0000E+00	0.3805E-02	0.5763E-02	0.7845E-02	0.9851E-02	0.1175E-01	0.1581E-01	0.1756E-01	0.2292E-01
1.299	-.5080E-03	0.3768E-02	0.5748E-02	0.7856E-02	0.9910E-02	0.1185E-01	0.1603E-01	0.1785E-01	0.2339E-01
1.324	0.7620E-03	0.3756E-02	0.5752E-02	0.7874E-02	0.9978E-02	0.1197E-01	0.1627E-01	0.1813E-01	0.2380E-01
1.349	0.1270E-02	0.3740E-02	0.5762E-02	0.7928E-02	0.1010E-01	0.1213E-01	0.1644E-01	0.1827E-01	0.2388E-01
1.361	-.1524E-02	0.3660E-02	0.5665E-02	0.7811E-02	0.9909E-02	0.1194E-01	0.1628E-01	0.1815E-01	0.2381E-01
1.381	0.0000E+00	0.3755E-02	0.5708E-02	0.7835E-02	0.9935E-02	0.1194E-01	0.1628E-01	0.1817E-01	0.2394E-01
1.324	0.4724E-01	0.3604E-02	0.5543E-02	0.7621E-02	0.9646E-02	0.1157E-01	0.1570E-01	0.1750E-01	0.2311E-01
1.325	0.3810E-01	0.3573E-02	0.5515E-02	0.7591E-02	0.9625E-02	0.1154E-01	0.1568E-01	0.1747E-01	0.2304E-01
1.324	0.2540E-01	0.3664E-02	0.5588E-02	0.7655E-02	0.9673E-02	0.1159E-01	0.1573E-01	0.1753E-01	0.2317E-01
1.324	0.1270E-01	0.3670E-02	0.5662E-02	0.7772E-02	0.9844E-02	0.1181E-01	0.1602E-01	0.1783E-01	0.2343E-01
1.324	-.1194E-01	0.3703E-02	0.5698E-02	0.7827E-02	0.9904E-02	0.1186E-01	0.1607E-01	0.1790E-01	0.2348E-01
1.324	-.2540E-01	0.3611E-02	0.5558E-02	0.7641E-02	0.9674E-02	0.1158E-01	0.1566E-01	0.1743E-01	0.2292E-01
1.324	-.2667E-01	0.3658E-02	0.5619E-02	0.7718E-02	0.9761E-02	0.1167E-01	0.1578E-01	0.1755E-01	0.2307E-01
1.324	-.3810E-01	0.3706E-02	0.5679E-02	0.7781E-02	0.9833E-02	0.1175E-01	0.1585E-01	0.1760E-01	0.2307E-01
1.325	-.5029E-01	0.3639E-02	0.5588E-02	0.7654E-02	0.9656E-02	0.1155E-01	0.1558E-01	0.1731E-01	0.2277E-01

Ref.: 17
Authors: Jayaram et al.
Geometry: Streamwise APG, curved ramp
Mach number: 3
Data: CTHWA turbulence data
(normal & inclined wire)



Jayaram, M., Taylor, M. W., and Smits, A. J., "The Response of a Compressible Turbulent Boundary Layer to Short Regions of Concave Surface Curvature," *Journal of Fluid Mechanics*, 1987, Vol. 175, pp. 343-362.

ABSTRACT (from Ref. 17): Experiments were performed to investigate the supersonic flow of a turbulent boundary layer over short regions of concave surface curvature. Upstream of each curved wall, the freestream Mach number was 2.87, and the incoming boundary layer was typical of a two-dimensional, zero-pressure-gradient, high-Reynolds number flow. Two different curvatures were used, with radii of curvature equal to 10 and 50 initial boundary layer thicknesses (Models I and II, respectively). The turning angle was 8° in each case. As the boundary layer passed through the curved region, it experienced a strong adverse pressure gradient, as well as the destabilizing influences of bulk compression and concave curvature. Downstream of the curved walls, the flow relaxed on a short plane wall. The mean and turbulent field for each flow was investigated, using normal and inclined hot wires to measure the turbulent fluctuations. Whenever possible, the results were compared with those from a corresponding 8° ramp. The ramp and Model I exhibited a very similar behaviour: turbulence levels increased significantly, and there was a marked increase in structural parameters such as the stress ratio and the length- and timescales of the turbulent motions. Model II behaved quite differently: although the turbulence levels increased, structural parameters were essentially unchanged. The similarities between the ramp and Model I results suggest that the perturbation in both cases is "rapid" in that the perturbation can be described in terms of total strains rather than local strains. In contrast, the flow in Model II is sensitive to the local variations in the strain rate.

The Jayaram data are the companion hot-wire data to the mean-flow measurements of Taylor, tabulated elsewhere in this report. These datasets are thoroughly documented in AGARDograph 315 under catalog entries 8401T and 8702T. Users are directed to that reference for further details concerning the datasets. In addition, the following brief description of the coordinates and the data files was provided with the data:

```
- All dimensional data is in MKS units
        - X-coordinate is measured from the start of curvature. This point
          is 1.149 m from the end of the nozzle; thus all points on the model
          have a + X value, and all those upstream of the start of curvature
          have a - X value.
        - Left-handed coordinate system
```

- The y coordinate is measured from the test surface. The origin of y is at the test surface. The y coordinate is measured in the survey direction.
- The z coordinate is normal to both x and y axes. The origin of z is on the tunnel centerline. z is measured positive to the left, when looking downstream.
- A reference Mach number of 2.90 was used

MODEL COORDAINATES

	MODEL I	MODEL II
Radius of Curvature R	254mm	1270mm
deltaref/R	0.10	0.02
width	152mm	152mm
total turning angle	8 °	8°

FILENAME	DESCRIPTION
JAYARAM1.DAT	Normal CTHWA data for Model I (9 x-stations represented)
JAYARAM2.DAT	Inclined CTHWA data for Model I (9 x-stations represented)
JAYARAM3.DAT	Normal CTHWA data for Model II (14 x-stations represented)
JAYARAM4.DAT	Inclined CTHWA data for Model II (14 x-stations represented)

****
FILE JAYARAM1.DAT   JAYARAM & SMITS
****

(SAMPLE OUTPUT PAGE)

NORMAL WIRE PROFILE TABULATION

DATA TABULATION FOR MODEL 1 TURNING ANGLE= 8.0DEG MODEL RADIUS= .2540M

X	= -.1270E-01
Z	= -.1270E-01
M ref	= 2.900
U ref hw	= 591.6
RHO ref hw	= 0.7332
TAU wall preston	= 139.6
P wall mean flow	= 0.2333E+05

Y	<(rhou)"> RHOU	U Uref	M	Ps Pwall	<u">**2 U**2	RHO<u">**2 RHOref Uref**2
0.4190E-02	0.1326	0.8075	1.812	1.004	0.3642E-02	0.1527E-02
0.5402E-02	0.1328	0.8237	1.876	0.9928	0.3371E-02	0.1499E-02
0.6766E-02	0.1293	0.8547	2.004	0.9860	0.2721E-02	0.1371E-02
0.8122E-02	0.1289	0.8707	2.078	0.9863	0.2461E-02	0.1335E-02
0.9469E-02	0.1247	0.8857	2.144	0.9830	0.2124E-02	0.1222E-02
0.1083E-01	0.1270	0.8990	2.214	0.9801	0.2022E-02	0.1236E-02
0.1219E-01	0.1295	0.9173	2.316	0.9790	0.1857E-02	0.1242E-02
0.1355E-01	0.1238	0.9273	2.370	0.9743	0.1589E-02	0.1107E-02
0.1492E-01	0.1192	0.9403	2.450	0.9731	0.1341E-02	0.9968E-03
0.1627E-01	0.1180	0.9455	2.484	0.9710	0.1262E-02	0.9620E-03
0.1761E-01	0.1164	0.9626	2.590	0.9678	0.1086E-02	0.8971E-03
0.1895E-01	0.1133	0.9715	2.656	0.9779	0.9527E-03	0.8369E-03
0.2033E-01	0.1029	0.9741	2.681	0.9847	0.7634E-03	0.6878E-03
0.2163E-01	0.9511E-01	0.9807	2.733	0.9879	0.6151E-03	0.5778E-03
0.2301E-01	0.8388E-01	0.9899	2.809	0.9819	0.4395E-03	0.4334E-03
0.2437E-01	0.7030E-01	0.9962	2.862	0.9745	0.2912E-03	0.2959E-03
0.2575E-01	0.5975E-01	0.9973	2.876	0.9700	0.2072E-03	0.2115E-03
0.2714E-01	0.4410E-01	0.9993	2.890	0.9666	0.1111E-03	0.1142E-03
0.2851E-01	0.3565E-01	1.000	2.899	0.9648	0.7193E-04	0.7422E-04
0.2987E-01	0.2492E-01	0.9996	2.893	0.9653	0.3533E-04	0.3634E-04
0.3125E-01	0.1864E-01	1.002	2.908	0.9621	0.1945E-04	0.2015E-04
0.3256E-01	0.1751E-01	1.001	2.906	0.9600	0.1723E-04	0.1777E-04
0.3387E-01	0.1383E-01	1.002	2.910	0.9584	0.1068E-04	0.1104E-04
0.3517E-01	0.1225E-01	1.002	2.910	0.9599	0.8387E-05	0.8678E-05
0.3649E-01	0.1161E-01	1.002	2.910	0.9608	0.7540E-05	0.7809E-05
0.3780E-01	0.1230E-01	1.004	2.927	0.9621	0.8294E-05	0.8705E-05
0.3919E-01	0.1193E-01	1.002	2.913	0.9639	0.7922E-05	0.8249E-05
0.4059E-01	0.1149E-01	1.002	2.913	0.9686	0.7357E-05	0.7698E-05
0.4200E-01	0.1151E-01	1.001	2.910	0.9696	0.7407E-05	0.7741E-05
0.4337E-01	0.1164E-01	1.001	2.910	0.9696	0.7574E-05	0.7916E-05

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*******************************************
FILE JAYARAM2.DAT    JAYARAM & SMITS
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(SAMPLE PRINTOUT PAGE)

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INCLINED WIRE PROFILE TABULATION
 DATA TABULATION FOR MODEL 1 TURNING ANGLE=  8.0DEG MODEL RADIUS= .2540M
 X                    = -.1270E-01
 Z                    = -.1270E-01
 M ref                =  2.900
 U   ref hw           =  587.4
 RHO ref hw           = 0.7436
 TAU wall preston     = 139.6
 P wall mean flow     = 0.2333E+05
```

Y	(rhou)"v" RHO U**2	U Uref	M	Ps Pwall	(u"v") U**2	RHO(u"v") RHOref Uref**2
0.2540E-02	-.3843E-02	0.7713	1.679	1.006	-.1807E-02	-.6519E-03
0.3735E-02	-.3398E-02	0.7969	1.766	1.011	-.1512E-02	-.6072E-03
0.5171E-02	-.2922E-02	0.8216	1.866	0.9935	-.1221E-02	-.5378E-03
0.6590E-02	-.3155E-02	0.8467	1.971	0.9864	-.1235E-02	-.6026E-03
0.8017E-02	-.2456E-02	0.8685	2.068	0.9866	-.9060E-03	-.4867E-03
0.9449E-02	-.2547E-02	0.8854	2.142	0.9831	-.8981E-03	-.5158E-03
0.1087E-01	-.1871E-02	0.9000	2.219	0.9797	-.6299E-03	-.3869E-03
0.1232E-01	-.2491E-02	0.9187	2.324	0.9790	-.7881E-03	-.5306E-03
0.1375E-01	-.2094E-02	0.9301	2.387	0.9743	-.6385E-03	-.4512E-03
0.1517E-01	-.1591E-02	0.9401	2.450	0.9725	-.4678E-03	-.3476E-03
0.1658E-01	-.1411E-02	0.9487	2.503	0.9701	-.4023E-03	-.3113E-03
0.1802E-01	-.1190E-02	0.9674	2.623	0.9707	-.3171E-03	-.2696E-03
0.1947E-01	-.1040E-02	0.9720	2.664	0.9814	-.2710E-03	-.2402E-03
0.2091E-01	-.9737E-03	0.9762	2.699	0.9873	-.2488E-03	-.2278E-03
0.2235E-01	-.9366E-03	0.9865	2.776	0.9856	-.2294E-03	-.2218E-03
0.2380E-01	-.4082E-03	0.9939	2.843	0.9774	-.9642E-04	-.9699E-04
0.2526E-01	-.3418E-03	0.9972	2.871	0.9714	-.7954E-04	-.8107E-04
0.2671E-01	-.2083E-03	0.9984	2.885	0.9675	-.4810E-04	-.4933E-04
0.2815E-01	-.1746E-03	0.9994	2.892	0.9645	-.4019E-04	-.4125E-04
0.2959E-01	-.7677E-04	1.000	2.899	0.9653	-.1760E-04	-.1818E-04
0.3106E-01	-.3703E-04	1.002	2.910	0.9623	-.8442E-05	-.8756E-05
0.3250E-01	-.8511E-05	1.001	2.905	0.9602	-.1945E-05	-.2006E-05
0.3398E-01	0.1150E-04	1.002	2.910	0.9584	0.2621E-05	0.2708E-05
0.3546E-01	0.1367E-04	1.002	2.910	0.9602	0.3116E-05	0.3225E-05
0.3689E-01	0.8187E-05	1.002	2.910	0.9610	0.1866E-05	0.1933E-05
0.3837E-01	0.6872E-05	1.003	2.921	0.9625	0.1558E-05	0.1628E-05

****
FILE JAYARAM3.DAT JAYARAM & SMITS
****

(SAMPLE PRINTOUT PAGE)

NORMAL WIRE PROFILE TABULATION
DATA TABULATION FOR MODEL 2 TURNING ANGLE= 8.0DEG MODEL RADIUS=1.2700M

X	= -.1270E-01
Z	= -.1270E-01
M ref	= 2.900
U ref hw	= 584.1
RHO ref hw	= 0.7556
TAU wall preston	= 142.6
P wall mean flow	= 0.2305E+05

Y	<(rhou)">	U	M	Ps	<u">**2	RHO<u">**2
	RHOU	Uref		Pwall	U**2	RHOref Uref**2
0.2940E-02	0.1536	0.7916	1.750	1.030	0.5289E-02	0.2088E-02
0.3974E-02	0.1465	0.8083	1.812	1.025	0.4448E-02	0.1873E-02
0.5166E-02	0.1380	0.8359	1.919	1.014	0.3446E-02	0.1611E-02
0.6362E-02	0.1368	0.8535	1.998	1.009	0.3067E-02	0.1546E-02
0.7538E-02	0.1420	0.8669	2.055	1.006	0.3077E-02	0.1635E-02
0.8726E-02	0.1376	0.8838	2.137	1.006	0.2608E-02	0.1500E-02
0.9923E-02	0.1405	0.8951	2.194	1.004	0.2535E-02	0.1534E-02
0.1113E-01	0.1396	0.9063	2.250	0.9999	0.2335E-02	0.1480E-02
0.1232E-01	0.1406	0.9210	2.336	1.000	0.2134E-02	0.1458E-02
0.1352E-01	0.1405	0.9315	2.392	0.9982	0.1993E-02	0.1426E-02
0.1472E-01	0.1334	0.9442	2.468	0.9972	0.1641E-02	0.1248E-02
0.1591E-01	0.1383	0.9499	2.510	0.9999	0.1679E-02	0.1324E-02
0.1712E-01	0.1327	0.9582	2.559	1.001	0.1460E-02	0.1199E-02
0.1833E-01	0.1282	0.9666	2.624	1.000	0.1264E-02	0.1090E-02
0.1952E-01	0.1207	0.9751	2.682	1.002	0.1050E-02	0.9479E-03
0.2072E-01	0.1113	0.9817	2.736	1.002	0.8399E-03	0.7886E-03
0.2190E-01	0.1052	0.9893	2.797	1.002	0.6998E-03	0.6866E-03
0.2309E-01	0.9597E-01	0.9901	2.810	1.006	0.5746E-03	0.5713E-03
0.2431E-01	0.8379E-01	0.9926	2.832	1.005	0.4273E-03	0.4314E-03
0.2545E-01	0.7518E-01	0.9936	2.844	1.004	0.3396E-03	0.3453E-03
0.2659E-01	0.6110E-01	0.9931	2.844	1.008	0.2242E-03	0.2288E-03
0.2772E-01	0.4142E-01	0.9934	2.847	1.008	0.1027E-03	0.1050E-03
0.2886E-01	0.3056E-01	0.9944	2.859	1.008	0.5518E-04	0.5692E-04
0.3002E-01	0.2681E-01	0.9928	2.842	1.010	0.4330E-04	0.4421E-04
0.3117E-01	0.2249E-01	0.9943	2.857	1.011	0.2995E-04	0.3094E-04
0.3231E-01	0.1913E-01	0.9932	2.845	1.010	0.2194E-04	0.2247E-04
0.3343E-01	0.1697E-01	0.9937	2.852	1.010	0.1715E-04	0.1764E-04

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FILE JAYARAM4.DAT   JAYARAM & SMITS
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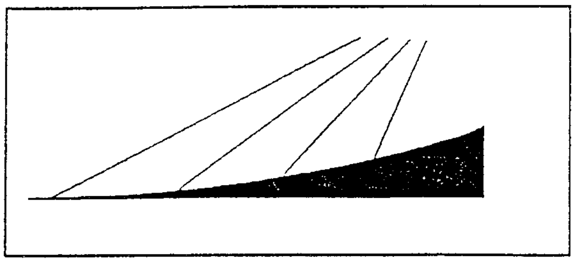
(SAMPLE PRINTOUT PAGE)

INCLINED WIRE PROFILE TABULATION
DATA TABULATION FOR MODEL 2 TURNING ANGLE= 8.0DEG MODEL RADIUS=1.2700M

