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Laminar Flow Control (1976-1982)
A Selected, Annotated Bibliography

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INTRODUCTION

Laminar Flow Control (LFC) technology development has undergone tremendous progress in recent years as focused research efforts in materials, aerodynamics, systems, and structures have begun to pay off. A virtual explosion in the number of research papers published on this subject has occurred since interest was first stimulated by the 1976 introduction of the NASA's Aircraft Energy Efficiency Laminar Flow Control (ACEE/LFC) Program. Today, a wide variety of fundamental and applied research programs exist, not only in controlled (active) boundary-layer flow, but also in natural (passive) laminar flow. Studies of airfoils which combine the two methods (hybrid) are now beginning.

The purpose of this selected bibliography is to list available, unclassified laminar flow research completed since the ACEE/LFC Program was begun. This bibliography is therefore limited to research conducted from about 1975 to mid 1982.

The reports listed herein emphasize the aerodynamics and systems studies which were the main product of this work, but some structures reports are also included. Aerodynamic research is mainly limited to the subsonic and transonic speed regimes. Because wind-tunnel flow qualities such as free stream disturbance level play such an important role in boundary-layer transition, much research has recently been done in this area and it is also included.

Laminar flow control research through 1978 was extensively surveyed in NASA RP-1035 (citation 141). Some pertinent publications from that reference are also included here. In addition, there is available a bibliography (citation 7) of Air Force Flight Dynamics Laboratory (AFFDL) reports on LFC which summarizes work accomplished during the X-21 program. A third LFC bibliography (citation 25) has been published by Lockheed-Georgia.

The appendix of this compilation includes reports published prior to 1976 which were not included in NASA RP-1035 but are pertinent to this subject.

Considerable effort was made to survey as much relevant literature as possible from many different sources. However, some important papers may have been inadvertently overlooked.

Persons wishing more information on specific topics should check the reference lists in those documents described herein which are pertinent to their interest. They also are urged to use the services available from NASA for computer data bank searches. Technical libraries at NASA research centers can fill such requests.

The items selected for inclusion in this bibliography are generally arranged chronologically by date of publication. Conference papers, however, are placed according to date of presentation. An author index is included at the end of the bibliography.

In most cases, abstracts used are from the NASA announcement bulletins "Scientific and Technical Aerospace Reports" (STAR) and "International Aerospace Abstracts" (IAA). In other cases, authors' abstracts were used. License was taken to modify or shorten abstracts. If it is known that a paper has appeared in several forms, mention is made of this fact.

Identifying information, including accession and report numbers (when known), is included in the citations in order to facilitate the filling of requests for specific items. When requesting material from your library or other source, it is advisable to include the complete citation; the abstract may be omitted.

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XXX-XXXXX Example: X72-76040	Report literature having some type of limited distribution.	NASA Scientific and Technical Information Facility (STIF) P.O. Box 8757 B.W.I. Airport, MD 21240
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Any others - include any information given	Ask your library, or	NASA Scientific and Technical Information Facility (STIF) P.O. Box 8757 B.W.I. Airport, MD 21240

BIBLIOGRAPHY

1. Aircraft Fuel Conservation Technology. *Task force report. NASA TM-X-74295, Sept. 9, 1975, 141 pp.

N77-11055#

An advanced technology program is described for reduced fuel consumption in air transport. Cost benefits and estimates are given for improved engine design and components, turboprop propulsion systems, active control systems, laminar flow control, and composite primary structures.

*NASA, Washington, D.C.

2. *Canu, M.: Noise and Turbulence in Transonic Wind Tunnels. Report No. AAAF-NT-76-12; ISBN-2-7170-0390-8; Paris Assoc. Aeron. et Astronautique de France. Presented at the 12th Ecole Natl. Super. de Mecan. et d'Aerotech./CEAT Colloq. d'Aerodyn. Appl., Poitiers, France, 5-7 Nov. 1975, 21 pp. (In French.)

N77-10082#

Reduction of noise in transonic wind tunnels, due largely to wall perforations, was studied. Different types of perforations were tested. Several of these bring the noise level down to that of guide vanes. The measurements were made with microphones or with hot wire probes; from the analogy of the spectra obtained it was concluded that noise is the major component of the turbulence.