```
X                   = -.1270E-01
Z                   = -.1270E-01
M ref               =  2.900
U   ref hw          =  587.9
RHO ref hw          = 0.7458
TAU wall preston    = 142.6
P wall mean flow    = 0.2305E+05
```

Y	(rhou)"v" RHO U**2	U Uref	M	Ps Pwall	(u"v") U**2	RHO(u"v") RHOref Uref**2
0.2680E-02	-.3014E-02	0.7850	1.726	1.028	-.1375E-02	-.5271E-03
0.3929E-02	-.2705E-02	0.8082	1.811	1.026	-.1170E-02	-.4926E-03
0.5341E-02	-.2558E-02	0.8383	1.930	1.013	-.1027E-02	-.4852E-03
0.6751E-02	-.2865E-02	0.8628	2.040	1.006	-.1075E-02	-.5634E-03
0.8170E-02	-.2058E-02	0.8730	2.089	1.007	-.7499E-03	-.4124E-03
0.9612E-02	-.2445E-02	0.8909	2.170	1.005	-.8478E-03	-.5022E-03
0.1103E-01	-.1841E-02	0.9043	2.240	1.000	-.6124E-03	-.3847E-03
0.1246E-01	-.1842E-02	0.9213	2.339	0.9997	-.5776E-03	-.3956E-03
0.1390E-01	-.1515E-02	0.9358	2.416	0.9975	-.4543E-03	-.3313E-03
0.1534E-01	-.1247E-02	0.9493	2.507	0.9986	-.3548E-03	-.2789E-03
0.1679E-01	-.1073E-02	0.9548	2.538	1.001	-.3000E-03	-.2422E-03
0.1823E-01	-.9369E-03	0.9658	2.619	1.000	-.2502E-03	-.2149E-03
0.1965E-01	-.5809E-03	0.9757	2.687	1.002	-.1494E-03	-.1354E-03
0.2107E-01	-.4603E-03	0.9840	2.754	1.001	-.1141E-03	-.1085E-03
0.2252E-01	-.1855E-03	0.9906	2.810	1.004	-.4461E-04	-.4425E-04
0.2397E-01	-.1734E-03	0.9920	2.828	1.006	-.4131E-04	-.4160E-04
0.2545E-01	-.9828E-04	0.9936	2.844	1.004	-.2321E-04	-.2359E-04
0.2690E-01	-.3362E-04	0.9927	2.841	1.009	-.7949E-05	-.8103E-05
0.2835E-01	-.2280E-04	0.9940	2.854	1.007	-.5356E-05	-.5501E-05
0.2983E-01	0.6927E-04	0.9928	2.842	1.010	0.1637E-04	0.1672E-04
0.3129E-01	-.1514E-04	0.9942	2.856	1.011	-.3552E-05	-.3666E-05

Ref.: 20
Author: Laderman
Geometry: Streamwise APG, curved ramp
Mach number: 3
Data: p_{wall}, c_f, mean-flow surveys



Laderman, A. J., "Pressure Gradient Effects on Supersonic Boundary Layer Turbulence," Aeronutronic Ford Corp. Report U-6467, 1978.

ABSTRACT: Measurements of mean flow profiles at several streamwise locations in a supersonic turbulent boundary layer growing under a continuous adverse pressure gradient are reported. Tests were performed at a freestream Mach number of 3, for an adiabatic wall, using two curved ramps designed to produce constant pressure gradient flows. The velocity profile data, when transformed to incompressible coordinates, are in good agreement with Coles universal 'wall-wake' velocity profile and they indicate that the boundary layer is in local equilibrium and essentially independent of upstream history. In addition, the Coles wake parameters and Clauser shape factors, characterizing the transformed profiles, are in accord with the results of low speed correlations of adverse pressure gradient flows. The turbulent transport terms were extracted from the mean flow field data and indicate that for a given ramp, the profile of turbulent shear stress normalized by the wall shear, versus distance from the surface, normalized by the local boundary thickness, is severely distorted by the pressure gradient although it is apparently insensitive to local conditions.

Laderman's experiment, along with those of Lewis et al. and Sturek and Danberg, tabulated elsewhere in this report, is one of the classic experiments on compressible turbulent boundary layers in adverse pressure gradients. As such, it was fully documented and discussed by Fernholz and Finley as Catalog number 7803 in AGARDograph 263, to which the interested reader is referred. Our present goal is not to repeat that documentation, but rather to make the dataset more readily available in machine-readable form than it was at the time of the original Fernholz-Finley tabulation. Accordingly, we have listed below only the test model coordinates and a brief recap of the standard Fernholz-Finley notation as used in the accompanying data file (SI units are used throughout). For more complete documentation, see AGARDograph 263 and the author's original report (Ref. 20) cited above.

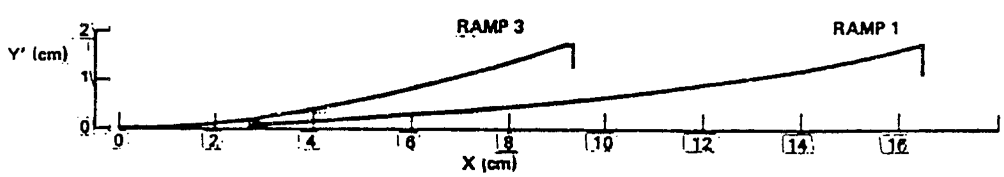
NOMENCLATURE

CF	skin friction coefficient
CQ	heat transfer coeffiicent
D	boundary layer thickness

D1	boundary layer displacement thickness
D2	boundary layer momentum thickness
D3	boundary layer kinetic energy thickness
D4	boundary layer total enthalpy thickness
H12	shape factor D1/D2
H32	shape factor D3/D2
H42	shape factor D4/D2
M	Mach number
MD	Mach number at boundary layer edge
P	static pressure
PI2	pressure gradient parameter
PD	static pressure at boundary layer edge
P0D	stagnation pressure at boundary layer edge
PT2	pitot pressure
PW	wall static pressure
R	recovery factor
RED2D	Reynolds number based on momentum thickness and b.l. edge viscosity
RED2W	Reynolds number based on momentum thickness and wall viscosity
RZ	transverse radius of curvature
T	static temperature
TAUW	wall shear stress
TD	static temperature at boundary layer edge
T0	stagnation temperature
T0D	stagnation temperature at boundary layer edge
TR	recovery temperature
TW	wall temperature
U	velocity component in x-direction
UD	velocity component in x-direction at boundary-layer edge
X	streamwise axial coordinate
Y	coordinate normal to wall

Table 1: Model coordinates

Facsimile from source paper. Author's symbols and units.



RAMP CONTOUR

RAMP 1 X (cm)	RAMP 1 Y'(cm)	RAMP 3 X (cm)	RAMP 3 Y' (cm)
2.736	0.076	1.27	0.0475
4.006	0.142	2.54	0.176
5.276	0.225	3.81	0.372
6.439	0.316	5.08	0.626
7.709	0.430	6.35	0.933
8.979	0.559	7.62	1.289
10.249	0.703	8.89	1.689
11.519	0.861	9.144	1.774
12.789	1.033		
14.059	1.219		
15.329	1.409		

(SAMPLE OUTPUT PAGE)

Fernholz and Finley AGARDograph 263 Case 7803S   LADERMAN   24 PROFILES

CAT 7803S   LADERMAN   BOUNDARY CONDITIONS AND EVALUATED DATA. SI UNITS

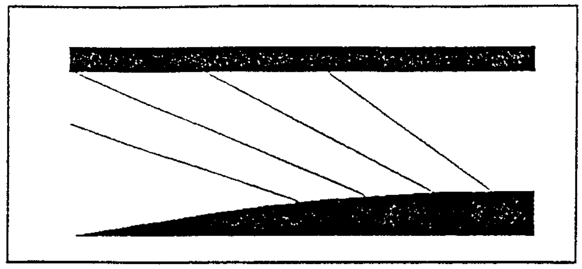
RUN X * RZ	MD * POD TOD*	TW/TR PW/PD TAUW *	RED2W RED2D D2	CF CQ PI2	H12 H32 H42	H12K H32K D2K	PW TW* UD	PD* TD TR
7803S0101	3.0360	1.0137	1.1904E+03	2.1469E-03	5.3391	1.4592	2.5728E+03	2.5051E+03
-1.2700E-02	9.7111E+04	1.0271	2.7862E+03	1.0000E-08	1.8003	1.7731	3.0000E+02	1.1161E+02
1.0000E+08	3.1735E+02	3.4700E+01	4.3855E-04	1.0000E-08	0.0608	6.8024E-04	6.4307E+02	2.9595E+02
7803S0102	2.8571	1.0114	1.4975E+03	2.2001E-03	4.1663	1.4469	3.3805E+03	3.0545E+03
2.7356E-02	9.0428E+04	1.1067	3.2631E+03	1.0000E-08	1.7842	1.7594	3.0000E+02	1.2044E+02
1.0000E+08	3.1706E+02	3.8400E+01	4.9945E-04	1.0000E-08	0.0583	7.1472E-04	6.2866E+02	2.9661E+02
7803S0103	2.8300	1.0144	1.6900E+03	2.1573E-03	4.1305	1.4007	3.5557E+03	3.2496E+03
4.0056E-02	9.2310E+04	1.0942	3.6540E+03	1.0000E-08	1.7893	1.7676	3.0000E+02	1.2144E+02
1.0000E+08	3.1596E+02	3.9300E+01	5.3711E-04	1.0000E-08	0.0397	7.6759E-04	6.2528E+02	2.9573E+02
7803S0104	2.7724	1.0095	1.7077E+03	2.1942E-03	4.3626	1.3597	3.6238E+03	3.4899E+03
5.2756E-02	9.0801E+04	1.0384	3.5944E+03	1.0000E-08	1.7991	1.7807	3.0000E+02	1.2500E+02
1.0000E+08	3.1717E+02	4.1200E+01	5.2338E-04	1.0000E-08	0.0677	7.5655E-04	6.2148E+02	2.9718E+02
7803S0105	2.8311	1.0096	1.8632E+03	2.2188E-03	4.1557	1.3930	3.7307E+03	3.3898E+03
6.4389E-02	9.6467E+04	1.1006	4.0124E+03	1.0000E-08	1.7965	1.7752	3.0000E+02	1.2197E+02
1.0000E+08	3.1749E+02	4.2200E+01	5.6866E-04	1.0000E-08	0.0699	8.0457E-04	6.2689E+02	2.9715E+02
7803S0106	2.7711	1.0100	2.0243E+03	2.2428E-03	3.7170	1.3453	4.0015E+03	3.6165E+03
7.7089E-02	9.3906E+04	1.1064	4.2606E+03	1.0000E-08	1.8012	1.7842	3.0000E+02	1.2501E+02
1.0000E+08	3.1701E+02	4.3600E+01	5.9900E-04	1.0000E-08	0.0557	8.2187E-04	6.2121E+02	2.9704E+02
7803S0107	2.7156	1.0079	2.0706E+03	2.2277E-03	4.0441	1.3849	4.1979E+03	3.9217E+03
8.9789E-02	9.3531E+04	1.0704	4.2572E+03	1.0000E-08	1.7968	1.7768	3.0000E+02	1.2821E+02
1.0000E+08	3.1732E+02	4.5100E+01	5.8388E-04	1.0000E-08	0.0623	8.1708E-04	6.1652E+02	2.9765E+02
7803S0108	2.6230	1.0090	2.0949E+03	2.2769E-03	3.9736	1.3811	4.5190E+03	4.2770E+03
1.0249E-01	8.8431E+04	1.0566	4.1596E+03	1.0000E-08	1.7994	1.7803	3.0000E+02	1.3316E+02
1.0000E+08	3.1639E+02	4.6900E+01	5.7151E-04	1.0000E-08	0.0523	7.8927E-04	6.0686E+02	2.9733E+02
7803S0109	2.5769	1.0058	2.1930E+03	2.3306E-03	3.8427	1.3690	4.7429E+03	4.5506E+03
1.1519E-01	8.7619E+04	1.0422	4.2655E+03	1.0000E-08	1.8039	1.7844	3.0000E+02	1.3619E+02
1.0000E+08	3.1707E+02	4.9300E+01	5.7881E-04	1.0000E-08	0.0597	7.9030E-04	6.0296E+02	2.9826E+02
7803S0110	2.5781	1.0060	2.3248E+03	2.3901E-03	3.5126	1.3270	4.9860E+03	4.5952E+03
1.2789E-01	8.8633E+04	1.0851	4.5245E+03	1.0000E-08	1.8104	1.7953	3.0000E+02	1.3611E+02
1.0000E+08	3.1703E+02	5.1100E+01	6.0719E-04	1.0000E-08	0.0579	8.0228E-04	6.0304E+02	2.9821E+02
7803S0201	2.9480	1.0104	1.4666E+03	2.0850E-03	4.7259	1.4231	2.9050E+03	2.7672E+03
-3.1750E-02	9.4007E+04	1.0498	3.3074E+03	1.0000E-08	1.7936	1.7677	3.0000E+02	1.1610E+02
1.0000E+08	3.1790E+02	3.5100E+01	5.1376E-04	1.0000E-08	0.0708	7.6738E-04	6.3688E+02	2.9692E+02
7803S0202	2.9613	1.0096	1.5320E+03	2.1520E-03	4.3434	1.3994	2.9884E+03	2.7404E+03
-1.9050E-02	9.4970E+04	1.0905	3.4703E+03	1.0000E-08	1.7914	1.7671	3.0000E+02	1.1556E+02
1.0000E+08	3.1822E+02	3.6200E+01	5.3825E-04	1.0000E-08	0.0814	7.8384E-04	6.3824E+02	2.9714E+02
7803S0203	2.9571	1.0104	1.4835E+03	2.1268E-03	4.8350	1.4088	2.8949E+03	2.7653E+03
-6.3500E-03	9.5239E+04	1.0469	3.3575E+03	1.0000E-08	1.7986	1.7752	3.0000E+02	1.1566E+02
1.0000E+08	3.1795E+02	3.6000E+01	5.1747E-04	1.0000E-08	0.0688	7.7477E-04	6.3764E+02	2.9691E+02
7803S0204	2.9229	1.0095	1.5040E+03	2.1403E-03	4.7930	1.4204	2.9056E+03	2.7969E+03
0.0000E+00	9.1482E+04	1.0389	3.3560E+03	1.0000E-08	1.8041	1.7832	3.0000E+02	1.1742E+02
1.0000E+08	3.1805E+02	3.5800E+01	5.2871E-04	1.0000E-08	0.0869	7.8367E-04	6.3503E+02	2.9718E+02
7803S0205	2.9194	1.0118	1.5546E+03	2.2925E-03	4.5490	1.4759	3.1255E+03	2.7637E+03
6.3500E-03	8.9922E+04	1.1309	3.4719E+03	1.0000E-08	1.7807	1.7551	3.0000E+02	1.1731E+02
1.0000E+08	3.1729E+02	3.7800E+01	5.5351E-04	1.0000E-08	0.0727	8.0345E-04	6.3399E+02	2.9649E+02
7803S0206	2.9347	1.0103	2.1378E+03	2.0977E-03	1.9081	1.4467	3.8924E+03	2.6570E+03
1.9050E-02	8.8461E+04	1.4649	4.7955E+03	1.0000E-08	1.7773	1.7592	3.0000E+02	1.1676E+02
1.0000E+08	3.1787E+02	3.3600E+01	7.8571E-04	1.0000E-08	0.0669	8.9842E-04	6.3579E+02	2.9695E+02

(SAMPLE OUTPUT PAGE)

7803S0102 LADERMAN PROFILE TABULATION 101 POINTS, DELTA AT POINT 88

I	Y	PT2/P	P/PD	TO/TOD	M/MD	U/UD	T/TD	R/RD*U/UD
1	0.0000E+00	1.0000E+00	1.10673	0.94618	0.00000	0.00000	2.49095	0.00000
2	7.6125E-05	1.1896E+00	1.10572	0.94819	0.17649	0.27201	2.37544	0.12662
3	9.5494E-05	1.2082E+00	1.10546	0.94959	0.18442	0.28381	2.36842	0.13247
4	1.2455E-04	1.2268E+00	1.10508	0.94992	0.19195	0.29481	2.35889	0.13811
5	1.4392E-04	1.2489E+00	1.10482	0.95030	0.20039	0.30706	2.34784	0.14449
6	1.7298E-04	1.3688E+00	1.10443	0.95219	0.23976	0.36295	2.29169	0.17492
7	1.9234E-04	1.5427E+00	1.10417	0.95451	0.28421	0.42347	2.22010	0.21061
8	2.2140E-04	1.7441E+00	1.10379	0.95676	0.32481	0.47612	2.14869	0.24459
9	2.4077E-04	1.8865E+00	1.10353	0.95816	0.34898	0.50621	2.10411	0.26549
10	2.6982E-04	2.0344E+00	1.10314	0.95942	0.37128	0.53312	2.06178	0.28524
11	2.8919E-04	2.1911E+00	1.10289	0.96071	0.39278	0.55830	2.02032	0.30477
12	3.0856E-04	2.3199E+00	1.10263	0.96165	0.40929	0.57708	1.98798	0.32007
13	3.2793E-04	2.4196E+00	1.10237	0.96208	0.42145	0.59055	1.96341	0.33157
14	3.5699E-04	2.5195E+00	1.10199	0.96227	0.43322	0.60327	1.93913	0.34283
15	3.7636E-04	2.6000E+00	1.10173	0.96250	0.44241	0.61307	1.92027	0.35174
16	4.0541E-04	2.6853E+00	1.10134	0.96255	0.45191	0.62298	1.90040	0.36103
17	4.3447E-04	2.7844E+00	1.10095	0.96286	0.46264	0.63408	1.87843	0.37164
18	4.5384E-04	2.8187E+00	1.10069	0.96298	0.46630	0.63782	1.87098	0.37523
19	4.9258E-04	2.8713E+00	1.10018	0.96311	0.47183	0.64342	1.85961	0.38066
20	5.0226E-04	2.9136E+00	1.10005	0.96334	0.47622	0.64788	1.85084	0.38507
21	5.5069E-04	2.9973E+00	1.09941	0.96360	0.48477	0.65639	1.83337	0.39362
22	5.9912E-04	3.0902E+00	1.09876	0.96357	0.49408	0.66542	1.81383	0.40309
23	6.5723E-04	3.1622E+00	1.09799	0.96326	0.50116	0.67209	1.79843	0.41033
24	6.9596E-04	3.2327E+00	1.09748	0.96396	0.50798	0.67878	1.78551	0.41722
25	7.4439E-04	3.2973E+00	1.09683	0.96490	0.51414	0.68487	1.77443	0.42334
26	8.0250E-04	3.3586E+00	1.09606	0.96592	0.51992	0.69059	1.76428	0.42903
27	8.4124E-04	3.4188E+00	1.09555	0.96659	0.52552	0.69596	1.75388	0.43473
28	8.7998E-04	3.4903E+00	1.09503	0.96730	0.53208	0.70218	1.74155	0.44151
29	9.3809E-04	3.5563E+00	1.09426	0.96792	0.53807	0.70779	1.73030	0.44761
30	9.8652E-04	3.6174E+00	1.09361	0.96797	0.54355	0.71267	1.71910	0.45337
31	1.0543E-03	3.6981E+00	1.09271	0.96822	0.55069	0.71904	1.70486	0.46086
32	1.1221E-03	3.7896E+00	1.09181	0.96953	0.55868	0.72645	1.69080	0.46910
33	1.2093E-03	3.8901E+00	1.09065	0.97095	0.56730	0.73436	1.67569	0.47797
34	1.2674E-03	3.9594E+00	1.08988	0.97171	0.57317	0.73961	1.66507	0.48411
35	1.3642E-03	4.0590E+00	1.08859	0.97249	0.58150	0.74685	1.64956	0.49287
36	1.4223E-03	4.1324E+00	1.08782	0.97293	0.58755	0.75200	1.63812	0.49938
37	1.5095E-03	4.2558E+00	1.08667	0.97467	0.59759	0.76082	1.62091	0.51005
38	1.5773E-03	4.3422E+00	1.08458	0.97576	0.60451	0.76678	1.60892	0.51689
39	1.6451E-03	4.4242E+00	1.08179	0.97656	0.61100	0.77222	1.59735	0.52298
40	1.7226E-03	4.5452E+00	1.07927	0.97762	0.62045	0.78000	1.58043	0.53266
41	1.8485E-03	4.7201E+00	1.07669	0.97908	0.63385	0.79081	1.55656	0.54701
42	1.9938E-03	4.8782E+00	1.07479	0.98018	0.64571	0.80009	1.53532	0.56010
43	2.1197E-03	5.0460E+00	1.07300	0.98178	0.65807	0.80975	1.51414	0.57383
44	2.2165E-03	5.2047E+00	1.07160	0.98313	0.66953	0.81849	1.49448	0.58689
45	2.3424E-03	5.3712E+00	1.07055	0.98449	0.68134	0.82731	1.47436	0.60071
46	2.4490E-03	5.5204E+00	1.07049	0.98516	0.69175	0.83471	1.45605	0.61368
47	2.5749E-03	5.6850E+00	1.07045	0.98664	0.70305	0.84292	1.43747	0.62770
48	2.7008E-03	5.8499E+00	1.06996	0.98810	0.71418	0.85085	1.41936	0.64140
49	2.8170E-03	6.0238E+00	1.06765	0.98884	0.72573	0.85860	1.39967	0.65493
50	2.9332E-03	6.2074E+00	1.06383	0.99022	0.73773	0.86675	1.38035	0.66800
51	3.0688E-03	6.3689E+00	1.06468	0.99095	0.74812	0.87348	1.36318	0.68221
52	3.1656E-03	6.5171E+00	1.06193	0.99206	0.75753	0.87966	1.34841	0.69277
53	3.2915E-03	6.7223E+00	1.05867	0.99305	0.77037	0.88770	1.32780	0.70777
54	3.4175E-03	6.8699E+00	1.06113	0.99470	0.77947	0.89372	1.31463	0.72138
55	3.5434E-03	7.0351E+00	1.06019	0.99575	0.78952	0.89993	1.29923	0.73436
56	3.6693E-03	7.1892E+00	1.05983	0.99678	0.79879	0.90558	1.28527	0.74674
57	3.7952E-03	7.3556E+00	1.05978	0.99710	0.80867	0.91116	1.26955	0.76062
58	3.9114E-03	7.5080E+00	1.05863	0.99827	0.81762	0.91654	1.25660	0.77214
59	4.0276E-03	7.6750E+00	1.05800	0.99905	0.82730	0.92204	1.24214	0.78535
60	4.1535E-03	7.8439E+00	1.05483	0.99966	0.83699	0.92737	1.22763	0.79684
61	4.2794E-03	8.0352E+00	1.05063	1.00018	0.84782	0.93316	1.21143	0.80930
62	4.3956E-03	8.2021E+00	1.04928	1.00062	0.85716	0.93805	1.19764	0.82185
63	4.5215E-03	8.3275E+00	1.04919	1.00144	0.86411	0.94188	1.18808	0.83177
64	4.6571E-03	8.4945E+00	1.04827	1.00195	0.87328	0.94658	1.17490	0.84456
65	4.7830E-03	8.6622E+00	1.04477	1.00279	0.88239	0.95134	1.16238	0.85508
66	4.8799E-03	8.8516E+00	1.04053	1.00352	0.89257	0.95647	1.14832	0.86669
67	5.0058E-03	9.0187E+00	1.03780	1.00359	0.90145	0.96060	1.13555	0.87792
68	5.1220E-03	9.1365E+00	1.03908	1.00448	0.90766	0.96386	1.12767	0.88814

Ref.: 22
Authors: Lewis, Gran, and Kubota
Geometry: Streamwise APG/FPG, axisymmetric wall
Mach number: 4
Data: p_{wall}, c_f, mean-flow surveys



Lewis, J. E., Gran, R. L. and Kubota, T., "An Experiment on the Adiabatic Compressible Turbulent Boundary layer in Adverse and Favourable Pressure Gradients," *Journal of Fluid Mechanics*, Vol. 51, 1972, pp. 657-672.

ABSTRACT: A wind-tunnel model was developed to study the two-dimensional turbulent boundary layer in adverse and favorable pressure gradients without the effects of streamwise surface curvature. Experiments were performed at Mach 4 with an adiabatic wall, and mean flow measurements within the boundary layer were obtained. The data, when viewed in the velocity transformation suggested by Van Driest, show good general agreement with the composite boundary-layer profile developed for the low-speed turbulent boundary layer. Moreover, the pressure gradient parameter suggested by Alber and Coats was found to correlate the data with low-speed results.

Lewis, Gran and Kubota's experiment, along with those of Laderman and Sturek and Danberg, tabulated elsewhere in this report, is one of the classic experiments on compressible turbulent boundary layers in adverse pressure gradients. As such, it was fully documented and discussed by Fernholz and Finley as Catalog number 7201 in AGARDograph 223, to which the interested reader is referred. Our present goal is not to repeat that documentation, but rather to make the dataset more readily available in machine-readable form than it was at the time of the original Fernholz-Finley tabulation. Accordingly, we have listed below only a brief recap of the standard Fernholz-Finley notation as used in the accompanying data file (SI units are used throughout). For more complete documentation, see AGARDograph 223 and the authors' original paper (Ref. 22) cited above.

NOMENCLATURE

CF	skin friction coefficient
CQ	heat transfer coeffiicent
D	boundary layer thickness
D1	boundary layer displacement thickness
D2	boundary layer momentum thickness
D3	boundary layer kinetic energy thickness

D4	boundary layer total enthalpy thickness
H12	shape factor D1/D2
H32	shape factor D3/D2
H42	shape factor D4/D2