*Office National d'Etudes et de Recherches Aerospatiales (ONERA), Modane, France

3. *Shevell, R. S.: Advanced Subsonic Aircraft - The Technological Response to Future Air Transportation Needs. In: Princeton Univ. Conference Proceedings (A76-45776), Princeton, N.J., Nov. 10, 11, 1975, pp. 5-1 to 5-26.

A76-45781#

Improvements, such as automatic flight management, advanced aerodynamics, laminar flow control, advanced engines, and advanced structural materials, could lead to significant reductions in fuel requirements; the development of new technologies is, however, dependent on the economic health of the aviation industry. The history of transport aircraft is reviewed as are technological advances - drag reduction, weight reduction, improvement in lift coefficient, etc. Some developments in air transportation which raised great expectations, but have failed to have a significant impact are reviewed: laminar flow control, nuclear powered aircraft, STOL and the supersonic transport. The feasibility of hydrogen-fueled aircraft is discussed.

*Stanford Univ., Stanford, Calif.

4. *Zuda, E.: Installation of a Flow Straightener in the Subsonic Wind Tunnel. DFVLR-Nachrichten, Nov. 1975, pp. 697, 698. (In German.)

A76-13407

Turbulence-produced disturbances in wind tunnel experiments led to the installation of a flow-straightening device. The elimination of turbulence effects in such a device is obtained by dividing the area of the flow cross section into a number of separate channels. The use of cylindrical tubes for this purpose has certain disadvantages. It was, therefore, decided to employ regular hexagonal pipes for the design of the flow straightener. Aluminum pipes were selected because of their low weight. Details concerning the design and the installation of the device are discussed.

*Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt. Zentralabteilung Niedergeschwindigkeits-Windkanaeale, Porz-Wahn, West Germany.

5. *Bauer, Frances; *Garabedian, Paul; *Korn, David; *Jameson, Antony; *Beckmann, M., ed.; and *Kuenzi, H. P., ed.: Supercritical Wing Sections 2, Volume 108. NASA CR-142229, 1975, 301 pp. Springer-Verlag, 1975.

N75-18167

A mathematical theory for the design and analysis of supercritical wing sections was previously presented. Examples and computer programs showing how this method works were included. The work on transonics is presented in a more definitive form. For design, a better model of the trailing edge is introduced which should eliminate a loss of fifteen or twenty percent in lift experienced with previous heavily aft loaded models, which is attributed to boundary layer separation. How drag creep can be reduced at off-design conditions is indicated. A rotated finite difference scheme is presented that enables the application of Murman's method of analysis in more or less arbitrary curvilinear coordinate systems. This allows the use of supersonic as well as subsonic free stream Mach numbers and to capture shock waves as far back on an airfoil as desired. Moreover, it leads to an effective three dimensional program for the computation of transonic flow past an oblique wing. In the case of two dimensional flow, the method is extended to take into account the displacement thickness com-

puted by a semi-empirical turbulent boundary layer correction.

*New York Univ., New York.

Contract AT(11-1)-3077
Grants NGR-33-016-201 and NGR-33-016-167

6. *Povinelli, F. P.; *Klineberg, J. M.; and *Kramer, J. J.: Improving Aircraft Energy Efficiency. Astronautics and Aeronautics, Vol. 14, Feb. 1976, pp. 18-31.

A76-19593#

Investigations conducted by a NASA task force concerning the development of aeronautical fuel-conservation technology are considered. The task force estimated the fuel savings potential, prospects for implementation in the civil air-transport fleet, and the impact of the technology on air-transport fuel use. Propulsion advances are related to existing engines in the fleet, to new production of current engine types, and to new engine designs. Studies aimed at the evolutionary improvement of aerodynamic design and a laminar flow control program are discussed and possibilities concerning the use of composite structural materials are examined.

*NASA, Office of Aeronautics and Space Technology, Aircraft Energy Efficiency Office, Washington, D.C.

7. *Jobe, Charles E.: A Bibliography of AFFDL/FXM Reports on Laminar Flow Control. AFFDL-TM-76-26-FXM, U.S. Air Force, Mar. 1976, 24 pp.

N79-70034

AFFDL/FXM was the Air Force office responsible for technically monitoring the X-21A Laminar Flow Control Flight Demonstration Program and the many associated research contracts. Approximately 165 reports and technical notes remain from the LFC research, due to the critical shortage of file cabinets and many "file Field days." The bibliography is arranged alphabetically by personal author and date. The corporate author was used when the personal author was unknown. The many progress reports are listed as such, by contract number. A cross-reference list by NORTHROP BLC- ( ) number is contained on page 22.

*Air Force Flight Dynamics Lab., Wright-Patterson AFB, Ohio.

8. *Maddalon, D. V.; and *Wagner, R. D.: Energy and Economic Trade Offs for Advanced Technology Subsonic Aircraft. NASA TM-X-72833, April 1976, 25 pp. Also presented at the 4th Annual Intersociety Conference on Transportation, Los Angeles, Calif., July 18-23, 1976, 11 pp.

N76-20124#
A77-29451#

Changes in future aircraft technology which conserve energy are studied, along with the effect of these changes on economic performance. Among the new technologies considered are laminar-flow control, composite materials with and without laminar-flow control, and advanced airfoils. Aircraft design features studied include high-aspect-ratio wings, thickness ratio, and range. Engine technology is held constant at the JT9D level. It is concluded that wing aspect ratios of future aircraft are likely to significantly increase as a result of new technology and the push of higher fuel prices. Composite materials may raise aspect ratio to about 11 to 12 and practical laminar flow-control systems may further increase aspect ratio to 14 or more. Advanced technology provides significant reductions in aircraft take-off gross weight, energy consumption, and direct operating cost.

*NASA, Langley Research Center, Hampton, Va.

9. *Payne, H. E.: Laminar Flow Rethink - Using Composite Structure. Society of Automotive Engineers, Business Aircraft Meeting, Wichita, Kansas, April 6-9, 1976, 12 pp.

SAE-76-0473 A76-31966

The use of composite structure in the design of the Skyrocket II, a general aviation aircraft capable of operating in the laminar flow "drag bucket" on a normal service, is discussed. The aircraft design utilizes a very stiff epoxy/fiberglass composite air-passage skin consisting of relatively few parts to eliminate air load stress ripples. A zero-lift drag coefficient in the area of 0.15 has been obtained by design engineering specifically for low drag, maximizing the extent of laminar flow by use of the stiff composite skin, and minimizing protuberances into the air passage.

*Bellanca Aircraft Engineering, Inc., Scott Depot, W. Va.

10. *Swinford, G. R.: A Preliminary Design Study of a Laminar Flow Control Wing of Composite Materials for Long Range Transport Aircraft, Final Rept., April. 1975 - Mar. 1976. NASA CR-144950, April 1976, 125 pp.

N76-25146#

The results of an aircraft preliminary design study are reported. The selected study airplane configuration is defined. The suction surface, ducting, and compressor systems are described. Techniques of manufacturing suction surfaces are identified and discussed. A wing box of graphite/epoxy composite is defined. Leading and trailing

edge structures of composite construction are described. Control surfaces, engine installation, and landing gear are illustrated and discussed. The preliminary wing design is appraised from the standpoint of manufacturing, weight, operations, and durability. It is concluded that a practical laminar flow control (LFC) wing of composite material can be built, and that such a wing will be lighter than an equivalent metal wing. As a result, a program of suction surface evaluation and other studies of configuration, aerodynamics, structural design and manufacturing, and suction systems are recommended. It is concluded that future development of composite primary structure should consider the requirements of LFC wings, and be coordinated with an LFC development program.

*Boeing Commercial Airplane Co., Seattle, Wash. Contract NAS1-13872

11. *Denning, R. M.; *Miller, S. C.; and *Wright, G. H.: Future Trends in Aero Gas Turbine Design. II - Unconventional Engines. Presented at the Royal Aeronautical Society Spring Convention on "Seeds for Success in Civil Aircraft Design in the Next Two Decades," London, England, May 19, 20, 1976. Aeronautical Journal, Vol. 80, Sept. 1976, pp. 385-393.