M	Mach number
MD	Mach number at boundary layer edge
NM	not measured
P	static pressure
PI2	pressure gradient parameter
PD	static pressure at boundary layer edge
P0D	stagnation pressure at boundary layer edge
PT2	pitot pressure
PW	wall static pressure
R	recovery factor
RED2D	Reynolds number based on momentum thickness and b.l. edge viscosity
RED2W	Reynolds number based on momentum thickness and wall viscosity
RHO	static density
RHOD	static density at boundary layer edge
RZ	transverse radius of curvature
SW	longitudinal pressure gradient number (see AGARDograph 223 eqn. 5.5)
T	static temperature
TAUW	wall shear stress
TD	static temperature at boundary layer edge
T0	stagnation temperature
T0D	stagnation temperature at boundary layer edge
TR	recovery temperature
TW	wall temperature
U	velocity component in x-direction
UD	velocity component in x-direction at boundary-layer edge
X	streamwise axial coordinate
Y	coordinate normal to wall

(SAMPLE OUTPUT PAGE)

Fernholz & Finley AGARDograph 223 Case 7201 LEWIS 28 PROFILES

CAT 7201 LEWIS BOUNDARY CONDITIONS AND EVALUATED DATA. SI UNITS.

RUN	MD *	TW/TR	RED2W	CF *	H12	H12K	PW	PD
X *	POD*	PW/PD*	RED2D	CQ	H32	H32K	TW*	TD
RZ *	TOD*	SW *	D2	PI2*	H42	D2K	UD	TR
72010101	3.9800	1.0005	1.4803"+03	1.5154"-03	7.9198	1.4601	3.3551"+03	3.3551"+03
2.9159"-01	4.9600"+05	1.0000	4.9214"+03	NM	1.8339	1.8099	2.9300"+02	7.6294"+01
-2.5400"-01	3.1800"+02	0.0000	2.5217"-04	0.0000"+00	0.1444	4.6448"-04	6.9701"+02	2.9286"+02
72010102	3.9800	1.0005	1.3601"+03	1.6150"-03	7.7991	1.4026	3.3551"+03	3.3551"+03
3.0455"-01	4.9600"+05	1.0000	4.5217"+03	NM	1.8344	1.8054	2.9300"+02	7.6294"+01
-2.5400"-01	3.1800"+02	0.0000	2.3169"-04	0.0000"+00	0.1445	4.2450"-04	6.9701"+02	2.9286"+02
72010103	3.9800	1.0005	1.5468"+03	1.5501"-03	7.7648	1.3919	3.3551"+03	3.3551"+03
3.1674"-01	4.9600"+05	1.0000	5.1425"+03	NM	1.8416	1.8169	2.9300"+02	7.6294"+01
-2.5400"-01	3.1800"+02	0.0000	2.6350"-04	0.0000"+00	0.1450	4.7561"-04	6.9701"+02	2.9286"+02
72010104	3.9800	1.0005	1.6522"+03	1.4531"-03	7.8327	1.4013	3.3551"+03	3.3551"+03
3.2969"-01	4.9600"+05	1.0000	5.4930"+03	NM	1.8241	1.7917	2.9300"+02	7.6294"+01
-2.5400"-01	3.1800"+02	0.0000	2.8146"-04	0.0000"+00	0.1436	5.2785"-04	6.9701"+02	2.9286"+02
72010105	3.9800	1.0005	1.5143"+03	1.4530"-03	7.8375	1.4032	3.3551"+03	3.3551"+03
3.4265"-01	4.9600"+05	1.0000	5.0346"+03	NM	1.8239	1.7927	2.9300"+02	7.6294"+01
-2.5400"-01	3.1800"+02	0.0000	2.5797"-04	0.0000"+00	0.1436	4.8452"-04	6.9701"+02	2.9286"+02
72010106	3.8329	0.9989	1.7003"+03	1.4466"-03	7.3983	1.4061	4.0919"+03	4.0919"+03
3.5509"-01	4.9600"+05	1.0000	5.3443"+03	NM	1.8156	1.7880	2.9300"+02	8.0747"+01
-2.5400"-01	3.1800"+02	0.0000	2.5369"-04	3.0310"-01	0.1418	4.6959"-04	6.9056"+02	2.9333"+02
72010107	3.5295	0.9952	2.2417"+03	1.3768"-03	6.5996	1.4481	6.2366"+03	6.2366"+03
3.8049"-01	4.9600"+05	1.0000	6.2620"+03	NM	1.7943	1.7674	2.9300"+02	9.1079"+01
-2.5400"-01	3.1800"+02	0.0000	2.5311"-04	3.8798"-01	0.1375	4.5352"-04	6.7536"+02	2.9440"+02
72010108	3.3775	0.9932	2.8211"+03	1.2666"-03	6.3806	1.5758	7.7487"+03	7.7487"+03
3.9319"-01	4.9600"+05	1.0000	7.4206"+03	NM	1.7926	1.7655	2.9300"+02	9.6907"+01
-2.5400"-01	3.1800"+02	0.0000	2.7635"-04	5.1195"-01	0.1358	4.7740"-04	6.6663"+02	2.9501"+02
72010109	3.2267	0.9910	2.9751"+03	1.2688"-03	5.8675	1.4972	9.6474"+03	9.6474"+03
4.0589"-01	4.9600"+05	1.0000	7.3685"+03	NM	1.7727	1.7483	2.9300"+02	1.0317"+02
-2.5400"-01	3.1800"+02	0.0000	2.5281"-04	5.2098"-01	0.1328	4.3478"-04	6.5712"+02	2.9566"+02
72010110	3.0747	0.9886	3.5624"+03	1.1742"-03	5.6828	1.6260	1.2077"+04	1.2077"+04
4.1859"-01	4.9600"+05	1.0000	8.3002"+03	NM	1.7680	1.7464	2.9300"+02	1.1001"+02
-2.5400"-01	3.1800"+02	0.0000	2.6205"-04	6.5298"-01	0.1308	4.3643"-04	6.4658"+02	2.9637"+02
72010111	2.9209	0.9860	4.1226"+03	1.2271"-03	5.1226	1.5220	1.5211"+04	1.5211"+04
4.3129"-01	4.9600"+05	1.0000	9.0268"+03	NM	1.7594	1.7373	2.9300"+02	1.1750"+02
-2.5400"-01	3.1800"+02	0.0000	2.6195"-04	7.0225"-01	0.1283	4.2337"-04	6.3482"+02	2.9715"+02
72010112	2.7713	0.9833	4.4661"+03	1.1809"-03	5.0278	1.7057	1.9096"+04	1.9096"+04
4.4400"-01	4.9600"+05	1.0000	9.2038"+03	NM	1.7662	1.7479	2.9300"+02	1.2539"+02
-2.5400"-01	3.1800"+02	0.0000	2.4610"-04	7.7118"-01	0.1268	3.7944"-04	6.2220"+02	2.9797"+02
72010113	2.6169	0.9803	5.7028"+03	1.5257"-03	4.2220	1.4395	2.4216"+04	2.4216"+04
4.5669"-01	4.9600"+05	1.0000	1.1040"+04	NM	1.7956	1.7808	2.9300"+02	1.3420"+02
-2.5400"-01	3.1800"+02	0.0000	2.7150"-04	7.4629"-01	0.1263	3.8797"-04	6.0781"+02	2.9888"+02
72010114	2.4661	0.9772	6.7840"+03	1.7262"-03	3.8493	1.4210	3.0603"+04	3.0603"+04
4.6939"-01	4.9600"+05	1.0000	1.2357"+04	NM	1.8182	1.8086	2.9300"+02	1.4348"+02
-2.5400"-01	3.1800"+02	0.0000	2.8041"-04	7.7286"-01	0.1252	3.7717"-04	5.9227"+02	2.9985"+02
72010115	2.5545	0.9790	6.7071"+03	1.8069"-03	3.9027	1.3467	2.6673"+04	2.6673"+04
4.8209"-01	4.9600"+05	1.0000	1.2661"+04	NM	1.8399	1.8298	2.9300"+02	1.3796"+02
-2.5400"-01	3.1800"+02	0.0000	3.0110"-04	-4.6879"-01	0.1280	4.0063"-04	6.0157"+02	2.9928"+02
72010116	2.6504	0.9810	6.3462"+03	1.9101"-03	4.0313	1.3145	2.2995"+04	2.2995"+04
4.9479"-01	4.9600"+05	1.0000	1.2453"+04	NM	1.8614	1.8514	2.9300"+02	1.3223"+02
-2.5400"-01	3.1800"+02	0.0000	3.1183"-04	-4.0969"-01	0.1308	4.0938"-04	6.1106"+02	2.9868"+02

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72010101 LEWIS PROFILE TABULATION 21 POINTS, DELTA AT POINT 15

I	Y	PT2/P	P/PD	TO/TOD	M/MD	U/UD	T/TD	RHO/RHOD*U/UD
1	0.0000"+00	1.0000"+00	NM	0.92138	0.00000	0.00000	3.84040	0.00000
2	3.5326"-04	3.4595"+00	NM	0.95219	0.37994	0.62700	2.72334	0.23023
3	4.1041"-04	3.4465"+00	NM	0.95209	0.37909	0.62600 ,	2.72689	0.22957
4	6.2341"-04	4.6355"+00	NM	0.96015	0.45039	0.70300	2.43627	0.28856
5	8.6238"-04	6.1482"+00	NM	0.96816	0.52684	0.77200	2.14725	0.35953
6	1.2780"-03	7.5520"+00	NM	0.97405	0.58878	0.81900	1.93490	0.42328
7	1.6988"-03	8.7200"+00	NM	0.97813	0.63568	0.85000	1.78798	0.47540
8	2.2079"-03	1.0470"+01	NM	0.98319	0.70004	0.88700	1.60548	0.55248
9	2.7170"-03	1.2286"+01	NM	0.98746	0.76105	0.91700	1.45180	0.63163
10	3.2157"-03	1.4354"+01	NM	0.99142	0.82505	0.94400	1.30912	0.72109
11	3.7612"-03	1.6465"+01	NM	0.99473	0.88560	0.96600	1.18980	0.81190
12	4.2911"-03	1.8454"+01	NM	0.99734	0.93908	0.98300	1.09572	0.89712
13	4.7431"-03	1.9669"+01	NM	0.99874	0.97029	0.99200	1.04525	0.94905
14	5.2678"-03	2.0553"+01	NM	0.99968	0.99239	0.99800	1.01135	0.98680
D 15	5.8133"-03	2.0863"+01	NM	1.00000	1.00000	1.00000	1.00000	1.00000
16	6.3224"-03	2.0863"+01	NM	1.00000	1.00000	1.00000	1.00000	1.00000
17	6.8990"-03	2.0707"+01	NM	0.99984	0.99618	0.99900	1.00568	0.99336
18	7.3926"-03	2.0863"+01	NM	1.00000	1.00000	1.00000	1.00000	1.00000
19	7.7458"-03	2.0863"+01	NM	1.00000	1.00000	1.00000	1.00000	1.00000
20	8.4160"-03	2.0863"+01	NM	1.00000	1.00000	1.00000	1.00000	1.00000
21	8.9563"-03	2.0863"+01	NM	1.00000	1.00000	1.00000	1.00000	1.00000

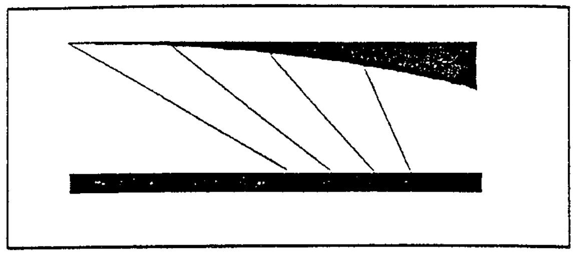
INPUT VARIABLES Y/DELTA,U/UD ASSUME P=PD AND VAN DRIEST

72010102 LEWIS PROFILE TABULATION 20 POINTS, DELTA AT POINT 13

I	Y	PT2/P	P/PD	TO/TOD	M/MD	U/UD	T/TD	RHO/RHOD*U/UD
1	0.0000"+00	1.0000"+00	NM	0.92138	0.00000	0.00000	3.84040	0.00000
2	1.5078"-04	2.8360"+00	NM	0.94709	0.33605	0.57300	2.90737	0.19709
3	3.8699"-04	4.3186"+00	NM	0.95818	0.43261	0.68500	2.50723	0.27321
4	7.9409"-04	6.7585"+00	NM	0.97088	0.55463	0.79400	2.04942	0.38743
5	1.2716"-03	7.9773"+00	NM	0.97561	0.60628	0.83100	1.87868	0.44233
6	1.6887"-03	9.4217"+00	NM	0.98029	0.66224	0.86600	1.71002	0.50643
7	2.1260"-03	1.1029"+01	NM	0.98460	0.71937	0.89700	1.55482	0.57691
8	2.5532"-03	1.2705"+01	NM	0.98833	0.77444	0.92300	1.42045	0.64979
9	2.9703"-03	1.4354"+01	NM	0.99142	0.82505	0.94400	1.30912	0.72109
10	3.3070"-03	1.6150"+01	NM	0.99427	0.87682	0.96300	1.20624	0.79835
11	3.8197"-03	1.7831"+01	NM	0.99657	0.92266	0.97800	1.12356	0.87044
12	4.3776"-03	1.9669"+01	NM	0.99874	0.97029	0.99200	1.04525	0.94905
D 13	4.9807"-03	2.0863"+01	NM	1.00000	1.00000	1.00000	1.00000	1.00000
14	6.0813"-03	2.0863"+01	NM	1.00000	1.00000	1.00000	1.00000	1.00000
15	7.2373"-03	2.0553"+01	NM	0.99968	0.99239	0.99800	1.01135	0.98680
16	8.3782"-03	2.0707"+01	NM	0.99984	0.99618	0.99900	1.00568	0.99336
17	9.5341"-03	2.0707"+01	NM	0.99984	0.99618	0.99900	1.00568	0.99336
18	1.0725"-02	2.0863"+01	NM	1.00000	1.00000	1.00000	1.00000	1.00000
19	1.1851"-02	2.2008"+01	NM	1.00111	1.02771	1.00700	0.96011	1.04884
20	1.2927"-02	2.2180"+01	NM	1.00127	1.03181	1.00800	0.95439	1.05618

INPUT VARIABLES Y/DELTA,U/UD ASSUME P=PD AND VAN DRIEST

Ref.: 25
Authors: Smith and Smits
Geometry: Streamwise APG, flat test surface
Mach number: 3
Data: p_{wall}, c_f, mean-flow profiles,
CTHWA turbulence data



D.R. Smith & A.J.Smits, "Investigation of a Supersonic Compressible Boundary Layer on a Flat Plate, Subjected to an Adverse Pressure Gradient," 1992 (in press).

(The following experiment description was provided by D. R. Smith)

WIND TUNNEL: 8" x 8" supersonic blowdown wind tunnel. Upstream of the pressure gradient, the rms frestream mass-flow fluctuation level is 2% of the mean freestream mass-flow rate. Details may be found in "A Preliminary Report on the Princeton University High-Reynolds Number 8" x 8" Supersonic Tunnel"; Internal Memo # 39, Gas Dynamics Laboratory, AMS Department, Princeton University, 1971.

TEST MODEL: Tunnel floor of second section after nozzle. An adverse pressure gradient is imposed on the tunnel floor b/l by a contoured plate in the freestream. The plate spans the entire width of the tunnel.

UNITS: All units are in SI (kg, m, s, K).

COORDINATE SYSTEM: X, Y & Z form a Right Handed Coordinate system, where:-
- X is the streamwise coordinate, measured from the nozzle exit.
  The maximum error in X is +/- 0.0005
- Y is measured normal to the test surface, with zero, being on the test surface.
  The maximum error in Y is +/- 0.00012
- Z is the spanwise co-ordinate, measured from the tunnel center line. Z is measured positive to the right, when looking downstream.
  The maximum error in Z is +/- 0.0005

FILENAME	NOTES
AGFPM.401	-Tunnel floor static pressure distribution. Two data sets are given.
AGFPM.402	-Raw and reduced Preston tube data; Utau from velocity profile fits to the log law; velocity profiles are transformed using two transformations (van Driest and Carvin/Smits)
AGFPM.403	-Reduced mean flow data from pitot, static pressure and assumed total temperature distribution in the boundary layer The static pressure is linearly interpolated to give the static pressure at each Y of the pitot probe. Pitot probe is built of flattened 0.000635 dia tubing. Probe tip height was0.00033 and the width was 0.00074. The opening was 0.00048 * 0.00008.

AGFPM.404 -Reduced data from constant temperature normal hotwire surveys and corresponding mean flow data. Hotwire data was reduced using the closest mean flow profile.

NOMENCLATURE IN FILES:

P wall, PW	-- wall static pressure
TAU wall, TAUWALL	-- wall friction obtained from Preston surveys
PS, Ps	-- local static pressure
PT	-- local pitot pressure
U	-- local flow speed
M	-- local mach number
M ref	-- upstream freestream mach number
UREF	-- upstream freestream speed
RHO	-- local density
RHO ref	-- upstream freestream density
RHOU	-- local mass flux
<(rhou)''>	-- rms of fluctuating mass flux
<u''>	-- rms of fluctuating streamwise velocity
PO	-- tunnel stagnation pressure
TO	-- tunnel stagnation temperature
PREST	-- measured preston pressure
CF	-- skin friction coefficient

COMMENTS:

1) For the pitot surveys, static pressure surveys, preston surveys & hot wire surveys the wall pressure was not obtained during the data runs. Instead the wall pressure from previously conducted SCANIVALVE surveys (in AGFPM.401) was directly used.

2) MREF was taken to be 2.859, based on upstream wall pressure and tunnel stagnation pressure.

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FILE AGFPM.401   SMITH & SMITS   (SAMPLE PRINTOUT PAGE)

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RUN 517   TEST 1   96 POINTS   P0=0.6903E+06 T0=268.8

17-MAY-88 APG,NEW MODEL SURFACE PRESSURE

X	Z	PW
2.000	-.9990	0.2172E+05
2.000	-.5000	0.2135E+05
2.000	0.0000E+00	0.2175E+05
2.000	0.5000	0.2169E+05
2.000	1.000	0.2175E+05
2.000	1.500	0.2188E+05
3.875	0.0000E+00	0.2200E+05
4.188	0.0000E+00	0.2216E+05
4.500	0.0000E+00	0.2235E+05
4.813	0.0000E+00	0.2262E+05
5.125	0.0000E+00	0.2262E+05
5.750	-.9990	0.2253E+05
5.750	-.5000	0.8594E+05
5.750	0.0000E+00	0.2379E+05
5.750	0.5000	0.2362E+05
5.750	1.000	0.2281E+05
5.750	1.500	0.2242E+05
6.375	0.0000E+00	0.2260E+05
6.688	0.0000E+00	0.2264E+05
7.000	0.0000E+00	0.2286E+05
7.313	0.0000E+00	0.2304E+05
7.625	0.0000E+00	0.2292E+05
8.250	-.9990	0.2661E+05
8.250	-.5000	0.2515E+05
8.250	0.0000E+00	0.2647E+05
8.250	0.5000	0.2636E+05
8.250	1.000	0.2631E+05
8.250	1.500	0.2285E+05
8.875	0.0000E+00	0.2540E+05
9.188	0.0000E+00	0.2785E+05
9.500	0.0000E+00	0.3362E+05
9.813	0.0000E+00	0.3339E+05
10.13	0.0000E+00	0.3349E+05
10.75	-.9990	0.3899E+05
10.75	-.5000	0.3869E+05
10.75	0.0000E+00	0.3962E+05
10.75	0.5000	0.3849E+05
10.75	1.000	0.3883E+05
10.75	1.500	0.3915E+05
11.38	0.0000E+00	0.4565E+05
11.69	0.0000E+00	0.4902E+05
12.00	0.0000E+00	0.5305E+05
12.31	0.0000E+00	0.5618E+05
12.63	0.0000E+00	0.5882E+05
13.25	-.9990	0.6291E+05
13.25	-.5000	0.6288E+05
13.25	0.0000E+00	0.6322E+05
13.25	0.5000	0.6390E+05
13.25	1.000	0.6442E+05
13.25	1.500	0.6451E+05

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FILE AGFPM.402 SMITH & SMITS

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STREAMWISE PRESTON TUBE DATA FOR FLAT PLATE MODEL 4

X(m)	Z	DIA	PO	TO	PREST	PWALL
1.000	0.0000E+00	0.1651E-02	0.6886E+06	269.0	0.7417E+05	0.2218E+05
1.026	0.0000E+00	0.1651E-02	0.6889E+06	268.0	0.7509E+05	0.2280E+05
1.064	0.0000E+00	0.1651E-02	0.6888E+06	269.0	0.7512E+05	0.2293E+05
1.089	0.0000E+00	0.1651E-02	0.6911E+06	266.0	0.7650E+05	0.2326E+05
1.127	0.0000E+00	0.1651E-02	0.6761E+06	270.0	0.7731E+05	0.2549E+05
1.153	0.0000E+00	0.1651E-02	0.6888E+06	266.0	0.8612E+05	0.3364E+05
1.191	0.0000E+00	0.1651E-02	0.6874E+06	266.0	0.1019E+06	0.4463E+05
1.216	0.0000E+00	0.1651E-02	0.6919E+06	264.0	0.1087E+06	0.5552E+05
1.254	0.0000E+00	0.1651E-02	0.6924E+06	265.0	0.1269E+06	0.6638E+05
1.280	0.0000E+00	0.1651E-02	0.6931E+06	266.0	0.1411E+06	0.6823E+05
1.318	0.0000E+00	0.1651E-02	0.6907E+06	266.0	0.1511E+06	0.6571E+05

REDUCED PRESTON TUBE DATA FOR FLAT PLATE MODEL 4

Bradshaw-Unsworth & Hopkins-Keener Preston probe calibration scheme

X	Z	B-U-Tauw	H-K-T"-Tauw	H-K-Tw-Tauw	B-U-Utau	B-U-Cfref
1.000	0.0000E+00	142.3	152.2	166.8	22.71	0.1072E-02
1.026	0.0000E+00	143.5	152.7	167.3	22.45	0.1081E-02
1.064	0.0000E+00	143.8	152.2	166.8	22.45	0.1084E-02
1.089	0.0000E+00	145.4	154.0	168.7	22.29	0.1092E-02
1.127	0.0000E+00	146.7	152.3	166.5	21.55	0.1126E-02
1.153	0.0000E+00	156.2	154.7	168.3	19.21	0.1177E-02
1.191	0.0000E+00	172.1	168.2	182.0	17.50	0.1299E-02
1.216	0.0000E+00	173.2	161.8	174.4	15.69	0.1299E-02
1.254	0.0000E+00	194.7	179.3	192.5	15.24	0.1459E-02
1.280	0.0000E+00	220.7	205.3	220.2	16.03	0.1652E-02
1.318	0.0000E+00	242.1	227.8	244.6	17.11	0.1819E-02

CLAUSER CHART WALL SHEAR FOR FLAT PLATE MODEL 4:

-UTAU FROM CLAUSER CHART USING THE VAN DRIEST TRANSFORMATION

X	Z	UTAU	TAUWALL	Cf
1.064	0.0000E+00	22.80	147.2	0.1100E-02
1.127	0.0000E+00	21.98	152.3	0.9850E-03
1.191	0.0000E+00	16.70	156.1	0.8621E-03
1.254	0.0000E+00	15.37	193.8	0.8812E-03
1.318	0.0000E+00	16.85	231.7	0.1054E-02

-UTAU FROM CLAUSER CHART USING THE CARVIN ET AL. TRANSFORMATION

X	Z	UTAU	TAUWALL	Cf
1.064	0.0000E+00	22.40	142.1	0.1062E-02
1.127	0.0000E+00	21.75	149.1	0.9645E-03
1.191	0.0000E+00	16.55	153.3	0.8467E-03
1.254	0.0000E+00	15.25	190.8	0.8675E-03
1.318	0.0000E+00	16.70	227.6	0.1036E-02

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FILE AGFPM.403 SMITH & SMITS (SAMPLE PRINTOUT PAGE)

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MEAN PROFILE TABULATION
24-MAY-88APG,PITOT PRESSURE

X		= 1.064
Z		= 0.0000E+00
Stagnation Pressure	pitot	= 0.6930E+06
Stagnation Temperature	pitot	= 271.0
M ref		= 2.859
U ref	pitot	= 581.4
P wall		= 0.2293E+05
TAU wall	preston	= 143.8

Y	PT/PWALL	PS/PWALL	U/UREF	M
0.8250E-03	3.333	1.000	0.7141	1.480
0.9509E-03	3.297	1.015	0.7056	1.455
0.1076E-02	3.426	1.014	0.7175	1.490
0.1187E-02	3.526	1.012	0.7268	1.519
0.1292E-02	3.604	1.010	0.7337	1.540
0.1383E-02	3.669	1.010	0.7393	1.558
0.1489E-02	3.796	1.009	0.7494	1.589
0.1586E-02	3.867	1.008	0.7548	1.607
0.1709E-02	3.914	1.007	0.7591	1.621
0.1835E-02	3.973	1.003	0.7645	1.639
0.1953E-02	4.085	1.002	0.7719	1.664
0.2179E-02	4.188	1.002	0.7791	1.689
0.2369E-02	4.259	1.000	0.7852	1.710
0.2583E-02	4.400	1.004	0.7932	1.738
0.2846E-02	4.427	1.005	0.7941	1.742
0.3068E-02	4.592	1.007	0.8034	1.775
0.3249E-02	4.666	1.012	0.8072	1.789
0.3462E-02	4.727	1.016	0.8091	1.797
0.3699E-02	4.845	1.016	0.8166	1.825
0.3914E-02	4.924	1.015	0.8203	1.839
0.4104E-02	4.967	1.014	0.8221	1.846
0.4528E-02	5.168	1.008	0.8348	1.896
0.4946E-02	5.299	1.003	0.8435	1.931
0.5370E-02	5.443	0.9995	0.8503	1.959
0.5770E-02	5.508	0.9993	0.8535	1.974
0.6189E-02	5.661	0.9944	0.8618	2.009
0.6600E-02	5.840	0.9919	0.8699	2.044
0.6979E-02	5.879	0.9904	0.8729	2.058
0.7389E-02	5.992	0.9880	0.8775	2.080
0.7791E-02	6.136	0.9892	0.8837	2.108
0.8200E-02	6.271	0.9871	0.8896	2.136
0.8592E-02	6.385	0.9867	0.8940	2.158
0.8979E-02	6.463	0.9862	0.8968	2.172
0.9348E-02	6.550	0.9854	0.8996	2.186
0.9739E-02	6.738	0.9871	0.9067	2.221