A77-11595

Unconventional types of aircraft gas turbine (GT) engines reviewed are so treated in the sense of: unconventional uses (other than propulsion) for the GT engine, modification of the thermodynamic cycle under some flight conditions, or use of extremes of the constant-pressure GT cycle. Variant thermodynamic/aerodynamic cycles under consideration include: a heat-exchanger engine, propulsion systems with ingestion or re-energizing of wake or boundary layer to reduce drag, and systems resorting to laminar flow control or boundary layer suction. Engines featuring in-flight variation of the thermodynamic cycle include: those using variable turbine stators, SST variable-cycle engines with compressor switching valve system, and variable-pitch fan engines. Engines developing vertical lift in addition to propulsive thrust include: blow-fan engines, externally blown flap engines, and rotatable remote lift/propulsion fan engines.

*Aero. Div., Rolls-Royce (1971), Ltd., Bristol, England

12. *Schrader, O. E.: Application of Advanced Technology to Future Long-Range Aircraft. Presented at the Society of Allied Weight Engineers, 35th Annual Conference, Philadelphia, May 24-26, 1976. NASA TM-X-73921, May 24, 1976, 49 pp.

SAWE Paper 1126 A77-12194# N76-29218#

An assessment is presented of three separate programs at Langley Research Center that have incorporated advanced technology into the design of long-range passenger and cargo aircraft. The first technology centers around the use of a span-loaded cargo aircraft with the payload distributed along the wing. The second technology is the application of laminar flow control to the aircraft to reduce the aerodynamic drag. The use of LFC can reduce the fuel requirements during long-range cruise. The last program evaluates the production of alternate aircraft fuels from coal and the use of liquid hydrogen as an aircraft fuel.

*NASA, Langley Research Center, Hampton, Va.

13. Geddes, J. P.: Civil Transport Technology up to 2000. (NASA believes fuel consumption is the major consideration.) Interavia, Vol. 31, May 1976, pp. 419-421.

A76-32649

The recommendations of a NASA task force formed to establish goals in a comprehensive program for developing fuel conservation technology for the civil air transport industry are compared with typical industry views of the developments that are feasible in the near future. A 9-year research program for an advanced turboprop engine cruising at Mach 0.8 at 9,500 m has been suggested, together with improved engine components for existing engines such as the JT8D, JT9D, and CF6, including mechanical mixers to mix the core and duct stream before discharge through a common nozzle, clearance control to improve compressor and turbine efficiency, and improved blade shapes. Four possible aerodynamic approaches to fuel consumption were selected for future study: drag clean-up, improved aerodynamic design, laminar flow control, and the use of small vertical end-plates on wing-tips to augment thrust. Work in these areas would be divided between an Energy Efficient Transport program and a separate Laminar Flow Control program. A greatly accelerated effort in the development of composite structures is urged. The total cost of the proposed programs is $670 million; a fuel savings of 79% over a fleet incorporating current advanced technology is predicted for a fleet resulting from the suggested program in the year 2005.

14. *Sturgeon, R. F.; *Bennett, J. A.; *Etchberger, F. R.; *Ferrill, R. S.; and *Meade, L. E.: Study of the Application of Advanced Technologies to Laminar-Flow Control Systems for Subsonic Transports. Volume I: Summary. Final Rept. NASA CR-144975, May 1976, 63 pp.

N76-24144#

A study was conducted to evaluate the technical and economic feasibility of applying laminar flow control to the wings and empennage of long-range subsonic transport aircraft compatible with initial operation in 1985. For a design mission range of 10,186 km (5500 n. mi.), advanced technology laminar-flow-control (LFC) and turbulent-flow (TF) aircraft were developed for both 200-

and 400-passenger payloads, and compared on the basis of production costs, direct operating costs, and fuel efficiency. As part of the study, parametric analyses were conducted to establish the optimum geometry for LFC and TF aircraft, advanced LFC system concepts and arrangements were evaluated, and configuration variations maximizing the effectiveness of LFC were developed. For the final LFC aircraft, analyses were conducted to define maintenance costs and procedures, manufacturing costs and procedures, and operational considerations peculiar to LFC aircraft. Compared to the corresponding advanced technology TF transports, the 200- and 400-passenger LFC aircraft realized reductions in fuel consumption up to 28.2%, reductions in direct operating costs up to 8.4%, and improvements in fuel efficiency, in ssm/lb of fuel, up to 39.4%. Compared to current commercial transports at the design range, the LFC study aircraft demonstrate improvements in fuel efficiency up to 131%. Research and technology requirements requisite to the development of LFC transport aircraft were identified.

*Lockheed-Georgia Co., Marietta, Georgia.
Contract NAS1-13694

15. *Sturgeon, R. F.; *Bennett, J. A.; *Etchberger, F. R.; *Ferrill, R. S.; and *Meade, L. E.: Study of the Application of Advanced Technologies to Laminar-Flow Control Systems for Subsonic Transports. Volume II, Analyses. NASA CR-144949, May 1976, 471 pp.

N76-24145#

The abstract given in Volume I covers both volumes.

*Lockheed-Georgia Co., Marietta, Ga.
Contract NAS1-13694.

16. *Mabey, Dennis G.: Some Remarks on the Design of Transonic Tunnels with Low Levels of Flow Unsteadiness. NASA CR-2722, Aug. 1976, 20 pp.

N79-25039#

The principal sources of flow unsteadiness in the circuit of a transonic wind tunnel are presented. Care must be taken to avoid flow separations, acoustic resonances and large scale turbulence. Some problems discussed are the elimination of diffuser separations, the aerodynamic design of coolers and the unsteadiness generated in ventilated working sections.

*Royal Aircraft Establishment, Bedford, England.
NASA L-32158-A

17. Aircraft Fuel Efficiency Program. GPO Rept. (GPO-57-010) for U.S. Senate (S-Rept-94-633) Comm. on Aeronautical and Space Sciences, 94th Congress, 2nd Sess. 17 Feb. 1976, 28 pp. Available from U.S. Capitol, Senate Document Room.)

N77-17032#

A technology plan is described for developing fuel-efficient aircraft. Inputs were obtained from industry, NASA research centers, and other governmental agencies. Six major programs are defined: engine component improvement, composite primary structures, turboprops, laminar flow control, fuel conservative transport, and the fuel conservative engine. Funding requirements and benefits are discussed.

18. *Maddalon, D. V.; and *Wagner, R. D.: Energy and Economic Trade Offs for Advanced Technology Subsonic Aircraft. In: Annual Intersociety Conference on Transportation, 4th, Los Angeles, Calif., July 18-23, 1976, Proceedings (A77-29451) ASME, 1976, 11 pp.

A77-29471

Changes in future aircraft technology which conserve energy are studied, along with the effect of these changes on economic performance. Among the new technologies considered are laminar-flow control, composite materials with and without laminar-flow control, and advanced airfoils. Aircraft design features studied include high-aspect-ratio wings, thickness ratio, and range. Engine technology is held constant at the JT9D level. It is concluded that wing aspect ratios of future aircraft are likely to significantly increase as a result of new technology and the push of higher fuel prices. Whereas current airplanes have been designed for AR = 7, supercritical technology and much higher fuel prices will drive aspect ratio to the AR = 9-10 range. Composite materials may raise aspect ratio to about 11-12 and practical laminar flow-control systems may further increase aspect ratio to 14 or more. Advanced technology provides significant reductions in aircraft take-off gross weight, energy consumption, and direct operating cost.

*NASA, Langley Research Center, Hampton, Va.

19. *Douglas Aircraft Co.: Development of Technology for the Fabrication of Reliable Laminar Flow Control Panels on Subsonic Transports. NASA CR-145125; MDC-J4546; Oct. 1976, 214 pp.

N77-17038#

The feasibility of using porous composite materials (Kevlar, Doweave, and Leno Weave) as lightweight, efficient laminar flow control (LFC) surface materials is compared to the metallic 319L stainless Dynapore surfaces and electron beam drilled composite surfaces. Areas investigated include: (1) selection of the LFC-suitable surface materials, structural materials, and fabrication techniques for the LFC aircraft skins; (2) aerodynamic static air flow test results in terms of pressure drop through the LFC panel and

the corresponding effective porosity; (3) structural design definition and analyses of the panels; and (4) contamination effects on static drop and effective porosity. Conclusions are presented and discussed.