0.1012E-01	6.908	0.9851	0.9123	2.250
0.1053E-01	6.973	0.9853	0.9149	2.264
0.1091E-01	6.986	0.9845	0.9146	2.264
0.1132E-01	7.222	0.9852	0.9227	2.306
0.1168E-01	7.283	0.9840	0.9253	2.320
0.1209E-01	7.423	0.9867	0.9291	2.342
0.1287E-01	7.811	0.9876	0.9404	2.405
0.1364E-01	8.003	0.9890	0.9450	2.434

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FILE AGFPM.404 SMITH & SMITS (SAMPLE PRINTOUT PAGE)

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NORMAL-WIRE PROFILE TABULATION

X	=	1.064
Z	=	0.0000E+00
M ref HW	=	2.859
U ref HW	=	581.8
RHO ref HW	=	0.7888
TAU wall	=	143.8
P wall mean flow	=	0.2293E+05

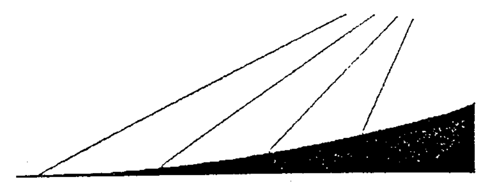
Y	<(rhou)"> RHOU	U UREF	M	Ps Pwall	<u">**2 U**2	RHO<u">**2 RHOref Uref**2
0.2448E-02	0.1513	0.7882	1.720	1.001	0.5329E-02	0.1900E-02
0.4101E-02	0.1407	0.8221	1.846	1.014	0.3929E-02	0.1633E-02
0.5715E-02	0.1321	0.8531	1.972	0.9993	0.2954E-02	0.1381E-02
0.7339E-02	0.1377	0.8769	2.077	0.9883	0.2813E-02	0.1444E-02
0.8935E-02	0.1362	0.8965	2.170	0.9863	0.2452E-02	0.1371E-02
0.1047E-01	0.1295	0.9145	2.262	0.9853	0.1982E-02	0.1203E-02
0.1200E-01	0.1314	0.9283	2.337	0.9861	0.1863E-02	0.1209E-02
0.1346E-01	0.1309	0.9439	2.427	0.9887	0.1660E-02	0.1165E-02
0.1485E-01	0.1242	0.9545	2.493	0.9941	0.1383E-02	0.1029E-02
0.1625E-01	0.1180	0.9654	2.564	0.9959	0.1149E-02	0.9065E-03
0.1765E-01	0.1134	0.9734	2.619	0.9965	0.9952E-03	0.8203E-03
0.1909E-01	0.1069	0.9826	2.686	0.9954	0.8199E-03	0.7097E-03
0.2053E-01	0.9901E-01	0.9915	2.752	0.9939	0.6525E-03	0.5925E-03
0.2193E-01	0.7097E-01	0.9937	2.774	0.9978	0.3271E-03	0.3030E-03
0.2327E-01	0.5544E-01	0.9949	2.789	1.053	0.1962E-03	0.1940E-03
0.2465E-01	0.4982E-01	0.9965	2.807	1.060	0.1553E-03	0.1566E-03
0.2605E-01	0.3032E-01	0.9989	2.831	1.043	0.5602E-04	0.5658E-04
0.2749E-01	0.1956E-01	1.001	2.851	1.028	0.2281E-04	0.2301E-04
0.2892E-01	0.9981E-02	1.001	2.858	1.021	0.5894E-05	0.5919E-05

NORMAL-WIRE PROFILE TABULATION

X	=	1.191
Z	=	0.0000E+00
M ref HW	=	2.859
U ref HW	=	580.3
RHO ref HW	=	0.7915
TAU wall	=	172.1
P wall mean flow	=	0.4463E+05

Y	<(rhou)"> RHOU	U UREF	M	Ps Pwall	<u">**2 U**2	RHO<u">**2 RHOref Uref**2
0.1538E-02	0.2050	0.6060	1.186	1.022	0.1896E-01	0.6395E-02
0.2608E-02	0.1940	0.6630	1.336	1.009	0.1419E-01	0.5999E-02
0.3710E-02	0.1883	0.7095	1.470	1.003	0.1132E-01	0.5760E-02
0.4783E-02	0.1698	0.7354	1.550	1.005	0.8327E-02	0.4721E-02
0.5853E-02	0.1623	0.7616	1.636	1.008	0.6824E-02	0.4323E-02
0.6942E-02	0.1596	0.7868	1.723	1.007	0.5907E-02	0.4149E-02
0.8062E-02	0.1494	0.8115	1.814	1.005	0.4611E-02	0.3582E-02
0.9148E-02	0.1517	0.8296	1.886	1.001	0.4343E-02	0.3632E-02
0.1020E-01	0.1488	0.8516	1.976	0.9992	0.3728E-02	0.3419E-02
0.1120E-01	0.1421	0.8680	2.047	1.000	0.3110E-02	0.3066E-02

Ref.: 28
Authors: Sturek and Danberg
Geometry: Streamwise APG,
curved wall
Mach number: 3.5
Data: p_{wall}, c_f, mean-flow surveys



Sturek, W. B., "An Experimental Investigation of the Supersonic Turbulent Boundary Layer in a Moderate Adverse Pressure Gradient, Part 1-A Detailed Description of the Experiment and Tabulation," Army BRL Report 1506-PT-1, 1970.

Sturek, W. B., and Danberg, J. E., "Supersonic Turbulent Boundary Layer in Adverse Pressure Gradient. Part I: The Experiment," *AIAA Journal*, Vol. 10, No. 4, April 1972, pp. 475-480.

ABSTRACT: Experimental measurements of the profile characteristics of the supersonic turbulent boundary layer in a region of moderate adverse pressure gradient and an analysis of the data are reported. The data are for a closely adiabatic wall at a tunnel nozzle setting of M = 3.54. All measurements necessary for a complete set of profile data were made. Turbulent boundary layer equations are analyzed by numerical integration using the tabulated profile data. The data correlated in law of the wall and velocity defect dimensionless coordinates using an integral compressibility transformation. Distributions of eddy viscosity and mixing length are calculated using the mean profile data.

Sturek and Danberg's experiment, along with those of Laderman and Lewis et al., tabulated elsewhere in this report, is one of the classic experiments on compressible turbulent boundary layers in adverse pressure gradients. As such, it was fully documented and discussed by Fernholz and Finley as Catalog number 7101 in AGARDograph 223, to which the interested reader is referred. Our present goal is not to repeat that documentation, but rather to make the dataset more readily available in machine-readable form than it was at the time of the original Fernholz-Finley tabulation. Accordingly, we have listed below only a brief recap of the standard Fernholz-Finley notation as used in the accompanying data file (SI units are used throughout) and a copy of the authors' model coordinate tables. For more complete documentation, see AGARDograph 223 and the authors' original paper and report (Ref. 28) cited above.

NOMENCLATURE

CF	skin friction coefficient
CQ	heat transfer coeffiicent
D	boundary layer thickness

D1	boundary layer displacement thickness
D2	boundary layer momentum thickness
D3	boundary layer kinetic energy thickness
D4	boundary layer total enthalpy thickness
H12	shape factor D1/D2
H32	shape factor D3/D2
H42	shape factor D4/D2
M	Mach number
MD	Mach number at boundary layer edge
NM	not measured
P	static pressure
PI2	pressure gradient parameter
PD	static pressure at boundary layer edge
P0D	stagnation pressure at boundary layer edge
PT2	pitot pressure
PW	wall static pressure
R	recovery factor
RED2D	Reynolds number based on momentum thickness and b.l. edge viscosity
RED2W	Reynolds number based on momentum thickness and wall viscosity
RHO	static density
RHOD	static density at boundary layer edge
RZ	transverse radius of curvature
SW	longitudinal pressure gradient number (see AGARDograph 223 eqn. 5.5)
T	static temperature
TAUW	wall shear stress
TD	static temperature at boundary layer edge
T0	stagnation temperature
T0D	stagnation temperature at boundary layer edge
TR	recovery temperature
TW	wall temperature
U	velocity component in x-direction
UD	velocity component in x-direction at boundary-layer edge
X	streamwise axial coordinate
Y	coordinate normal to wall

FACSIMILES OF TABLES SUPPLIED BY AUTHORS. DIMENSIONS IN INCHES.

TABLE 1 CORRECTED MODEL COORDINATES (INCHES)

X	Y		X	Y		X	Y
12.006	.010		15.756	.224		18.661	.673
12.914	.023		16.000	.252		18.901	.722
					06 ········		
13.141	.030		16.243	.282		19.141	.772
13.368	.036		16.486	.313		19.380	.824
13.594	.049		16.729	.346		19.619	.877
13.821	.061		16.971	.381		19.853	.932
		04 ········			07 ········		
14.046	.074		17.213	.416		20.097	.989
14.292	.090		17.455	.455		20.366	1.055
14.537	.108		17.697	.496		20.638	1.124
14.781	.128		17.938	.538		20.908	1.194
		05 ········			08 ········		
15.025	.149		18.180	.581		21.178	1.266
15.269	.172		18.420	.627		21.447	1.341
15.513	.197						

CORRECTED TABLE 2

STA	X	Y	¢	CAT 7101
116	16.000	.252	6.75	-
117	17.019	.388	8.13	04
118	18.035	.559	9.55	05
119	19.021	.747	11.48	06
120	20.024	.959	13.24	07
121	21.016	1.215	14.65	08

(SAMPLE OUTPUT PAGE)

Fernholz & Finley AGARDograph 223 Case 7101 STUREK 26 PROFILES

CAT 7101 STUREK BOUNDARY CONDITIONS AND EVALUATED DATA. SI UNITS.

RUN	MD *	TW/TR	RED2W	CF	H12	H12K	PW*	PD*
X *	POD	PW/PD	RED2D	CQ	H32	H32K	TW*	TD*
RZ	TOD	SW *	D2	PI2*	H42	D2K	UD	TR
71010101	3.5090	1.0213	6.5554"+03	1.0722"-03	6.5853	1.3544	3.3623"+03	3.3626"+03
1.5240"-01	2.5977"+05	0.9999	1.8664"+04	NM	1.8023	1.7738	2.9056"+02	8.8722"+01
INFINITE	3.0721"+02	1.0000	1.3540"-03	0.0000"+00	0.0666	2.3769"-03	6.6269"+02	2.8449"+02
71010102	3.5320	1.0244	6.7225"+03	1.0929"-03	6.7025	1.3510	3.3477"+03	3.3474"+03
2.0320"-01	2.6716"+05	1.0001	1.9365"+04	NM	1.7988	1.7706	2.9056"+02	8.7667"+01
INFINITE	3.0640"+02	1.0000	1.3775"-03	0.0000"+00	0.0573	2.4621"-03	6.6305"+02	2.8365"+02
71010103	3.4890	1.0217	7.0625"+03	1.0846"-03	6.5986	1.3571	3.3800"+03	3.3798"+03
2.5400"-01	2.5379"+05	1.0001	1.9961"+04	NM	1.7990	1.7715	2.9056"+02	8.9389"+01
INFINITE	3.0702"+02	1.0000	1.4651"-03	0.0000"+00	0.0517	2.5870"-03	6.6138"+02	2.8438"+02
71010104	3.2450	1.0183	1.0678"+04	9.3101"-04	4.2465	1.4812	6.0456"+03	4.8891"+03
4.3307"-01	2.5819"+05	1.2366	2.7381"+04	NM	1.7368	1.7128	2.9056"+02	9.8833"+01
INFINITE	3.0698"+02	1.0000	1.7313"-03	1.5068"+00	0.0755	2.6448"-03	6.4681"+02	2.8533"+02
71010105	3.1650	1.0230	1.1430"+04	9.1943"-04	4.3163	1.4765	6.8158"+03	5.6047"+03
4.5872"-01	2.6316"+05	1.2161	2.8538"+04	NM	1.7346	1.7118	2.9056"+02	1.0161"+02
INFINITE	3.0518"+02	1.0000	1.6805"-03	1.4557"+00	0.0397	2.5843"-03	6.3967"+02	2.8401"+02
71010106	3.0550	1.0305	1.1879"+04	9.3654"-04	4.0283	1.4614	7.6395"+03	6.3480"+03
4.8463"-01	2.5318"+05	1.2035	2.8612"+04	NM	1.7412	1.7199	2.9056"+02	1.0550"+02
INFINITE	3.0243"+02	1.0000	1.6278"-03	1.3830"+00	0.0443	2.4219"-03	6.2914"+02	2.8195"+02
71010107	2.9820	1.0169	1.2814"+04	9.1815"-04	4.1472	1.4635	8.6486"+03	7.3815"+03
5.1079"-01	2.6391"+05	1.1717	2.9620"+04	NM	1.7365	1.7165	2.9056"+02	1.1017"+02
INFINITE	3.0609"+02	1.0000	1.5809"-03	1.3116"+00	0.0513	2.3780"-03	6.2754"+02	2.8572"+02
71010108	2.9050	1.0175	1.3377"+04	9.7906"-04	4.1479	1.4673	9.4723"+03	8.3006"+03
5.3670"-01	2.6424"+05	1.1412	3.0022"+04	NM	1.7417	1.7226	2.9056"+02	1.1367"+02
INFINITE	3.0551"+02	1.0000	1.5303"-03	1.1699"+00	0.0612	2.2869"-03	6.2097"+02	2.8556"+02
71010201	3.5100	1.0183	8.1975"+03	1.0429"-03	6.6118	1.3598	4.1929"+03	4.1927"+03
1.5240"-01	3.2436"+05	1.0001	2.3290"+04	NM	1.7983	1.7688	2.9000"+02	8.8778"+01
INFINITE	3.0753"+02	1.0000	1.3560"-03	0.0000"+00	0.0662	2.4033"-03	6.6308"+02	2.8478"+02
71010202	3.5400	1.0218	8.0409"+03	1.0578"-03	6.7987	1.3490	4.1494"+03	4.1493"+03
2.0320"-01	3.3493"+05	1.0000	2.3186"+04	NM	1.8008	1.7739	2.9000"+02	8.7444"+01
INFINITE	3.0661"+02	1.0000	1.3226"-03	0.0000"+00	0.0354	2.3621"-03	6.6371"+02	2.8382"+02
71010203	3.5000	1.0185	8.6932"+03	1.0567"-03	6.6072	1.3582	4.2020"+03	4.2017"+03
2.5400"-01	3.2047"+05	1.0001	2.4608"+04	NM	1.7998	1.7716	2.9000"+02	8.9111"+01
INFINITE	3.0743"+02	1.0000	1.4417"-03	0.0000"+00	0.0588	2.5480"-03	6.6244"+02	2.8473"+02
71010204	3.2350	1.0136	1.2718"+04	9.2766"-04	4.1686	1.4575	7.5495"+03	6.1212"+03
4.3307"-01	3.1856"+05	1.2333	3.2354"+04	NM	1.7462	1.7229	2.9000"+02	9.9500"+01
INFINITE	3.0776"+02	1.0000	1.6552"-03	1.3927"+00	0.0743	2.4931"-03	6.4699"+02	2.8610"+02
71010205	3.1610	1.0139	1.3762"+04	9.0079"-04	4.1987	1.4503	8.5265"+03	7.0333"+03
4.5872"-01	3.2830"+05	1.2123	3.4024"+04	NM	1.7435	1.7216	2.9000"+02	1.0250"+02
INFINITE	3.0733"+02	1.0000	1.6191"-03	1.4103"+01	0.0677	2.4508"-03	6.4165"+02	2.8603"+02
71010206	3.0670	1.0134	1.4135"+04	9.0454"-04	4.3941	1.4642	9.5647"+03	8.0772"+03
4.8412"-01	3.2796"+05	1.1842	3.3676"+04	NM	1.7451	1.7185	2.9000"+02	1.0656"+02
INFINITE	3.0702"+02	1.0000	1.5217"-03	1.3443"+00	0.0641	2.3669"-03	6.3476"+02	2.8617"+02
71010207	2.9950	1.0106	1.5429"+04	9.1215"-04	4.1367	1.4512	1.0809"+04	9.1866"+03
5.1079"-01	3.3493"+05	1.1767	3.5649"+04	NM	1.7401	1.7210	2.9000"+02	1.1006"+02
INFINITE	3.0750"+02	1.0000	1.5199"-03	1.2884"+00	0.0629	2.2807"-03	6.2996"+02	2.8696"+02
71010208	2.9090	1.0089	1.5908"+04	9.7347"-04	4.1065	1.4280	1.1865"+04	1.0415"+04
5.3670"-01	3.3357"+05	1.1392	3.5486"+04	NM	1.7524	1.7360	2.9000"+02	1.1422"+02
INFINITE	3.0754"+02	1.0000	1.4498"-03	1.1273"+00	0.0717	2.1466"-03	6.2335"+02	2.8743"+02

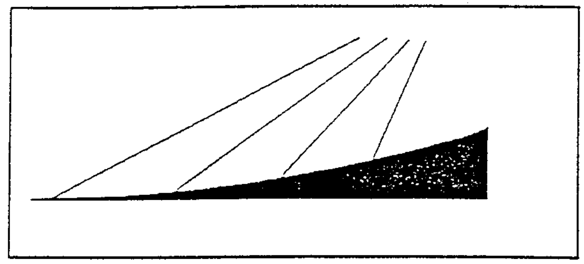
71010101 STUREK PROFILE TABULATION 68 POINTS, DELTA AT POINT 65

(SAMPLE OUTPUT PAGE)

I	Y	PT2/P	P/PD	TO/TOD	M/MD	U/UD	T/TD	RHO/RHOD*U/UD
1	0.0000"+00	1.0000"+00	0.99991	0.94578	0.00000	0.00000	3.27489	0.00000
2	9.9060"-05	1.3264"+00	1.00000	0.94176	0.18473	0.32040	3.00814	0.10651
3	1.7018"-04	1.5395"+00	1.00000	0.94182	0.23082	0.39191	2.88291	0.13594
4	3.2004"-04	2.0869"+00	1.00000	0.93980	0.30834	0.50069	2.63682	0.18988
5	5.3086"-04	2.3999"+00	1.00000	0.93822	0.34123	0.54220	2.52473	0.21475
6	7.1120"-04	2.6233"+00	1.00000	0.93787	0.36236	0.56764	2.45398	0.23132
7	1.1201"-03	3.0613"+00	1.00000	0.93974	0.39996	0.61108	2.33438	0.26177
8	1.3691"-03	3.2446"+00	1.00000	0.94196	0.41454	0.62755	2.29180	0.27383
9	1.5799"-03	3.5629"+00	1.00000	0.94476	0.43859	0.65346	2.21979	0.29438
10	2.1006"-03	3.8254"+00	1.00000	0.94945	0.45741	0.67375	2.16969	0.31053
11	2.6086"-03	4.1339"+00	1.00000	0.95446	0.47850	0.69561	2.11334	0.32915
12	3.1166"-03	4.3921"+00	1.00000	0.95835	0.49543	0.71250	2.06825	0.34449
13	3.6246"-03	4.6313"+00	1.00000	0.96148	0.51059	0.72704	2.02755	0.35858
14	4.1326"-03	4.9045"+00	1.00000	0.96402	0.52735	0.74227	1.98121	0.37465
15	4.6406"-03	5.1475"+00	1.00000	0.96648	0.54180	0.75511	1.94239	0.38875
16	5.1486"-03	5.4711"+00	1.00000	0.96858	0.56045	0.77071	1.89105	0.40756
17	5.6566"-03	5.7047"+00	1.00000	0.97052	0.57353	0.78147	1.85661	0.42092
18	6.1646"-03	6.0009"+00	1.00000	0.97318	0.58969	0.79450	1.81528	0.43767
19	6.6726"-03	6.3009"+00	1.00000	0.97536	0.60560	0.80674	1.77458	0.45461
20	7.1806"-03	6.5425"+00	1.00000	0.97784	0.61811	0.81640	1.74452	0.46798
21	7.6886"-03	6.8253"+00	1.00000	0.98032	0.63243	0.82703	1.71008	0.48362
22	8.1966"-03	7.0584"+00	1.00000	0.98255	0.64399	0.83550	1.68316	0.49639
23	8.7046"-03	7.4506"+00	1.00000	0.98478	0.66299	0.84838	1.63745	0.51811
24	9.2126"-03	7.7795"+00	1.00000	0.98664	0.67850	0.85855	1.60113	0.53622
25	9.7206"-03	8.0698"+00	1.00000	0.98863	0.69190	0.86725	1.57107	0.55201
26	1.0229"-02	8.4496"+00	1.00000	0.99038	0.70905	0.87769	1.53225	0.57281
27	1.0737"-02	8.7471"+00	1.00000	0.99228	0.72219	0.88570	1.50407	0.58887
28	1.1245"-02	9.0906"+00	1.00000	0.99395	0.73707	0.89430	1.47214	0.60749
29	1.1753"-02	9.4922"+00	1.00000	0.99535	0.75409	0.90360	1.43582	0.62933
30	1.2261"-02	9.7858"+00	1.00000	0.99661	0.76630	0.91018	1.41077	0.64516
31	1.2769"-02	1.0205"+01	1.00000	0.99821	0.78340	0.91906	1.37633	0.66776
32	1.3277"-02	1.0534"+01	1.00000	0.99955	0.79655	0.92573	1.35066	0.68539
33	1.3785"-02	1.0893"+01	1.00000	1.00047	0.81064	0.93245	1.32311	0.70474
34	1.4293"-02	1.1277"+01	1.00000	1.00153	0.82548	0.93935	1.29493	0.72541
35	1.4801"-02	1.1577"+01	1.00000	1.00222	0.83687	0.94446	1.27364	0.74154
36	1.5309"-02	1.2006"+01	1.00000	1.00303	0.85290	0.95136	1.24421	0.76463
37	1.5817"-02	1.2304"+01	1.00000	1.00329	0.86389	0.95583	1.22417	0.78079
38	1.6325"-02	1.2639"+01	1.00000	1.00392	0.87603	0.96080	1.20288	0.79875
39	1.6833"-02	1.2956"+01	1.00000	1.00455	0.88737	0.96535	1.18347	0.81570
40	1.7341"-02	1.3266"+01	1.00000	1.00483	0.89834	0.96949	1.16468	0.83241
41	1.7849"-02	1.3575"+01	1.00000	1.00505	0.90912	0.97345	1.14652	0.84904
42	1.8357"-02	1.3834"+01	1.00000	1.00505	0.91808	0.97658	1.13150	0.86309
43	1.8865"-02	1.4085"+01	1.00000	1.00486	0.92668	0.97943	1.11709	0.87677
44	1.9373"-02	1.4361"+01	1.00000	1.00502	0.93604	0.98265	1.10207	0.89165
45	1.9881"-02	1.4511"+01	1.00000	1.00492	0.94106	0.98426	1.09393	0.89975
46	2.0389"-02	1.4730"+01	1.00000	1.00464	0.94839	0.98652	1.08203	0.91173
47	2.0897"-02	1.4903"+01	1.00000	1.00426	0.95413	0.98817	1.07264	0.92126
48	2.1405"-02	1.5060"+01	1.00000	1.00354	0.95930	0.98946	1.06387	0.93006
49	2.1913"-02	1.5256"+01	1.00000	1.00337	0.96573	0.99140	1.05385	0.94074
50	2.2421"-02	1.5355"+01	1.00000	1.00328	0.96898	0.99236	1.04884	0.94615
51	2.2929"-02	1.5506"+01	1.00000	1.00313	0.97387	0.99379	1.04133	0.95435
52	2.3437"-02	1.5653"+01	1.00000	1.00271	0.97862	0.99503	1.03381	0.96249
53	2.3945"-02	1.5755"+01	1.00000	1.00257	0.98191	0.99595	1.02880	0.96807
54	2.4453"-02	1.5801"+01	1.00000	1.00224	0.98338	0.99623	1.02630	0.97070
55	2.4961"-02	1.5931"+01	1.00000	1.00206	0.98753	0.99738	1.02004	0.97778
56	2.5469"-02	1.5951"+01	1.00000	1.00176	0.98818	0.99742	1.01879	0.97903
57	2.5977"-02	1.6049"+01	1.00000	1.00130	0.99131	0.99811	1.01378	0.98455
58	2.6485"-02	1.6100"+01	1.00000	1.00052	0.99293	0.99821	1.01064	0.98769
59	2.6993"-02	1.6145"+01	1.00000	1.00070	0.99436	0.99871	1.00877	0.99003
60	2.7501"-02	1.6200"+01	1.00000	1.00070	0.99610	0.99922	1.00626	0.99300
61	2.8009"-02	1.6225"+01	1.00000	1.00060	0.99691	0.99940	1.00501	0.99442
62	2.8517"-02	1.6270"+01	1.00000	1.00013	0.99834	0.99959	1.00250	0.99709
63	2.9025"-02	1.6295"+01	1.00000	0.99997	0.99910	0.99972	1.00125	0.99847
64	2.9533"-02	1.6298"+01	1.00000	1.00010	0.99919	0.99982	1.00125	0.99857
D 65	3.0041"-02	1.6323"+01	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
66	3.0549"-02	1.6316"+01	1.00000	0.99967	0.99977	0.99977	1.00000	0.99977
67	3.1057"-02	1.6326"+01	1.00000	1.00013	1.00009	1.00009	1.00000	1.00009
68	3.1565"-02	1.6323"+01	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

INPUT VARIABLES Y,U,T,P

Ref.: 29, 17
Authors: Taylor et al.
Geometry: Streamwise APG, curved ramp
Mach number: 3
Data: p_{wall}, c_f, mean-flow profiles



Taylor, M. W., "A Supersonic Turbulent Boundary Layer on Concavely Curved Surfaces," Princeton University, Mechanical and Aerospace Engrg. Dept. Report MAE-1684, 1984.

Jayaram, M., Taylor, M. W., and Smits, A. J., "The Response of a Compressible Turbulent Boundary Layer to Short Regions of Concave Surface Curvature," *Journal of Fluid Mechanics*, 1987, Vol. 175, pp. 343-362.

The Taylor data are the companion mean-flow data to the hot-wire measurements of Jayaram, tabulated elsewhere in this report. These datasets are thoroughly documented in AGARDograph 315 under catalog entries 8401T and 8702T. Users are directed to that reference for further details concerning the datasets. In addition, the following description of the experiment and the data files was provided with the data:

```
ABTSRACT    THESE RESULTS FOLLOW AN EXPERIMENTAL STUDY OF A SUPERSONIC
            TURBULENT BOUNDARY LAYER EXPERIENCING CONCAVE STREAMLINE
            CURVATURE.  TWO-DIMENSIONAL CURVED MODELS WERE MOUNTED ON THE
            FLOOR OF THE PRINCETON UNIVERSITY 0.2 X 0.2 M HIGH REYNOLDS
            NUMBER SUPERSONIC BLOWDOWN WIND TUNNEL.  THREE CONSTANT RADII
            CURVATURES OF DELTAO/R = 0.1 AND 0.2 AND FIXED TURNING ANGLES
            OF 8 DEGREES AND 16 DEGREES WERE INVESTIGATED.  THE INCOMING
            BOUNDARY LAYER WAS AT A NOMINAL FREESTREAM MACH NUMBER OF 2.9
            AND UNIT REYNOLDS NUMBER OF 6.3E+07/M.
               FLOWFIELD DATA PRESENTED HERE ARE FOR THE THREE MODELS
            INVESTIGATED.  MODEL 1 HAD A RADIUS OF CURVATURE R=0.254M
            AND A TURNING ANGLE OF 8 DEGREES.  FOR MODEL 2, R=1.270M
            AND THE TURNING ANGLE WAS 8 DEGREES. MODEL 3 HAD A 16 DEGREE
            TURNING ANGLE AND A RADIUS OF CURVATURE, R=1.270M.
            THE CURVED PORTIONS WERE FOLLOWED BY A SHORT RECOVERY SECTION
            DOWNSTREAM FOR ALL CASES.
            SURFACE AND FLOWFIELD MEASUREMENTS ARE GIVEN AT STATIONS
            THROUGHOUT EACH INTERACTION.  THE X COORDINATE IS DEFINED IN
            THE STREAMWISE DIRECTION ALONG THE SURFACE OF THE WIND TUNNEL
            FLOOR AND THE CURVED CORNERS.  THE ORIGIN OF X IS AT THE
            START OF CURVATURE;  THUS, ALL LOCATIONS UPSTREAM OF THE
            START OF CURVATURE BEAR NEGATIVE X-VALUES, WHILE ALL THOSE
            ON THE CURVED MODELS BEAR POSITIVE VALUES.  THE Y COORDINATE
            IS ZERO ON THE TEST SURFACE, POSITIVE ABOVE IT AND IS
            ORIENTED NORMAL TO THE LOCAL MODEL SURFACE.  THE Z COORDINATE
            IS DEFINED IN THE SPANWISE DIRECTION WITH THE ORIGIN AT THE
            MODEL CENTERLINE.  POSITIVE Z IS TO THE LEFT OF CENTER WHEN
            LOOKING DOWNSTREAM.
```

INSTRUMENTATION/MEASURED VARIABLES:

WALL STATIC PRESSURE DISTRIBUTION WERE SENSED THROUGH ORIFICES INSTALLED IN THE MODELS. SKIN FRICTION WAS ESTIMATED BY PRESTON TUBE MEASUREMENTS AND BY MATCHING THE LOGARITHMIC VELOCITY PROFILES TO THE LAW OF THE WALL. MEAN FLOW PROFILES WERE OBTAINED FROM SURVEYS OF PITOT PRESSURE, STATIC PRESSURE AND TOTAL TEMPERATURE. ALL MEASUREMENT ARE GIVEN IN DIMENSIONAL UNITS: DISTANCE--M, PRESSURE--N/M**2, VELOCITY--M/S, DENSITY--KG/M**3

NOMENCLATURE:

```
MODNO -- MODEL NUMBER
ANGLE -- TURNING ANGLE (IN DEGREES)
R     -- MODEL RADIUS OF CURVATURE (IN METERS)
X,Y,Z -- SURVEY LOCATION (IN METERS)
PO    -- TUNNEL STAGNATION PRESSURE (N/M**2)
TO    -- TUNNEL STAGNATION TEMPERATURE (KELVIN)
NPTS  -- NUMBER OF DATA POINTS
PT    -- PITOT PRESSURE (N/M**2)
PS    -- STATIC PRESSURE (N/M**2)
T     -- STATIC TEMPERATURE (KELVIN)
RHO   -- DENSITY (KG/M**3)
M     -- MACH NUMBER
PW    -- WALL STATIC PRESSURE (NSM**2)
CF    -- SKIN FRICTION COEFFICIENT
TAUWL -- WALL SHEAR STRESS (N/M**2)
PREST -- PRESTON TUBE PRESSURE (N/M**2)
```

FILE #	DESCRIPTION
TAYLOR1.DAT	DATA COMPILATION FOR MODEL 1 (8 DEG 0.254M RADIUS)
	DATA COMPILATION FOR MODEL 2 (8 DEG 1.270M RADIUS)
	DATA COMPILATION FOR MODEL 3 (16 DEG 1.270M RADIUS)
TAYLOR2.DAT	SPANWISE DATA COMP FOR MODEL 1 AT X=-0.0254M
	SPANWISE DATA COMP FOR MODEL 1 AT X= 0.0635M
	SPANWISE DATA COMP FOR MODEL 1 AT X= 0.1778M
	SPANWISE DATA COMP FOR MODEL 2 AT X=-0.0476M
	SPANWISE DATA COMP FOR MODEL 2 AT X= 0.1524M
	SPANWISE DATA COMP FOR MODEL 2 AT X= 0.2921M
TAYLOR3.DAT	WALL PRESSURE DISTRIBUTIONS FOR MODEL 1
	WALL PRESSURE DISTRIBUTIONS FOR MODEL 2
	WALL PRESSURE DISTRIBUTIONS FOR MODEL 3
TAYLOR4.DAT	SKIN FRICTION VALUES FOR MODEL 1
	SKIN FRICTION VALUES FOR MODEL 2
	SKIN FRICTION VALUES FOR MODEL 3
	SPANWISE SKIN FRICTION VALUES FOR MODEL 1
	SPANWISE SKIN FRICTION VALUES FOR MODEL 2

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LINE #	CONTENTS	DATA FORMAT FOR FILES TAYLOR1 AND TAYLOR2
1	MODNO,ANGLE,R	25X,I2,15X,F5.1,17X,F6.4
2	COMMENTS	36A2
3	X,Z,PO,TO,NPTS	13X,F7.4,4X,F7.4,6X,G10.4,5X,F5.1,7X,I4
4	HEADINGS	36A2
5	Y,PT,PS,T,RHO,M,U	2(G10.4,1X),G10.4,3X,F5.1,1X,F6.4,1X,F5.2, 1X,F6.1
"	"	"
5+NPTS	"	"

REPEAT LINES 3 THRU 5+NPTS FOR SUBSEQUENT SURVEY LOCATIONS

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LINE #	CONTENTS	DATA FORMAT FOR FILE TAYLOR3
1	COMMENTS	36A2
2	NPTS	5X,I3
3	HEADINGS	36A2
4	X,Z,PW	3G10.4
"	"	"
4+NPTS	"	"

REPEAT ENTIRE SEQUENCE FOR EACH DISTRIBUTION IN FILE

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LINE #	CONTENTS	DATA FORMAT FOR FILE TAYLOR4
1	MODNO,ANGLE,R,NPTS	28X,I2,8X,F6.2,9X,F6.3,7X,I3
2	COMMENTS	36A2
3	HEADINGS	36A2
4	X,Z,PO,TO,CF,TAUWL,PREST,PW	3(G10.4,1X),F5.1,1X,F9.7,1X,F5.1, 2(1X,G10.4)
"	"	"
4+NPTS	"	"

REPEAT SEQUENCE FOR EACH DISTRIBUTION IN FILE

NOTE: PREST AND PW GIVEN FOR PRESTON TUBE MEASUREMENTS ONLY

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FILE TAYLOR1.DAT TAYLOR & SMITS
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(SAMPLE OUTPUT PAGE)

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************************************************************************************************************
MODEL I
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MEAN PROFILE TABULATION
DATA TABULATION FOR MODEL 1 TURNING ANGLE= 8.0DEG MODEL RADIUS= .2540M

X		= -.3810E-01
Z		= -.1270E-01
Stagnation Pressure	pitot	= 0.6875E+06
Stagnation Temperature	pitot	= 261.0
M ref		= 2.900
U ref	pitot	= 573.7
P wall		= 0.2317E+05
TAU wall	preston	= 146.4

Y	PT/PWALL	PS/PWALL	U/UREF	M
0.8890E-04	1.692	1.000	0.4806	0.9000
0.1719E-03	1.989	1.000	0.5433	1.040
0.2982E-03	2.349	1.000	0.6003	1.180
0.3667E-03	2.554	1.000	0.6281	1.250
0.4461E-03	2.659	1.020	0.6347	1.270
0.5868E-03	2.838	1.025	0.6532	1.320
0.6481E-03	2.920	1.025	0.6622	1.340
0.7203E-03	3.074	1.023	0.6786	1.390
0.8574E-03	3.250	1.022	0.6959	1.440
0.9404E-03	3.364	1.023	0.7055	1.470
0.1009E-02	3.415	1.025	0.7102	1.480
0.1218E-02	3.468	1.016	0.7171	1.500
0.1409E-02	3.559	1.018	0.7239	1.520
0.1583E-02	3.703	1.020	0.7353	1.560
0.1799E-02	3.865	1.017	0.7483	1.600
0.2008E-02	3.887	1.013	0.7504	1.610
0.2135E-02	3.985	1.015	0.7569	1.630
0.2369E-02	4.045	1.017	0.7611	1.640
0.2539E-02	4.009	1.017	0.7577	1.630
0.2770E-02	4.307	1.019	0.7774	1.700
0.2954E-02	4.454	1.020	0.7876	1.730
0.3408E-02	4.493	1.022	0.7883	1.740
0.3917E-02	4.752	1.015	0.8062	1.800
0.4339E-02	4.743	1.010	0.8059	1.800
0.4855E-02	5.093	1.007	0.8261	1.880
0.5364E-02	5.196	1.002	0.8331	1.910
0.5800E-02	5.257	0.9970	0.8364	1.920
0.6291E-02	5.339	0.9970	0.8412	1.940
0.6789E-02	5.697	0.9996	0.8562	2.010
0.7200E-02	5.706	1.000	0.8561	2.010
0.7713E-02	6.107	1.000	0.8737	2.090
0.8200E-02	6.047	1.009	0.8684	2.070
0.8690E-02	6.344	1.013	0.8792	2.110
0.9221E-02	6.262	1.012	0.8773	2.110
0.9675E-02	6.608	1.010	0.8907	2.170
0.1012E-01	6.854	1.009	0.8993	2.210
0.1066E-01	6.763	1.004	0.8960	2.200
0.1109E-01	6.905	0.9983	0.9030	2.240
0.1156E-01	7.117	0.9953	0.9111	2.280
0.1209E-01	7.376	0.9940	0.9190	2.320
0.1257E-01	7.216	0.9901	0.9145	2.300
0.1350E-01	7.795	0.9849	0.9336	2.410
0.1447E-01	8.105	0.9819	0.9418	2.450
0.1542E-01	8.248	0.9784	0.9460	2.480
0.1640E-01	8.710	0.9758	0.9582	2.560
0.1735E-01	9.085	0.9763	0.9666	2.620
0.1831E-01	9.176	0.9750	0.9680	2.630
0.1929E-01	9.573	0.9728	0.9769	2.700
0.2025E-01	10.12	0.9702	0.9884	2.780
0.2128E-01	10.24	0.9685	0.9906	2.800

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FILE TAYLOR2.DAT TAYLOR & SMITS
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(SAMPLE OUTPUT PAGE)

MEAN PROFILE TABULATION
DATA TABULATION FOR MODEL 1 TURNING ANGLE= 8.0DEG MODEL RADIUS= .2540M

X		=	-.2540E-01
Z		=	-.5080E-01
Stagnation Pressure	pitot	=	0.6879E+06
Stagnation Temperature	pitot	=	249.4
M ref		=	2.900
U ref	pitot	=	560.8
P wall		=	0.2342E+05
TAU wall	preston	=	144.4

Y	PT/PWALL	PS/PWALL	U/UREF	M
0.8890E-04	2.252	1.000	0.5861	1.140
0.2060E-03	2.560	1.000	0.6281	1.250
0.3419E-03	3.014	1.000	0.6801	1.390
0.4967E-03	3.172	1.000	0.6947	1.430
0.5873E-03	3.349	1.000	0.7115	1.480
0.6477E-03	3.454	1.000	0.7208	1.510
0.7610E-03	3.586	1.000	0.7311	1.540
0.8328E-03	3.678	1.000	0.7390	1.570
0.1071E-02	3.795	1.000	0.7477	1.600
0.1191E-02	3.927	1.000	0.7573	1.630
0.1361E-02	4.061	1.000	0.7670	1.660
0.1743E-02	4.190	1.000	0.7761	1.690
0.2060E-02	4.509	1.000	0.7971	1.770
0.2373E-02	4.671	1.000	0.8071	1.800
0.2702E-02	4.876	1.000	0.8181	1.850
0.3038E-02	4.932	1.000	0.8199	1.850
0.3427E-02	5.094	1.000	0.8288	1.890
0.3755E-02	5.265	1.000	0.8376	1.920
0.4054E-02	5.252	1.000	0.8374	1.920
0.4375E-02	5.457	1.000	0.8476	1.970
0.4737E-02	5.470	1.000	0.8474	1.970
0.5394E-02	5.798	1.000	0.8622	2.030
0.6104E-02	6.055	1.000	0.8731	2.080
0.6803E-02	6.289	1.000	0.8820	2.120
0.7490E-02	6.546	1.000	0.8921	2.170
0.8139E-02	6.836	1.000	0.9021	2.220
0.8804E-02	6.926	1.000	0.9045	2.240
0.9484E-02	7.246	1.000	0.9153	2.290
0.1019E-01	7.370	1.000	0.9189	2.310
0.1088E-01	7.553	1.000	0.9239	2.340
0.1154E-01	7.976	1.000	0.9364	2.410
0.1217E-01	8.211	1.000	0.9423	2.450
0.1288E-01	8.318	1.000	0.9453	2.470
0.1358E-01	8.757	1.000	0.9556	2.530
0.1429E-01	8.924	1.000	0.9597	2.560
0.1491E-01	9.291	1.000	0.9683	2.620
0.1559E-01	9.535	1.000	0.9733	2.650
0.1626E-01	9.778	1.000	0.9781	2.690
0.1694E-01	10.03	1.000	0.9827	2.720
0.1765E-01	10.36	1.000	0.9893	2.770
0.1828E-01	10.50	1.000	0.9909	2.790
0.1967E-01	10.82	1.000	0.9966	2.840
0.2098E-01	10.91	1.000	0.9965	2.840
0.2243E-01	11.14	1.000	1.000	2.880
0.2373E-01	11.19	1.000	1.000	2.890
0.2511E-01	11.19	1.000	0.9990	2.890
0.2651E-01	11.18	1.000	0.9983	2.890
0.2783E-01	11.19	1.000	0.9983	2.890
0.2925E-01	11.22	1.000	0.9983	2.890
0.3055E-01	11.21	1.000	0.9983	2.890
0.3192E-01	11.24	1.000	0.9991	2.890
0.3330E-01	11.30	1.000	1.000	2.900
0.3464E-01	11.32	1.000	1.000	2.900
0.3606E-01	11.33	1.000	1.000	2.900

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FILE TAYLOR3.DAT     TAYLOR & SMITS
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(SAMPLE PRINTOUT PAGE)

SURFACE PRESSURE FOR MODEL 1 ANGLE=8 DEG RADIUS= .254M
NPTS= 37

X	Z	VAR
-.3810E-01	0.000	.2266E+05
-.2540E-01	.5080E-01	.2253E+05
-.2540E-01	.2540E-01	.2275E+05
-.2540E-01	0.000	.2257E+05
-.2540E-01	-.1270E-01	.2288E+05
-.2540E-01	-.2540E-01	.2283E+05
-.2540E-01	-.5080E-01	.2229E+05
-.1270E-01	0.000	.2286E+05
0.000	0.000	.2340E+05
.6350E-02	0.000	.2469E+05
.1270E-01	.5080E-01	.2655E+05
.1270E-01	.2540E-01	.2655E+05
.1270E-01	0.000	.2670E+05
.1270E-01	-.1270E-01	.2624E+05
.1270E-01	-.2540E-01	.2637E+05
.1270E-01	-.5080E-01	.2602E+05
.1905E-01	0.000	.2849E+05
.2540E-01	0.000	.3096E+05
.3175E-01	0.000	.3371E+05
.3810E-01	0.000	.3516E+05
.5080E-01	0.000	.3673E+05
.6350E-01	.5080E-01	.3819E+05
.6350E-01	.2540E-01	.3835E+05
.6350E-01	0.000	.3791E+05
.6350E-01	-.1270E-01	.3725E+05
.6350E-01	-.2540E-01	.3745E+05
.6350E-01	-.5080E-01	.3773E+05
.7620E-01	0.000	.3841E+05
.1016	0.000	.4009E+05
.1270	0.000	.3975E+05
.1524	0.000	.4058E+05
.1778	.5080E-01	.4025E+05
.1778	.2540E-01	.4110E+05
.1778	0.000	.4136E+05
.1778	-.1270E-01	.4092E+05
.1778	-.2540E-01	.4125E+05
.1778	-.5080E-01	.4053E+05

SURFACE PRESSURE FOR MODEL 1 ANGLE= 8 DEG RADIUS= .254
NPTS= 37

X	Z	VAR
-.3810E-01	0.000	.2288E+05
-.2540E-01	.5080E-01	.2316E+05
-.2540E-01	.2540E-01	.2301E+05
-.2540E-01	0.000	.2327E+05
-.2540E-01	-.1270E-01	.2288E+05
-.2540E-01	-.2540E-01	.2279E+05
-.2540E-01	-.5080E-01	.2288E+05
-.1270E-01	0.000	.2266E+05
0.000	0.000	.2371E+05
.6350E-02	0.000	.2487E+05
.1270E-01	.5080E-01	.2646E+05
.1270E-01	.2540E-01	.2683E+05
.1270E-01	0.000	.2659E+05
.1270E-01	-.1270E-01	.2692E+05
.1270E-01	-.2540E-01	.2677E+05
.1270E-01	-.5080E-01	.2635E+05
.1905E-01	0.000	.2904E+05
.2540E-01	0.000	.3120E+05
.3175E-01	0.000	.3441E+05
.3810E-01	0.000	.3564E+05
.5080E-01	0.000	.3642E+05
.6350E-01	.5080E-01	.3878E+05
.6350E-01	.2540E-01	.3850E+05
.6350E-01	0.000	.3813E+05
.6350E-01	-.1270E-01	.3749E+05

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FILE TAYLOR4.DAT TAYLOR & SMITS
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(SAMPLE OUTPUT PAGE)

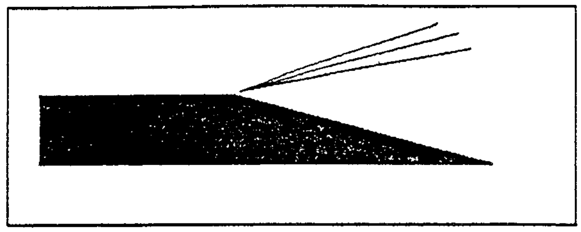
SKIN FRICTION DATA FOR MODEL 1 ANGLE= 8.00 RADIUS= .2540M NPTS= 11
UNITS IN MKS SYSTEM, FROM VELOCITY PROFILES

X	Z	PO	TO	CF	TAUWL
-.3810E-01	-.1270E-01	.6880E+06	261.0	.0010440	138.5
-.2540E-01	-.1270E-01	.6880E+06	261.0	.0010620	141.3
-.1270E-01	-.1270E-01	.6890E+06	265.0	.0010520	139.9
0.000	-.1270E-01	.6880E+06	260.0	.0010540	141.5
.1270E-01	-.1270E-01	.6880E+06	258.0	.0009720	139.5
.2540E-01	-.1270E-01	.6880E+06	255.0	.0007250	112.5
.5080E-01	-.1270E-01	.6890E+06	252.0	.0006920	116.1
.7620E-01	-.1270E-01	.6890E+06	255.0	.0009910	171.1
.1143	-.1270E-01	.6900E+06	264.0	.0010510	185.5
.1524	-.1270E-01	.6880E+06	257.0	.0011120	197.1
.1778	-.1270E-01	.6880E+06	256.0	.0011540	205.5

SKIN FRICTION DATA FOR MODEL 1 ANGLE= 8.00 RADIUS= .2540M NPTS= 17
UNITS IN MKS SYSTEM, FROM PRESTON TUBE MEASUREMENTS

X	Z	PO	TO	CF	TAUWL	PRESTON	PW
-.3810E-01	-.1270E-01	.6876E+06	259.7	.0011177	146.4	.7224E+05	.2288E+05
-.2540E-01	-.1270E-01	.6876E+06	259.9	.0011228	147.1	.7252E+05	.2288E+05
-.1270E-01	-.1270E-01	.6875E+06	258.7	.0010757	139.6	.6883E+05	.2266E+05
0.000	-.1270E-01	.6884E+06	257.8	.0010371	138.8	.6961E+05	.2371E+05
0.000	-.1270E-01	.6909E+06	269.9	.0010151	135.9	.6722E+05	.2371E+05
.6350E-02	-.1270E-01	.6883E+06	269.9	.0009716	133.6	.6703E+05	.2487E+05
.1270E-01	-.1270E-01	.6889E+06	258.4	.0010792	154.9	.7940E+05	.2692E+05
.1270E-01	-.1270E-01	.6880E+06	270.4	.0009466	135.9	.6965E+05	.2692E+05
.1905E-01	-.1270E-01	.6891E+06	270.6	.0009034	134.9	.7074E+05	.2904E+05
.2540E-01	-.1270E-01	.6903E+06	256.8	.0008920	137.8	.7487E+05	.3120E+05
.2540E-01	-.1270E-01	.6899E+06	270.7	.0008935	138.1	.7384E+05	.3120E+05
.5080E-01	-.1270E-01	.6884E+06	255.7	.0009664	162.7	.9025E+05	.3642E+05
.7620E-01	-.1270E-01	.6899E+06	255.7	.0010226	176.9	.9881E+05	.3861E+05
.7620E-01	-.1270E-01	.6901E+06	253.6	.0010047	173.8	.9738E+05	.3861E+05
.1143	-.1270E-01	.6900E+06	260.3	.0010827	190.7	.1059E+06	.4025E+05
.1524	-.1270E-01	.6896E+06	255.0	.0011032	195.1	.1090E+06	.4075E+05
.1778	-.1270E-01	.6890E+06	255.3	.0011110	198.8	.1113E+06	.4123E+05

Ref.: 38
Author: Zheltovodov, et al.
Geometry: 8° Expansion Corner
Mach number: 2.9 and 3.7
Data: p_{wall}, c_f, mean flowfield profiles



Zheltovodov, A.A., Trofimov, V.M., Shilein, E.H. and Yakovlev, V.N., "An Experimental Documentation of Supersonic Turbulent Flows in the Vicinity of Forward- and Backward-Facing Ramps," Inst. of Theoretical and Applied Mechanics Report 2013, Siberian Division, USSR Academy of Sciences, April 1990.

Special circumstances arise in the case of this experiment. Not only are the data relatively new, but also the key reference describing the experiment is not generally available. A self-contained description is therefore provided below.

The test model, illustrated in Fig. 1 below, was tested in the 0.6x0.6m T-313 supersonic wind tunnel of ITPM Novosibirsk, which has a freestream turbulence level in the 0.4-0.6% range. An inital flat plate section (1), was followed by an 8° expansion corner (2) and a final flat plate section (3). A 0.5mm wire trip (4) was located 3mm from the leading edge of plate (1). Other pertinent dimensions are indicated in Fig. 1.

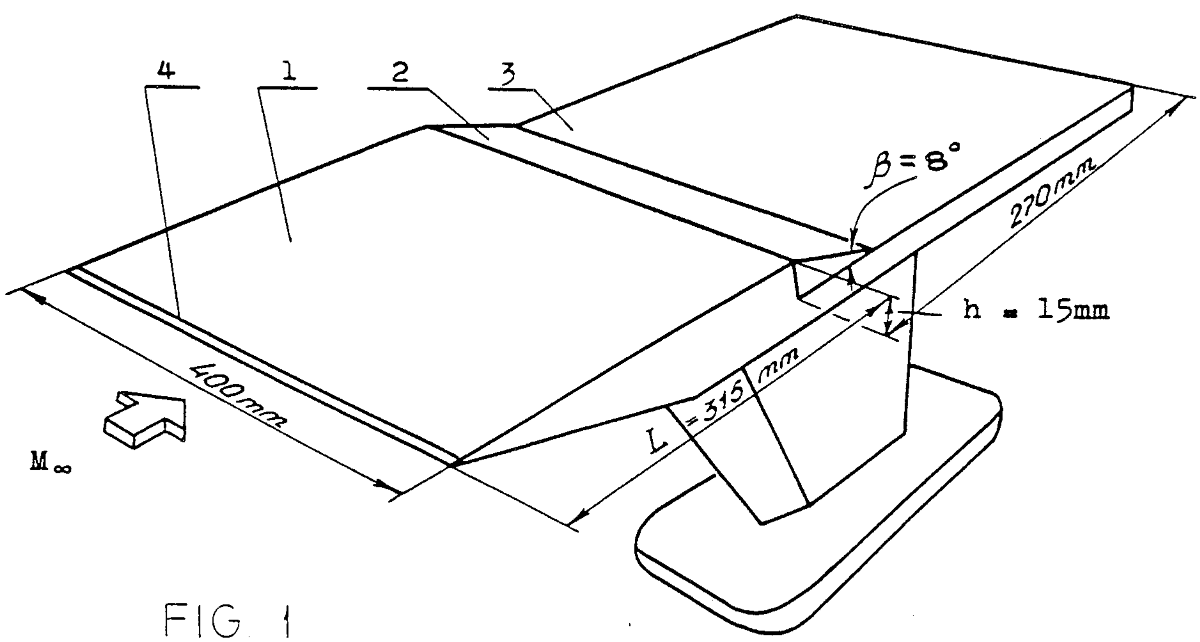


FIG. 1

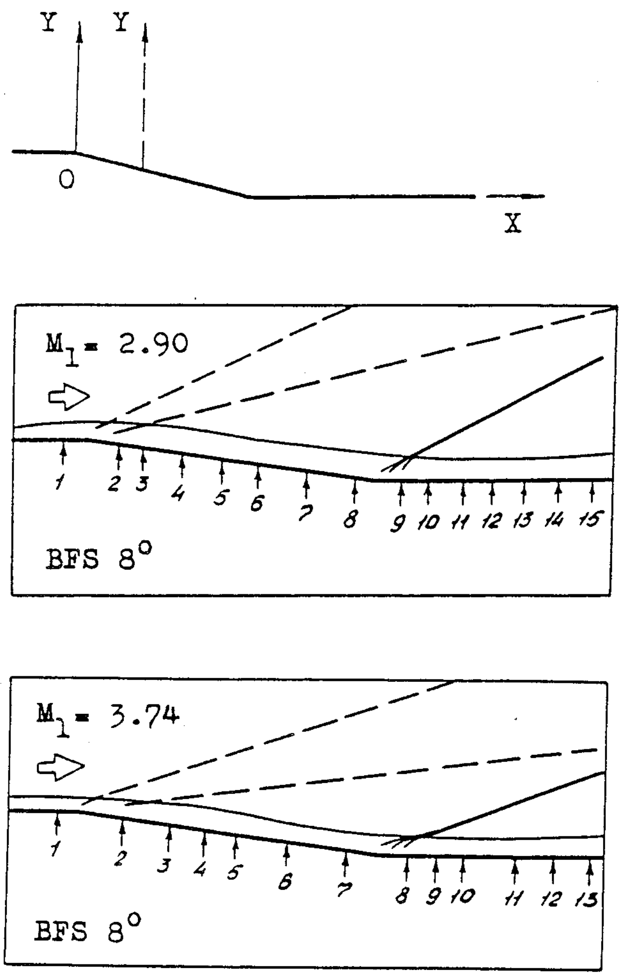


FIG. 2

The data file ZHELT2.DAT contains the data from this experiment. The sample output page printed here includes the nominal wind tunnel freestream conditions, incoming flow parameters, and test model coordinates.

The test model coordinate frame and schematics of the flowfields at Mach 2.90 and 3.74 are shown in Fig. 2. Flowfield surveys were made in the Y-direction, which is vertical with respect to the wind tunnel despite the local slope of the expansion corner. The X-coordinate, on the other hand, is measured *along* the surface of the model whether sloped or not, as indicated in Fig. 2. The numbers shown along the expansion corner in Fig. 2 are the measurement locations ("section" numbers) corresponding to the tabulated data in the data file ZHELT2.DAT.

Other than incoming flow parameters, the data file also contains surface pressure distributions and pitot and static pressure survey data. These surveys were reduced by standard techniques under the assumption of a Crocco-integral total-temperature distribution in order to arrive at velocity and Mach number profiles, which form the bulk of the tabulated data. The last table in the data file also gives boundary-layer integral thicknesses and skin friction.

Model surface temperatures are described as "very close to adiabatic" for both test Mach numbers. Wall pressures were measured on rows at or near the longitudinal model centerline. The probe survey mechanism had a spatial accuracy of 0.1mm in Y and 0.5mm in X. The pitot-pressure probe had a flattened tip with a 0.1mm orifice. The static pressure probe was 0.87mm in diameter, with a 20° conical tip and 4 holes of 0.2mm located either 9mm or 13mm downstream of the tip, depending upon the probe used. Surveys were carried out in vertical streamwise planes which intersected the model surface at 5mm on either side of its longitudinal centerline.

The general accuracy of pitot pressures was judged by the experimenters to be ± 2%, while that of the static pressure probe was quoted as ± 3-4%. In both cases, more serious error levels in the range of 30% occurred in the immediate vicinity of expansion fans and shocks. Taken together, these tolerances resulted in an average Mach number accuracy of $\pm$ 3% with a worst-combination error of $\pm$ 6%. Velocity is believed accurate to $\pm$ 5% except in the immediate vicinity of waves as noted. The skin friction accuracy is judged to be $\pm$ 10% in constant-pressure regions and $\pm$ 15% in pressure gradients. Surface flow visualizations revealed an overall two-dimensional flow pattern in the center region of the test model with no flow separation being observed.

Finally, the following nomenclature list defines those variables which are used here and in the data file ZHELT2.DAT. Metric units are used as indicated in the tabulations.

Cf1	skin friction coefficient on flat plate at beginning of interaction
M_∞	wind tunnel freestream Mach number (also Minf)
M1	incoming Mach number ahead of expansion corner
Me	Mach number at edge of boundary layer
P	static pressure
Pinf	freestream static pressure
P1	static pressure at beginning of interaction
P0	pitot pressure
Po inf	freestream stagnation pressure
Pw	wall static pressure
Re	freestream unit Reynolds number (per meter)
RHO	static density
RHOe	static density at edge of boundary layer
T	static temperature
Te	static temperature at edge of boundary layer
To inf	freestream stagnation temperature
U	velocity component in X-direction
Ue	velocity component in X-direction at boundary-layer edge
X	distance along model surface
Y	vertical distance from test model normal to undisturbed flow direction
β	expansion-corner angle (8°)
δ	boundary-layer overall thickness
δ^*	compressible boundary-layer displacement thickness
δ^{**}	compressible boundary-layer momentum thickness

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Zheltovodov et al 8 Degree Expansion Corner Data at Mach 2.9 and 3.7

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(SAMPLE OUTPUT PAGE)

NOMINAL FREE-STREAM CONDITONS (T-313 Facilty)

M inf	P inf [kg/cm²]	Po inf [kg/cm²]	Re x 10-6 [1/m]	To inf [K]
3.04±0.005	0.110±0.002	4.263±0.04	38.3±0.6	265±02
4.04±0.020	0.067±0.002	10.683±0.05	58.3±1.0	269±02

MODEL COORDINATES

M1 = 2.90 SECT.	X[cm]	M1 = 3.74 SECT.	X[cm]
1	-0.80	1	-0.60
2	1.75	2	2.25
3	2.25	3	3.85
4	3.35	4	5.15
5	4.65	5	6.80
6	6.15	6	7.85
7	8.10	7	9.50
8	9.80	8	12.05
9	11.40	9	13.00
10	12.50	10	14.40
11	13.80	11	16.05
12	14.40	12	17.45
13	15.80	13	18.65
14	17.20		
15	18.65		

INCOMING FLOW PARAMETERS

M1	P1 [kg/cm²]	δ [mm]	δ* [mm]	δ** [mm]	Cf1 x10-3