*McDonnell Douglas Corp, Long Beach, Calif.
Contract NAS1-14408

20. *Econ, Inc.: An Assessment of the Benefits of the Use of NASA Developed Fuel Conservative Technology in the U. S. Commercial Aircraft Fleet. NASA CR-148148 (Revised); Rept.-75-163-1, Oct. 1975, 84 pp.

N76-23249#

Cost and benefits of a fuel conservative aircraft technology program proposed by NASA are estimated. NASA defined six separate technology elements for the proposed program: (a) engine component improvement (b) composite structures (c) turboprops (d) laminar flow control (e) fuel conservative engine and (f) fuel conservative transport. There were two levels postulated: The baseline program was estimated to cost $490 million over 10 years with peak funding in 1980. The level two program was estimated to cost an additional $180 million also over 10 years. Discussions with NASA and with representatives of the major commercial airframe maufacturers were held to estimate the combinations of the technology elements most likely to be implemented, the potential fuel savings from each combination, and reasonable dates for incorporation of these new aircraft into the fleet.

*Princeton, N. J.
Contract NASW-2781

21. *Fasel, H.: Investigation of the Stability of Boundary Layers by a Finite-Difference Model of the Navier-Stokes Equations. Journal of Fluid Mechanics, Nov. 23, 1976, Part 2, pp. 355-383.

A77-20041

The stability of incompressible boundary-layer flows on a semi-infinite flat plate and the growth of disturbances in such flows are investigated by numerical integration of the complete Navier-Stokes equations for laminar two-dimensional flows. Forced time-dependent disturbances are introduced into the flow field and the reaction of the flow to such disturbances is studied by directly solving the Navier-Stokes equations using a finite-difference method. An implicit finite-difference scheme was developed for the calculation of the extremely unsteady flow fields which arose from the forced time-dependent disturbances. The problem of the numerical stability of the method called for special attention in order to avoid possible distortions of the results caused by the interaction of unstable numerical oscillations with physically meaningful perturbations. A demonstration of the suitability of the numerical method for the investigation of stability and the initial growth of disturbances is presented for small periodic perturbations. For this particular case the numerical results can be compared with linear stability theory and experimental measurements. In this paper a number of numerical calculations for small periodic disturbances are discussed in detail. The results are generally in fairly close agreement with linear stability theory or experimental measurements.

*Institut A für Mechanik, Universität, Stuttgart, Germany.

22. *Leonard, Robert W.; and *Wagner, Richard D.: Airframe Technology for Energy Efficient Transport Aircraft. Paper presented at SAE 1976 Aerospace Engineering and Manufacturing Meeting, San Diego, Calif., Nov. 29-Dec. 2, 1976, 17 pp.

SAE 760929 A77-28234

NASA has initiated a comprehensive Aircraft Energy Efficiency Program which is concerned with the development of approaches for reducing fuel consumption in new aircraft of the 1980-2000 time period. A review is presented of the airframe technologies selected for emphasis in the NASA program, taking into account an evaluation of their potential for reducing transport direct operating cost for derivative and new aircraft introduced by 1985. Technology for maintenance of a laminar boundary layer in cruise offers great benefits in fuel efficiency and direct operating cost and may be ready for application to transports introduced in the 1990's.

*NASA, Langley Research Center, Hampton, Va.

23. *Herbert, Th.: On the Stability of the Boundary Layer Along a Concave Wall. Biennial Fluid Dynamics Symposium on Advanced Problems and Methods in Fluid Dynamics, 12th, Bialowieza, Poland, Sept. 8-13, 1975. Arch. Mech. Stosow., vol. 28, no. 5-6, 1976, pp. 1039-1055.

A77-29371

Various approaches for investigating the linear stability of the laminar boundary layer along a concave wall with respect to Görtler vortices are compared concerning their order in the two small parameters, wall curvature and inverse Reynolds number, as well as the treatment of the curvature terms. Numerical results show separately the effects of wall curvature, streamline curvature and its finite extent on the neutral conditions. The influence of the growing boundary layer thickness on the stability characteristics is estimated and found to be of first order.