2.90	0.123	5.08	1.84	0.38	1.41
3.74	0.070	4.85	2.04	0.29	1.18

SURFACE PRESSURES

M1 = 2.90 P1 = 0.1243 kg/cm² X[cm]	P/P1	M1 = 3.74 P1 = 0.0705 kg/cm² X[cm]	P/P1
- 1.60	1.000	- 1.60	1.000
- 1.40	1.000	- 1.40	1.000
- 1.20	0.999	- 1.20	1.000
- 1.00	0.998	- 1.00	1.000
- 0.80	0.996	- 0.80	1.000
- 0.60	0.996	- 0.60	0.996
- 0.40	0.999	- 0.40	0.998
- 0.05	0.947	- 0.05	0.957
0.30	0.786	0.70	0.745
0.70	0.625	1.60	0.532
1.90	0.544	2.70	0.496
2.70	0.524	3.10	0.496
3.10	0.504	3.50	0.496
3.50	0.504	3.90	0.455
3.90	0.504	4.30	0.455
4.30	0.504	4.70	0.455
4.70	0.504	5.10	0.455
5.10	0.504	5.50	0.455
5.50	0.504	5.90	0.455
5.90	0.504	6.30	0.455

PITOT PRESSURE PROFILES

(SAMPLE OUTPUT PAGE)

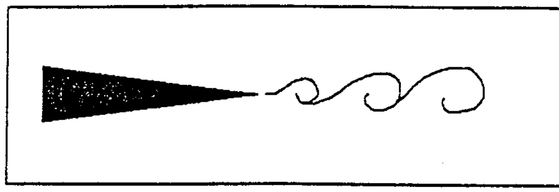
M1 = 2.90				M1 = 3.74			
SECTION 2		SECTION 9		SECTION 2		SECTION 9	
Y	PO	Y	PO	Y	PO	Y	PO
[cm]	[kG/cm²]	[cm]	[kG/cm²]	[cm]	[kG/cm²]	[cm]	[kG/cm²]
0.02	0.123	0.01	0.148	0.01	0.049	0.01	0.104
0.03	0.168	0.03	0.180	0.02	0.069	0.02	0.110
0.04	0.210	0.04	0.206	0.03	0.107	0.03	0.128
0.05	0.234	0.05	0.215	0.04	0.131	0.04	0.140
0.06	0.269	0.06	0.230	0.05	0.152	0.05	0.152
0.07	0.295	0.07	0.243	0.06	0.169	0.07	0.181
0.08	0.306	0.08	0.255	0.07	0.185	0.09	0.198
0.09	0.327	0.09	0.275	0.09	0.200	0.11	0.220
0.10	0.336	0.10	0.292	0.11	0.218	0.15	0.266
0.12	0.361	0.11	0.310	0.13	0.238	0.19	0.317
0.14	0.378	0.13	0.341	0.16	0.253	0.23	0.382
0.16	0.394	0.15	0.365	0.19	0.275	0.27	0.461
0.18	0.417	0.17	0.410	0.24	0.311	0.31	0.524
0.21	0.437	0.19	0.434	0.28	0.341	0.37	0.609
0.24	0.465	0.21	0.475	0.32	0.367	0.41	0.670
0.28	0.502	0.24	0.517	0.36	0.402	0.47	0.757
0.32	0.534	0.27	0.572	0.41	0.437	0.52	0.828
0.36	0.568	0.30	0.610	0.46	0.480	0.60	0.656
0.40	0.604	0.33	0.656	0.51	0.522	0.66	0.672
0.44	0.639	0.36	0.703	0.57	0.568	0.71	0.688
0.48	0.680	0.39	0.734	0.62	0.627	0.77	0.692
0.52	0.722	0.43	0.698	0.69	0.702	0.82	0.698
0.56	0.753	0.47	0.654	0.76	0.768	0.89	0.699
0.61	0.798	0.50	0.672	0.83	0.839	0.96	0.703
0.65	0.838	0.55	0.712	0.92	0.939	1.08	0.704
0.71	0.874	0.60	0.745	0.99	1.017		
0.76	0.920	0.65	0.780	1.07	1.094		
0.81	0.961	0.69	0.801	1.16	1.180		
0.88	1.024	0.73	0.808	1.31	1.327		
0.95	1.095	0.77	0.816	1.44	1.267		
1.02	1.138	0.81	0.822	1.57	1.268		
1.12	1.211	0.86	0.823				
1.21	1.288	0.89	0.828				
1.45	1.255	0.97	0.824				
1.79	1.256	1.03	0.834				
1.91	1.256	1.08	0.831				
		1.17	0.839				
		1.23	0.835				
		1.30	0.840				
		1.45	0.839				

BOUNDARY LAYER INTEGRAL THICKNESSES AND SKIN FRICTION

M1 = 2.90					M1 = 3.74				
	δ	δ^*	δ^{**}	Cf1		δ	δ^*	δ^{**}	Cf1
SECT.	[mm]	[mm]	[mm]	x10	SECT.	[mm]	[mm]	[mm]	x10
1	5.08	1.84	0.38	1.41	1	4.85	2.04	0.29	1.18
3	7.70	2.57	0.49	1.08	3	9.44	4.23	0.48	0.64
4	7.25	2.53	0.48	1.01	4	8.73	3.94	0.46	0.61
5	7.12	2.46	0.48	1.01	5	9.87	4.23	0.51	0.60
6	7.20	2.56	0.49	0.96	6	8.58	3.82	0.47	0.59
7	7.23	2.60	0.50	0.92	7	8.20	3.65	0.46	0.58
8	7.46	2.77	0.52	0.91	9	5.52	2.52	0.38	0.81
10	5.61	2.14	0.46	1.13	10	5.66	2.67	0.39	0.83
11	5.47	2.12	0.46	1.21	11	5.83	2.75	0.39	0.93
13	5.92	2.23	0.49	1.28	12	6.09	2.78	0.40	1.00
14	6.27	2.30	0.50	1.34	13	6.23	2.85	0.42	1.00
15	6.37	2.51	0.51	1.31					

************************************END************************************

Refs.: 17, 18
Authors: Goebel, Gruber, et al.
Geometry: 2-D Splitter Plate
Convective Mach number: 0.2 - 0.99
Data: mean & fluctuating 2-D & 3-D LDV data



Goebel, S. G., "An Experimental Investigation of Compressible, Turbulent Mixing Layers," Ph.D.Thesis, University of Illinois, 1990.

Gruber, M. R., Messersmith, N. L., and Dutton, J. C., "Three-Dimensional Velocity Measurements in a Turbulent, Compressible Mixing Layer," AIAA Paper 92-3544, July 1992.

ABSTRACT (Goebel): Experiments were conducted using pressure measurements, schlieren photography, and velocity measurements with a two-component laser Doppler velocimeter (LDV) system. These diagnostic systems were developed for use with the mixing layer wind-tunnel facility. Many conditions were evaluated, and seven mixing layer cases were fully examined, with relative Mach numbers ranging from 0.40 to 1.97. The spatial development and similarity of the mixing layers were examined, as well as the entrainment process and the effects of particle dynamics. Analyses to predict the mean density profiles, mean transverse velocity profiles, shape of the kinematic Reynolds stress profiles, and entrainment mass fraction of a fully developed, compressible mixing layer were also developed. From the schlieren photographs, no organized, large-scale structures were observed to dominate the mixing layers. The development of the mixing layers required a Reynolds number (based on the freestream velocity difference and local mixing layer thickness) on the order of 10(exp 5). In the fully developed regions of the mixing layers, it was found that transverse turbulence intensities and normalized kinematic Reynolds stresses decreased with increasing relative Mach number like the decreases measured in normalized growth rate, while the streamwise turbulence intensities and kinematic Reynolds stress correlation coefficients remained approximately constant. By examining the LDV velocity measurements from particles with different response characteristics, it was shown that particle dynamics effects were not a problem with these measurements. Also, by measuring velocity profiles on both sides of the wind-tunnel midplane, it was found that the flow fields were reasonably two-dimensional.

ABSTRACT (Gruber, Messersmith, & Dutton): A turbulent compressible mixing layer with a relative Mach number of 1.59 has been investigated experimentally using pressure measurements, schlieren photographs, and velocity measurements. A two-component laser Doppler velocimeter system was used to obtain the transverse velocity profiles across the mixing layer. The system was set up twice: once to obtain the streamwise and transverse veocity components and once to obtain the streamwise and spanwise velocity components. Full development of the mean and fluctuating velocities of the mixing layer required a local

Reynolds number based on the freestream velocity difference and the mixing layer thickness on the order of 1×10^5. Results from the fully-developed region of the mixing layer showed constant peak values with increasing compressibility of streamwise and spanwise turbulence intensities and primary Reynolds shear stress correlation coefficient along with decreasing peak values of transverse turbulence intensity, normalized primary Reynolds shear stress, and normalized turbulent kinetic energy. Various turbulence profiles demonstrated a reduction of lateral extent on the high speed side of the mixing layer as compared to profiles in incompressible mixing layers. Finally, the Reynolds normal stress ratio decresed with increasing relative Mach number, implying that the mixing layer turbulence became more three-dimensional as compressibility was increased.

The experiments by Goebel and Dutton and Gruber et al. comprise one of the very few datasets to include well-documented, quantitative data with direct applicability to compressible turbulence modeling and code validation. The following information was provided by Prof. Dutton as an aid to the interpretation of the data files, samples of which also follow:

TWO-STREAM COMPRESSIBLE MIXING LAYER DATA

Department of Mechanical and Industrial Engineering
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

References:

1. Goebel, S.G., "LDV Measurements of a Supersonic Mixing Layer," M.S. Thesis, Department of Mechanical and Industrial Engineering, University of Illinois at Urbana-Champaign, May 1988.

2. Goebel, S.G., Dutton, J.C., Krier, H., and Renie, J.P., "Mean and Turbulent Velocity Measurements of Supersonic Mixing Layers," Experiments in Fluids, Vol. 8, No. 5, Feb. 1990, pp. 263-272.

3. Goebel, S.G., "An Experimental Investigation of Compressible, Turbulent Mixing Layers," Ph.D. Thesis, Department of Mechanical and Industrial Engineering, University of Illinois at Urbana-Champaign, May 1990.

4. Goebel, S.G., and Dutton, J.C., "An Experimental Study of Compressible, Turbulent Mixing Layers," AIAA Journal, Vol. 29, No. 4, April 1991, pp. 538-546.

5. Gruber, M.R., "Three-Dimensional Velocity Measurements in a Turbulent, Compressible Mixing Layer," M.S. Thesis, Department of Aeronautical and Astronautical Engineering, University of Illinois at Urbana-Champaign, Jan. 1992.

6. Gruber, M.R., and Dutton, J.C., "Three-Dimensional Velocity Measurements in a Turbulent, Compressible Mixing Layer," AIAA Paper 92-3544, July 1992.

7. Sun, C.C., and Childs, M.E., "A Modified Wall Wake Velocity Profile for Turbulent Compressible Boundary Layers," AIAA Journal of Aircraft, Vol. 10, 1973, pp. 381-383.

Discussion

The data described and tabulated herein have been obtained from two-stream, planar, turbulent, compressible mixing layer experiments. Seven cases (1, 1d, 2, 3, 3r, 4, and 5) are available from the two-dimensional LDV measurements of Goebel and Dutton (Refs. 1-4). These cases span a range of freestream velocity ratios, density ratios, and convective Mach numbers (compressibility levels). Although the data are available in digital form for all 7 cases, the experimenters feel that cases 2, 3, 4, and 5 are the most useful and reliable for database purposes and CFD comparison because of the slow spatial development and/or flowfield disturbances present for cases 1, 1d, and 3r. One three-dimensional LDV study (case 6) is also available from the work of Gruber and Dutton (Refs. 5 and 6) at a convective Mach number of 0.80.

In all cases, the turbulent boundary layer velocity profiles immediately upstream of the splitter plate tip were measured to establish the inflow boundary condition for the shear layer flowfield. A least-squares curve fit of the boundary layer data to the Sun and Childs (Ref. 7) profile equation was performed and the resulting profile used to determine the boundary layer integral parameters.

The data for each case are listed as the operating conditions for each stream, the boundary layer integral parameters for each stream, the shear layer parameters including freestream velocity ratio, density ratio, convective Mach number, and growth rate, as well as LDV flowfield traverses. The 10%dU thickness definition (b) is used, i.e. the transverse distance between the locations where U = U1 - 0.1dU and U = U2 + 0.1dU. The major emphasis of these studies was the LDV measurement of the mean and fluctuating velocities in the developing and fully-developed regions of the shear layers. The x-coordinate is measured in the streamwise direction from the splitter plate tip with the y-coordinate normal to x in the transverse direction. For each case a number of y-traverses at fixed x-locations were obtained. The two-dimensional data from Goebel and Dutton at each x-location are listed as y(mm), the mean streamwise velocity U(m/s), the streamwise rms fluctuating velocity <u'>(m/s), the transverse rms fluctuating velocity <v'>(m/s), and the velocity correlation coefficient <u'v'>/(<u'><v'>) from which the kinematic Reynolds shear stress <u'v'> may be obtained. For the three-dimensional data of Gruber and Dutton, the spanwise rms velocity <w'>(m/s) is also reported. Since the data for the latter case were obtained in two independent traverses whose y-locations did not necessarily correspond, these locations are reported as (y-y0), i.e. they have been shifted to a common origin, the shear layer center y0.

In making LDV measurements in high-speed flows, there are a number of bias and error sources that must be carefully considered, including: velocity bias, fringe bias, velocity gradient bias, particle concentration bias, particle dynamics effects, limitations due to finite counter clock resolution, statistical uncertainty due to finite sample size, signal noise, errors due to optical system misalignment, etc. These sources of error and estimates of their magnitudes are discussed in detail in the references, particularly Refs. 1, 3, and 5.

Data Files

CASE.1
CASE.1D
CASE.2
CASE.3
CASE.3R
CASE.4
CASE.5
CASE.6

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****
CASE.1
****
(SAMPLE OUTPUT PAGE)

Shear Layer Data - Case 1

Operating Conditions

	Primary	Secondary
Pt(kPa)	366	142
Tt(K)	295	295
P(kPa)	46	46
T(K)	163	214
U(m/s)	515	404
a(m/s)	256	293
Mach	2.01	1.38
Rho(kg/m3)	0.98	0.75
Mu(Pa-s)	1.1e-5	1.4e-5

Boundary Layer Parameters

	Primary	Secondary
Delta(mm)	2.5	2.6
Disp Thick(mm)	0.58	0.42
Mom Thick(mm)	0.20	0.20
Frict Vel(m/s)	19	16

Shear Layer Parameters

Velocity Ratio(r = U2/U1)	0.78
Velocity Parameter (lam = (1-r)/(1+r))	0.12
Density Ratio (s = rho2/rho1)	0.76
Vel-Dens Parameter(lam,s = (1-r)(1+s^0.5)/(2(1+rs^0.5))	0.12
Relative Mach#(Mr = 2dU/(a1+a2))	0.40
Convective Mach#(Mc = dU/(a1+a2))	0.20
db/dx	0.020
(db/dx)/(db/dx)i	1.01
Unit Reynolds#(/m)	7.7e6

Velocity Profile Data

x = 10 mm

y(mm)	U(m/s)	u'(m/s)	v'(m/s)	<u'v'>/u'v'
7.2	517.8	4.932	7.753	-0.00936
6.4	517.6	4.624	6.922	0.07293
5.6	516	5.833	6.998	-0.1064
4.8	525.7	7.649	9.629	0.02845
4.0	520.3	7.049	8.324	-0.03167
3.2	520.8	9.859	7.766	-0.2638
2.4	506.9	17.33	9.171	-0.3975
1.6	474.7	30.03	12.54	-0.5112
.8	410.2	43.2	16.58	-0.585
0.	305.3	36.85	17.08	-0.4445
-.8	323.4	29.64	17.18	0.711
-1.6	369.1	21.21	10.88	0.6223
-2.4	396	13.38	7.396	0.53
-3.2	403.6	7.078	5.147	0.4498
-4.0	407.1	5.114	4.995	0.4301
-4.8	411.4	4.719	4.918	0.4513
-5.6	410.7	5.237	5.923	0.4511
-6.4	417	6.304	7.168	0.4852
-7.2	412.4	7.734	8.176	0.6434

x = 25 mm

y(mm)	U(m/s)	u'(m/s)	v'(m/s)	<u'v'>/u'v'
7.2	515	5.17	7.411	-0.06903
6.4	515	4.887	7.424	-0.07949
5.6	516.3	4.952	6.884	-0.005262
4.8	517.7	5.137	6.428	-0.1074
4.0	516.2	8.146	6.693	-0.2995
3.2	507.9	16.52	8.325	-0.4158

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****
CASE.6
****

Shear Layer Data - Case 6

(SAMPLE OUTPUT PAGE)

Operating Conditions

	Primary	Secondary
Pt(kPa)	552	43.4
Tt(K)	279	289
P(kPa)	40.3	40.3
T(K)	132	285
U(m/s)	543	91.2
a(m/s)	230	338
Mach	2.36	0.27
Rho(kg/m3)	1.06	0.49
Mu(Pa-s)	9.10e-6	1.77e-5

Boundary Layer Parameters

	Primary	Secondary
Delta(mm)	1.6	1.5
Disp Thick(mm)	0.21	0.12
Mom Thick(mm)	0.061	0.082
Frict Vel(m/s)	27	8

Shear Layer Parameters

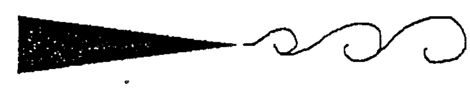
Velocity Ratio(r = U2/U1)	0.17
Velocity Parameter (lam = (1-r)/(1+r))	0.71
Density Ratio (s = rho2/rho1)	0.46
Vel-Dens Parameter(lam,s = (1-r)(1+s^0.5)/(2(1+rs^0.5))	0.63
Relative Mach # (Mr = 2dU/(a1+a2))	1.59
Convective Mach # (Mc = dU/(a1+a2))	0.80
db/dx	0.052
(db/dx)c/(db/dx)i	0.50
Unit Reynolds# (/m)	26.2e6

Velocity Profile Data

x = 50 mm

y-y0(mm)	U(m/s)	u'(m/s)	v'(m/s)	<u'v'>/u'v'	y-y0(mm)	w'(m/s)
13.10	559.5	16.69	17.13	-0.1422	11.54	13.58
11.10	558.2	18.90	19.35	0.1499	9.540	8.080
9.104	561.2	16.42	17.06	-0.0010	7.540	8.387
7.104	560.1	18.23	17.03	-0.1893	5.540	10.67
5.104	559.0	18.06	18.08	-0.2636	3.540	16.70
3.104	558.8	17.62	17.40	-0.1681	1.540	54.99
2.704	555.8	20.66	19.38	-0.2107	1.140	56.31
2.304	547.5	27.82	21.61	-0.2402	0.7400	61.35
1.904	530.1	40.50	28.64	-0.1046	0.3400	66.67
1.504	506.6	52.09	32.64	-0.2208	-0.0600	58.92
1.104	462.5	65.03	38.26	-0.2979	-0.4600	55.43
0.7035	397.2	68.69	51.57	-0.1587	-0.8600	49.36
0.3035	351.2	65.59	51.27	-0.2962	-1.260	47.35
-0.0965	306.8	65.59	49.08	-0.3286	-1.660	44.40
-0.4965	275.3	60.09	45.07	-0.3475	-2.060	40.52
-0.8965	237.7	54.11	41.66	-0.3370	-2.460	35.17
-1.296	192.4	45.93	35.32	-0.3361	-2.860	31.49
-1.696	161.4	39.20	29.59	-0.4818	-3.260	27.67
-2.096	142.3	29.41	23.59	-0.5540	-3.660	24.38
-2.496	128.2	20.51	16.70	-0.3457	-4.060	19.98
-2.896	127.1	18.44	14.42	-0.3382	-4.460	15.82
-3.296	124.2	17.46	14.99	-0.0507	-4.860	12.97
-3.696	123.2	14.96	11.68	0.0702	-5.260	12.12
-4.096	122.2	16.22	12.66	0.1850	-5.660	10.57
-4.496	122.3	14.68	11.32	-0.0719	-6.060	11.65
-4.896	122.7	15.26	12.83	-0.0685	-6.460	11.12
-6.896	122.3	15.69	13.26	-0.0809	-8.460	11.82
-8.896	119.9	16.01	13.99	-0.0407	-10.46	12.99
-10.90	118.2	16.66	14.69	-0.0710	-12.46	13.37

Ref.: 33
Authors: Samimy and Elliot
Geometry: 2-D Splitter Plate
Convective Mach number: 0.51-0.86
Data: mean & fluctuating 2-D LDV data



Samimy, M. and Elliott, G. S., "Effects of Compressibility on the Characteristics of Free Shear Layers," *AIAA Journal*, Vol. 28, 1990, pp. 439-445.

ABSTRACT: A high Reynolds number two-dimensional constant pressure compressible shear layer was formed at the trailing edge of an 0.5 mm-thick splitter plate. Convective Mach numbers of 0.51 and 0.64 were investigated using a two-component coincident LDV for the measurements. For the lower convective Mach number case, the nondimensionalized shear-layer and vorticity thickness growth rates were over 20 percent higher and the momentum thickness growth rate was over 30 percent higher than those of the higher convective Mach number case. The results seen to indicate that both small scale and large scale mixing are reduced with increasing convective Mach number.

The experiment by Samimy and Elliott is one of the very few to include well-documented, quantitative data with direct applicability to compressible turbulence modeling and code validation. Even so, in the three flows documented in which supersonic streams mixed with subsonic streams meeting one another at a splitter plate, the boundary layers on the splitter plate are only documented on the supersonic side. This will necessitate some assumptions about the subsonic-side boundary layer for those who may wish to compute these flows.