*Freiburg, Universitaet, Freiburg im Breisgau, Germany

24. *Kutateladze, S. S.; and *Migirenko, G. S. (editors): Investigations of Boundary Layer Control. Novosibirsk - 1976. (In Russian.)

In this digest are set out some results of investigations of various boundary layer controlling methods including distributed suction, polymeric addition introduction, gas saturation of boundary layer and the formation of viscoelastic properties for streamlined surfaces.

Most of the papers deal with the investigation of transition of boundary layer into turbulence and the development of measuring equipment and methods.

Contents

1. Kolobov, B. P.; Migirenko, G. S.; and Novikov, B. G.: Boundary-Layer Control by the Distributed Suction.

2. Vedyakin, P. I.; Garipov, R. M.; and Novikov, B. G.: The Effect of Homogeneous Suction Through Perforated Surfaces on Laminar and Turbulent Boundary Layer.

3. On the Effect of Saturation on the Wall Turbulence.

4. Bogdevich, V. G.; and Malyuga, A. G.: Surface Friction Distribution in the Turbulent Boundary Layer Behind the Place of Gas Injection.

5. Kobets, M. L.; and Kobets, G. F.: The Drag Reducing Natural Polymers.

6. Vanin, Yu. P.; and Migirenko, G. S.: On the Distribution of Polymer Concentrations in Boundary Layer.

7. Semenov, B. N.: The Effect of Elastic Covers on a Turbulent Boundary Layer.

8. Trifonov, G. F.: On Measurement of Skin Friction in Dilute Polymer Solution Using Hot Films.

9. Belousov, P. Ya.; and Evseev, A. R.: Multichannel Laser Doppler Velocimeter.

10. Voitenko, A. N.; and Tetyanko, V. A.: On the Measurement of an Intermittency Coefficient in Laminar-Turbulent Transition.

11. Sobstel, N. B.; Tetyanko, V. A.; Sharapova, T. A.; and Shtatnov, Yu. V.: On the Formation of the Turbulent Boundary Layer.

*Institute of Thermophysics, Academy of Sciences of the USSR, Siberian Branch

25. *Kopkin, T. J.; and *Rife, C. D.: Laminar Flow Control Bibliography. Rep. No. LG 77ER0018, Lockheed-Georgia Co., Jan. 17, 1977. (Available to U. S. Gov't. Agencies Only)

AD B026 321L X78-75877

*Lockheed-Georgia Co., Marietta, Georgia

26. *Weiss, D. D.; and *Lindh, D. V.: Development of the Technology for the Fabrication of Reliable Laminar Flow Control Panels. Final Rept. NASA CR-145124; D6-44184; Feb. 1977, 119 pp.

N77-18131#

The results of a 5 months test program to evaluate LFC surface materials are reported. Requirements for LFC surface smoothness and flow were compiled from existing data. Various configurations of porous, perforated and slotted materials were flow tested to determine if they would meet these requirements. The candidate materials were then tested for susceptibility to clogging and for resistance to corrosion. Of the materials tested, perforated titanium, porous polyimide, and slotted assemblies demonstrated a much greater resistance to clogging than other porous materials. Three concepts for installing LFC materials were studied.

*Boeing Commercial Airplane Co., Seattle, Wash. Contract NAS1-14407

27. *Meade, L. E.; *Kays, A. O.; *Ferrill, R. S.; and *Young, H. R.: Development of the Technology for the Fabrication of Reliable Laminar Flow Control Panels. Final Technical Rept., Apr.-Sept., 1976. NASA CR-145168, Feb. 1977, 91 pp.

N77-22178

Materials were assessed and fabrication techniques were developed for use in the manufacture of wing surface materials compatible with the application of both aluminum alloys and nonmetallic composites. The concepts investigated included perforations and slots in the metallic test panels and microporosity and perforations in the composite test panels. Perforations were produced in the metallic test panels by the electron beam process and slots were developed by controlled gaps between the metal sheets. Microporosity was produced in the composite test panels by the resin bleed process, and perforations were produced by the fugitive fiber technique. Each of these concepts was fabricated into test panels, and air flow tests were conducted on the panels.