The following file description and nomenclature was provided by Prof. Samimy as an aid to the interpretation of the data files, sample of which also follow:

DATA FILES:

MEANFLOW.PRN Mean flow results such as thicknesses, free stream velocities, etc.

ALLMCAVG.PRN Averaged results of streamwise locations in the fully developed region for each convective Mach number

BLM2.PRN Boundary layer at the splitter plate tip for Mach 1.8 flow

BLM3.PRN Boundary layer at the splitter plate tip for Mach 3.0 flow

M5X60.PRN
M5X120.PRN
M5X150.PRN
M5X180.PRN
M5X210.PRN
M6X120.PRN
M6X150.PRN
M6X165.PRN
M6X180.PRN
M8X180.PRN
M8X210.PRN
M8X250.PRN

STANDARD FORMAT IS: MgXjkl.stv

Files with data for a given convective Mach number and streamwise location, where

g - Convective Mach number
g = 5 Mc = 0.51
g = 6 Mc = 0.64
g = 8 Mc = 0.86

jkl - Streamwise location from splitter plate (X)
jkl = 250 means X = 250 mm location

stv - Type of data file
.stv = .PRN ASCII data

NOMENCLATURE

CORR. COEF. — Ruv = $uv/\sigma_u\sigma_v$

DEL — Boundary layer thickness defined by 0.99*U1

FLAT u — $uuuu/(\sigma_u)^4$ Streamwise flatness

FLAT v — $vvvv/(\sigma_v)^4$ Lateral flatness

GROWTH MOM c — Compressible momentum thickness growth rate

GROWTH MOM n — Compressible momentum thickness growth rate normalized by incompressible

GROWTH THICK c — Compressible thickness growth rate

GROWTH THICK n — Compressible thickness growth rate normanized by the incompressible

GROWTH VORT c — Compressible vorticity thickness growth rate

GROWTH VORT n	Compressible vorticity thickness growth rate normalized by the incompressible
M1	Mach number of top stream (supersonic)
M2	Mach number of bottom stream (subsonic)
Mc	Convective Mach number
MOMENTUM THICK	Momentum thickness (MOM) [mm]
REYNOLDS STRESS uv	
RW2/RW1	Density ratio
SIGMAo	Spread rate parameter
SIGMA u	Standard deviation of streamwise velocity
SIGMA v	Standard deviation of lateral velocity
SKEW u	$uuu/(\sigma_u)^3$ Streamwise skewness
SKEW v	$vvv/(\sigma_v)^3$ Lateral skewness
THICK	Shear layer thickness as defined by Y@.9-Y@.1 [mm]
To	Stagnation temperature [K]
U1	Free stream velocity of top flow (supersonic) [m/s]
U2	Free stream velocity of bottom flow (subsonic) [m/s]
U	Streamwise mean velocity [m/s]
u	Streamwise velocity fluctuations
V	Lateral mean velocity [m/s]
v	Lateral velocity fluctuations

VORTICITY THICK	Vorticity thickness (VORT)(U1-U2)/(dU/dy)max [mm]
X	Streamwise distance from splitter plate [mm]
Y	Relative lateral distance [mm]
Y.5	Lateral position where (U-U2)/(U1-U2) = 0.5 [mm]
Y@.9U	Lateral position where (U-U2)/(U1-U2) = 0.9 [mm]
Y@.1U	Lateral position where (U-U2)/(U1-U2) = 0.1 [mm]
uuu	uuu
uuv	uuv
vvv	vvv
uuuu	uuuu
vvvv	vvvv
U-U2 /U1-U2	Normalized velocity
SIG.u /U1-U2	Streamwise turbulence intensity
SIG.v /U1-U2	Lateral turbulence intensity
-RNDLS /U1-U2	Reynolds stress $-uv/(U1-U2)^2$
vvv+vuu /U1-U2	$v(u^2+v^2)/(U1-U2)^3$ Lateral covection of kinetic energy
uuu+uvv /U1-U2	$u(u^2+v^2)/(U1-U2)^3$ Streamwise convection of kinetic energy

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SAMIMY & ELLIOTT MEANFLOW.PRN

MEAN FLOW CALCULATIONS FOR ALL Mc

FILE	X	U1	U2	U1-U2	Y.5	Y@.9U	Y@.1U	To	M1	M2	RW2/RW1	Mc
M3_180	180	581.061	136.8248	444.2362	-10.0219	-0.60122	-19.7589	260.00	3.023178	0.431120	0.366761	0.871782
M3_210	210	584.0838	145.4337	438.6501	-12.1536	-2.37123	-24.3451	260.00	3.068299	0.459355	0.361512	0.865248
M3_250	250	596.578	150.8232	445.7528	-15.9018	-4.93024	-27.9733	276.00	2.993517	0.462492	0.373457	0.848408
P7300	120	496.14	118	378.14	-8.89614	-1.27309	-13.5756	276.00	1.997937	0.358876	0.570368	0.655207
P7100	150	490.833	122.540	368.09	-10.9892	-3.74267	-19.4994	276.00	1.958578	0.373061	0.581615	0.635765
P7400	165	498.94	121.11	377.83	-11.0703	-3.05579	-19.6981	276.00	2.018353	0.368568	0.566012	0.656206
P7200	180	491.424	125.000	366.42	-15.3062	-6.97357	-24.4472	276.00	1.964168	0.380765	0.580631	0.633425
P12300	80	476.99	176.85	300.14	3.622377	7.957945	0.197450	276.00	1.865279	0.546704	0.624922	0.518193
P12200	120	483.37	173.07	310.3	6.407606	11.47826	0.721056	276.00	1.908192	0.534344	0.611665	0.537590
P12A	150	465.213	166.700	298.51	7.161208	13.53271	-0.56317	276.00	1.769120	0.513618	0.641852	0.510642
P12B	180	462.298	164.330	297.97	7.219054	14.63025	-1.80618	276.00	1.770639	0.505939	0.646024	0.508598
P12	210	468.831	164.240	304.59	4.310709	13.35626	-5.54869	276.00	1.812118	0.505648	0.634455	0.521960

FILE	SIGMAo	GROWTH INCOMPR	THICK	GROWTH THICK c	GROWTH THICK n	VORTICITY THICK	GROWTH VORT c	GROWTH VORT n	MOMENTUI THICK	GROWTH MOM c	GROWTH MOM n
M3_180	10	1.237623	19.15769			23.99068			2.197483		
M3_210	10	1.202575	21.97367	0.053949	0.450447	26.55648	0.062651	0.559359	2.305833	0.006021	0.284109
M3_250	10	1.192810	23.04305			29.06453		*.181/2con.	2.612402		
P7300	10	1.231445	12.30253			13.2720*			1.61288*		
P7100	10	1.200617	15.75673			17.65693			2.425652		
P7400	10	1.218708	16.64233	0.05723	0.475633	18.52977	0.076961	0.707062	2.434908	0.007697	0.375193
P7200	10	1.188870	17.47365			19.96578			2.662579		
P12300	10	0.91806*	7.760494			7.71320*			1.23664*		
P12200	10	0.94540*	10.75720			11.1825*			1.65399*		
P12A	10	0.944791	14.09569			16.15055			2.260668		
P12B	10	0.951019	16.43644	0.06154	0.655690	16.39192	0.076639	0.912097	2.675531	0.0141	0.645723
P12	10	0.962285	18.90516			20.66694			3.108609		

NOTE: * MEASUREMENTS WERE DELETED FROM GROWTHRATE CALCULATIONS
BECAUSE THEY WERE IN DEVELOPING REGION

AVERAGED VALUES FOR ALL CASES (Mc=.86,.64,.51)

ALLMCAVG.PRN

Mc=.86

Y-Y.5 /VORT	U-U2 /U1-U2	SIG.u /U1-U2	SIG.v /U1-U2	-RNDLS /U1-U2	-Ruv	vvv+uuv /U1-U2	uuu+uvv /U1-U2	SIG.u /SIG.v	SKEW u	SKEW v	FLAT u	FLAT v
-0.91610	0	0.021292	0.021873	-0.00003	-0.07137	0.000006	-0.00000	0.973411	-0.34153	0.504485	4.075388	5.617596
-0.82585	0	0.023943	0.024674	-0.00005	-0.10040	-0.00000	-0.00000	0.970616	-0.23109	-0.31990	5.477093	6.072135
-0.75379	0.001832	0.025502	0.025971	-0.00002	-0.04031	-0.00000	0.000002	0.981902	0.039843	-0.21825	4.745823	5.351518
-0.66304	0.009288	0.033386	0.033030	0.000134	0.079562	-0.00004	0.000047	1.002521	0.442921	-0.55030	7.172527	5.587641
-0.56363	0.028450	0.050920	0.043742	0.000635	0.253422	-0.00017	0.000321	1.148760	1.543012	-0.82741	8.482855	5.747026
-0.45412	0.073525	0.078315	0.056000	0.001449	0.312031	-0.00035	0.000746	1.383052	1.204657	-0.59412	5.461763	4.405250
-0.35024	0.156232	0.112865	0.071709	0.003336	0.411950	-0.00053	0.001186	1.573399	0.662151	-0.45054	3.091981	3.424741
-0.24344	0.256727	0.128995	0.082067	0.004507	0.428618	-0.00034	0.000745	1.572985	0.278253	-0.19008	2.640914	3.040025
-0.14394	0.350419	0.130447	0.086583	0.005216	0.461944	-0.00008	0.000269	1.506098	0.080802	0.019978	2.543445	3.107061
-0.05366	0.433416	0.133730	0.085867	0.005276	0.458854	0.000060	-0.00022	1.557200	-0.08660	0.065396	2.628940	3.012161
0.039163	0.540955	0.128161	0.083002	0.004882	0.457990	0.000338	-0.00090	1.543559	-0.36518	0.206579	2.843234	3.160007
0.146061	0.642585	0.116220	0.073256	0.003676	0.430523	0.000439	-0.00109	1.586724	-0.56757	0.347913	3.145161	3.456538
0.243276	0.738099	0.101046	0.064007	0.002508	0.378177	0.000407	-0.00099	1.577198	-0.75651	0.477617	3.884312	4.006566
0.348086	0.874779	0.064688	0.043239	0.000559	0.193095	0.000088	-0.00018	1.494698	-0.49433	0.362745	3.930381	4.097908
0.451679	0.939944	0.052397	0.038037	0.000185	0.094229	0.000005	-0.00007	1.377082	-0.43266	0.032954	3.456733	3.918582
0.547204	0.978335	0.041452	0.035723	0.000073	0.050761	0.000017	-0.00003	1.158152	-0.43234	0.169899	3.487238	3.313116
0.645173	0.995861	0.033798	0.033755	-0.00001	-0.01378	0.000003	-0.00001	1.000614	-0.28430	0.068753	3.499423	3.230421
0.752378	0.998331	0.033171	0.032910	-0.00006	-0.05661	0.000008	-0.00001	1.008178	-0.29059	0.086879	3.552727	3.360162
0.862873	0.996714	0.032909	0.034024	-0.00012	-0.10930	0.000003	-0.00001	0.967127	-0.17437	0.017096	3.061788	3.122134

Mc=.64

Y-Y.5 /VORT	U-U2 /U1-U2	SIG.u /U1-U2	SIG.v /U1-U2	-RNDLS /U1-U2	-Ruv	vvv+uuv /U1-U2	uuu+uvv /U1-U2	SIG.u /SIG.v	SKEW u	SKEW v	FLAT u	FLAT v
-1.04490	0.000063	0.021802	0.022287	-0.00005	-0.10941	-0.00000	-0.00000	0.980061	-0.36855	-0.16602	5.371602	4.428143
-0.91364	-0.00307	0.022109	0.022997	-0.00005	-0.10773	-0.00000	-0.00000	0.961420	-0.04332	-0.28388	3.51519	4.1225
-0.83065	0.000548	0.027186	0.029432	0.000041	0.050146	-0.00002	0.000007	0.923642	0.121840	-0.79381	5.071843	8.1623
-0.73640	0.007061	0.034593	0.035942	0.000236	0.187536	-0.00006	0.000072	0.960366	1.101550	-0.88426	9.52155	6.938
-0.65238	0.026388	0.053376	0.046339	0.000626	0.187562	-0.00020	0.000318	1.142659	1.096732	-0.81502	7.660433	5.631166
-0.54525	0.064736	0.075689	0.057389	0.001743	0.380027	-0.00039	0.000759	1.315737	1.303600	-0.74835	5.7134	4.562486
-0.45867	0.099663	0.091489	0.067844	0.002375	0.381189	-0.00054	0.000900	1.349221	0.915370	-0.76216	4.16927	4.8664
-0.36876	0.167463	0.113887	0.077646	0.003964	0.448330	-0.00071	0.001333	1.466276	0.730411	-0.58831	3.45351	3.722846
-0.26163	0.252313	0.128155	0.085868	0.005248	0.477020	-0.00055	0.001234	1.493136	0.458501	-0.35119	2.95129	3.369326
-0.15451	0.348513	0.136673	0.092770	0.006350	0.500035	-0.00045	0.000932	1.473181	0.276295	-0.19333	2.795236	3.029366
-0.04738	0.449843	0.148638	0.098420	0.007606	0.518671	-0.00036	0.000744	1.510216	0.164550	-0.11031	2.683573	2.936661
0.059737	0.564033	0.150796	0.095858	0.007464	0.517030	0.000299	-0.00056	1.573444	-0.13868	0.107707	2.458006	2.864110
0.153312	0.658100	0.145378	0.092076	0.006618	0.494182	0.000766	-0.00146	1.579056	-0.37367	0.336900	2.599685	3.164574
0.261973	0.777568	0.124505	0.079047	0.004346	0.436449	0.000995	-0.00191	1.571767	-0.78398	0.689144	3.455600	3.833747
0.381112	0.873327	0.093700	0.064597	0.002045	0.316887	0.000661	-0.00125	1.446470	-1.17817	0.973896	5.242833	6.1425
0.477803	0.937785	0.070586	0.053268	0.001100	0.289693	0.000372	-0.00067	1.325018	-1.41343	1.000264	6.7357	6.08705
0.557606	0.966048	0.050367	0.040413	0.000144	0.073043	0.000080	-0.00018	1.246193	-1.17631	0.458080	7.818366	4.4744
0.644414	0.980702	0.039816	0.036019	-0.00000	-0.00381	0.000009	-0.00002	1.105417	-0.35502	0.095897	3.218506	3.306342
0.751135	0.995833	0.034943	0.031673	0.000090	0.082719	0.000003	-0.00001	1.103000	-0.31883	0.070516	3.278575	3.27481
1.188726	0.997193	0.032932	0.031184	0.000082	0.081114	0.000001	-0.00000	1.056230	-0.09467	0.034835	2.993115	2.973688

Mc=.51

Y-Y.5 /VORT	U-U2 /U1-U2	SIG.u /U1-U2	SIG.v /U1-U2	-RNDLS /U1-U2	-Ruv	vvv+uuv /U1-U2	uuu+uvv /U1-U2	SIG.u /SIG.v	SKEW u	SKEW v	FLAT u	FLAT v
-1.04497	0.004530	0.029536	0.027583	-0.00010	-0.12940	-0.00000	-0.00000	1.070786	-0.12482	0.083516	3.33689	3.5476
-0.93343	0	0.031877	0.030255	-0.00006	-0.06597	-0.00000	-0.00000	1.053571	-0.11942	-0.22133	4.021493	4.028556
-0.82119	0.002397	0.037144	0.036437	0.000074	0.054221	-0.00004	0.000032	1.019208	0.372270	-0.49299	6.98825	5.0161
-0.75016	0.012273	0.046884	0.042254	0.000268	0.121058	-0.00008	0.000154	1.105374	0.963793	-0.44612	6.61465	5.03085
-0.66227	0.028790	0.057708	0.049839	0.000680	0.222840	-0.00017	0.000358	1.148976	1.290849	-0.62059	7.492933	5.1816
-0.55279	0.066076	0.078975	0.062471	0.001742	0.347411	-0.00039	0.000802	1.260828	1.256851	-0.60004	5.997366	4.622733
-0.46120	0.106747	0.093685	0.069622	0.002594	0.389324	-0.00051	0.001121	1.345525	1.028710	-0.59224	4.630266	4.34304
-0.35317	0.191739	0.117699	0.083591	0.004305	0.436379	-0.00072	0.001542	1.407783	0.711423	-0.46527	3.531592	3.612892
-0.24516	0.274990	0.133591	0.094403	0.005590	0.443277	-0.00082	0.001740	1.415125	0.545784	-0.38268	3.208835	3.561645
-0.16049	0.349354	0.150944	0.102581	0.006928	0.447489	-0.00082	0.001927	1.471901	0.424657	-0.26486	2.986446	3.209836
-0.05102	0.446128	0.160508	0.105350	0.007562	0.447541	-0.00063	0.001410	1.524559	0.261870	-0.12730	2.741423	2.957598
0.058448	0.568239	0.163758	0.107329	0.007999	0.455610	0.000067	-0.00009	1.527803	-0.02425	0.094381	2.573906	2.919987
0.167919	0.687674	0.163712	0.104016	0.007974	0.467773	0.000818	-0.00149	1.573472	-0.26330	0.304342	2.543563	3.122769
0.277391	0.809527	0.139718	0.088497	0.005348	0.429017	0.001075	-0.00236	1.575943	-0.71207	0.560297	3.335146	3.545483
0.368573	0.876117	0.119253	0.081071	0.003808	0.393057	0.000962	-0.00206	1.471120	-0.94259	0.743205	3.825885	4.25514
0.445385	0.917287	0.099793	0.068252	0.002378	0.345156	0.000682	-0.00156	1.460539	-1.26658	0.766790	5.3603	4.6329
0.564527	0.975319	0.064622	0.051318	0.000754	0.226245	0.000190	-0.00038	1.259423	-1.12138	0.653226	6.359366	5.505466
0.683015	0.995827	0.052311	0.043973	0.000399	0.173717	0.000050	-0.00012	1.190283	-0.71167	0.252915	5.2589	3.682645
0.794944	0.999989	0.046655	0.039328	0.000181	0.098956	0.000024	-0.00007	1.186293	-0.63207	0.161327	4.674	3.58253
0.991391	0.999305	0.042804	0.040037	0.000169	0.099184	0.000001	-0.00002	1.069105	-0.27712	0.043036	3.53014	3.31989

BOUNDARY LAYER RESULTS FOR (Mo=0.51, UPPER STREAM M=1.8)

FILE	U	V	SIGMA U	SIGMA V	REYNOLDS STRESS	CORR. COEF.	uuu	uuv	uvv	vvv	Y	Y/DEL	U/U1	−Ruv	SIG1/U1
BL111	367.71		33.65								0.5	0.0625	0.747378		
BL112	380.96		33.7								1	0.125	0.774308		
BL110	386.54		33.31								1.6	0.2	0.785650		
BL109	410.34		30.96								2.2	0.275	0.834024		
BL3110	415.81	3.03	36.90462	19.14526	310.82	−0.43991	−20762	−7030.4	−3826.2	−1941.4	2.5	0.3125	0.845142	0.439913	0.075009
BI3109	429.69	1.72	35.29781	18.99660	293.62	−0.43788	−20776	−7780.2	−4417.1	−2506.4	3	0.375	0.873353	0.437886	0.071743
BI3108	445.83	0.91	31.04356	17.95129	216.95	−0.38930	−16026	−4664.9	−3647.7	−1122.3	4	0.5	0.906158	0.389307	0.063096
BL3107	462.4	0.48	27.26378	15.66630	181.2	−0.42423	−18985	−8080.1	−5764.1	−4102.5	5	0.625	0.939837	0.424234	0.055414
BL3106	471.77	−0.86	23.80445	14.54771	134.93	−0.38963	−14981	−4970.3	−2983.6	−1129	6	0.75	0.958882	0.389632	0.048383
BL3105	478.85	−1.72	20.57739	13.24363	97.55	−0.35795	−8773.6	−2973.4	−1880.4	−1229.7	7	0.875	0.973272	0.357955	0.041823
BL3104	486.15	0.14	16.42309	12.37404	56.33	−0.27718	−5165.4	−2107.7	−1793.8	−1164.2	8	1	0.988109	0.277187	0.033380
BL3103	491.2	0.75	13.50248	7.371634	13.99	−0.14055	−1708	−261.37	−49.39	−156.96	9	1.125	0.998373	0.140553	0.027444
BL3102	492.09	−0.84	13.46309	11.51577	30.63	−0.19756	−1569.3	−692.86	−870.42	−404.3	10	1.25	1	0.197564	0.027364
BL3101	491.83	−3.73	13.05511	11.53321	33.76	−0.22421	−1258.5	−17.695	−391.78	46.845	12	1.5	1	0.224218	0.026534
BL3100	492.08	−5.84	13.16480	12.78323	49.13	−0.29193	−6353.2	−5419.1	−5269.6	−4135.2	16	2	1	0.291938	0.026757

U1	492
DEL	8

SAMIMY & ELLIOTT M5X60.PRN

SHEAR LAYER RESULTS (Mc=0.51, X=60mm)

FILE	U	V	SIGMA u	SIGMA v	REYNOLDS STRESS	CORR. COEF.	uuu	uuv	uvv	vvv	uuuu	vvvv
12312	176.66	-2.16	10.60	8.10	17.84	0.209622	-242.18	-96.611	-30.060	-82.019	44067.00	13741.64
12311	178.7	-2.11	11.60	8.86	20.84	0.196560	-494.5	-101.76	-86.821	-138.18	80303.20	19627.22
12310	171.17	-0.08	14.18	11.28	14.06	0.087897	-694.21	-148.48	-81.182	-697.13	129254.4	73890.46
12308	173.6	2.4	19.11	16.44	-61	-0.19394	2462.6	-2833.2	1806.8	-2586.8	677085.6	372626.1
12307	201.21	4.32	33.93	24.26	-362.04	-0.44006	42778	-19418	13941	-9211.7	6906346.	1421726.
12306	264.48	6.34	60.60	30.15	-787.84	-0.81618	77113	-27009	14447	-8663.2	19704926	2447486.
12305	342.86	2.96	64.90	32.22	-1014.96	-0.56384	-18018	7846.6	-8166	5307.6	26063826	2934692.
12304	414.2	-2.29	40.87	24.33	-471.81	-0.47338	-40738	16316	-11208	11606	8625914.	1460004.
12303	447.69	-4.08	28.29	17.64	-187.14	-0.37610	-22271	7244.6	-4366.3	3372.9	2727866.	416710.6
12302	466.86	-4.2	20.67	14.28	-76.27	-0.25606	-9620.2	3016.8	-1743.1	1063.6	876129.1	171464.3
12301	473.68	-4.39	18.04	12.38	-18.6	-0.08015	-2677.4	826.31	-410.86	612.28	237563.7	75361.87
12300	478.99	-3.13	12.06	11.11	-3.27	-0.02442	-379.63	363.61	-120.94	416.26	68232.96	82706.07

FILE	X (mm)	Y (mm)	Y-Y.5 /THICK	Y-Y.5 /VORT	U-U2 /U1-U2	SIG. u /U1-U2	SIG. v /U1-U2	-RNOLS /(U1-U2)^2	-Ruv
12312	60	-8	-1.49763	-1.80681	0.000	0.036	0.027	-1.96E-04	-0.210
12311	60	-6	-1.23991	-1.24762	-0.004	0.038	0.030	-2.26E-04	-0.197
12310	60	-4	-0.98220	-0.98822	-0.016	0.047	0.038	-1.56E-04	-0.096
12308	60	-2	-0.72448	-0.72892	-0.010	0.064	0.066	6.77E-04	0.194
12307	60	0	-0.46677	-0.46963	0.061	0.113	0.081	4.02E-03	0.440
12306	60	2	-0.20906	-0.21032	0.272	0.166	0.100	8.74E-03	0.818
12305	60	4	0.048666	0.048967	0.553	0.190	0.107	1.13E-02	0.664
12304	60	6	0.306374	0.308283	0.791	0.136	0.081	6.24E-03	0.473
12303	60	8	0.564090	0.567646	0.902	0.094	0.066	2.06E-03	0.378
12302	60	10	0.821806	0.826846	0.963	0.068	0.046	8.36E-04	0.258
12301	60	12	1.079620	1.086140	0.988	0.060	0.041	1.84E-04	0.089
12300	60	18	1.864981	1.804732	1.000	0.040	0.037	3.63E-06	0.024

FILE	vvv+uuv /(U1-U2)^3	uuu+uvv /(U1-U2)^3	SKEW u	SKEW v	FLAT u	FLAT v
12312	-6.96E-06	-1.01E-05	-0.20916	-0.17336	3.6232	3.19730
12311	-1.11E-05	-2.10E-05	-0.30064	-0.19656	3.10672	3.18248
12310	-2.70E-05	-2.67E-05	-0.24371	-0.41646	3.20106	4.8702
12308	-1.89E-04	1.60E-04	0.361306	-0.56034	6.0784	6.0794
12307	-1.06E-03	2.10E-03	1.094881	-0.64634	6.2318	4.1148
12306	-1.22E-03	3.39E-03	0.896190	-0.21384	3.006699	2.981464
12305	4.86E-04	-6.57E-04	-0.09778	0.184644	2.46692	2.72236
12304	1.00E-03	-1.92E-03	-0.59260	0.803466	3.026794	4.1564
12303	3.93E-04	-8.86E-04	-0.98418	0.614666	4.2619	4.296
12302	1.74E-04	-4.20E-04	-1.06918	0.579691	4.7966	4.1278
12301	6.32E-05	-1.11E-04	-0.76716	0.270190	4.6397	3.21078
12300	2.84E-06	-1.86E-06	-0.21664	0.303121	3.231	3.44787