Flow test results for each material specimen were compared with an analytically predicted variable suction criteria, and indicated acceptable performance for all but the microporous composite specimens. Contamination and cleaning tests were conducted on selected electron beam perforated panels. Maximum increases in pressure loss due to

contamination of 23 percent were observed, and in general the cleaning process successfully removed the contaminant. Further flow analysis included flow friction factor evaluation with good data consolidation for all test conditions of electron beam perforations and slotted test panels. Several samples of the perforated composite panels were submitted to NASA along with material data sheets.

*Lockheed-Georgia Co., Marietta, Ga.
Contract NAS1-14409

28. *Carter, James E.: STAYLAM: A FORTRAN Program for the Suction Transition Analysis of a Yawed Wing Laminar Boundary Layer. NASA TM X-74013, March 1977, 80 pp.

N77-18390

A computer program called STAYLAM is presented for the computation of the compressible laminar boundary-layer flow over a yawed infinite wing including distributed suction. This program is restricted to the transonic speed range or less due to the approximate treatment of the compressibility effects. The prescribed suction distribution is permitted to change discontinuously along the chord measured perpendicular to the wing leading edge. Estimates of transition are made by considering leading edge contamination, cross flow instability, and instability of the Tollmien-Schlichting type. A program listing is given in addition to user instructions and a sample case.

*NASA, Langley Research Center, Hampton, Va.

29. *Gregorek, G. M.; *Hoffmann, M. J.; **Payne, H. E.; and **Harris, J. P.: Drag Evaluation of the Bellanca Skyrocket II. Presented at Society of Automotive Engineers, Business Aircraft Mtg. Wichita, Kan., Mar. 29 - Apr. 1, 1977, 13 pp.

SAE Paper-770472 A77-37090

The Bellanca Skyrocket II, possessor of five world speed records, is a single engine aircraft with high performance that has been attributed to a laminar flow airfoil and an all composite structure. Utilization of composite materials in the Skyrocket II is unique since this selection was made to increase the aerodynamic efficiency of the aircraft. Flight tests are in progress to measure the overall aircraft drag and the wing section drag for comparison with the predicted performance of the Skyrocket. Initial results show the zero lift drag is indeed low, equalling 0.016.

*Ohio State Univ., Columbus, Ohio
**Bellanca Aircraft Engineering, Scott Depot, W. Va.
Grant NSG 1327

30. *Kahawita, R. A.; and **Meroney, R. N.: The Influence of Heating on the Stability of Laminar Boundary Layers Along Concave Curved Walls. Presented at the ASME Applied Mechanics/Bioengineering/Fluids Engineering Summer Conference, Yale Univ., New Haven, Conn., June 15-17, 1977. Journal of Applied Mechanics, vol. 44, March 1967, p. 11-17.

ASME Paper No. 77-APM-4 A77-28411#

This paper considers the effect of heating on Taylor-Görtler vortices in laminar boundary layers. The effect of higher-order terms and the normal velocity component of the primary flow in the stability calculations has been demonstrated. The findings indicate that terms involving the higher-order effects of curvature as well as the normal component of the primary flow become increasingly important at small wave numbers. The effect of heating is to stabilize the flow to disturbances of long lateral wavelength but has a destabilizing effect on short wavelength disturbances.

*Ecole Polytechnique, Montreal, Canada
**Colorado State Univ., Fort Collins, Colo.

31. *Mojola, O. O.: Transition in a Streamwise Corner. AIAA Journal, vol. 15, March 1977, pp. 427-429.

A77-26736#

Some aspects of natural and artificial transition to turbulent flow in a right-angled streamwise corner formed by the intersection, at low subsonic speed, of two smooth flat plates with unswept leading and trailing edges are analyzed. The importance of this analysis for wing-body junctions of aircraft is pointed out. The measurements were carried out in a closed circuit wind tunnel with a freestream turbulence of 0.03%.

*Ife University, Ife, Nigeria.

32. Volodin, A. G.; and Zel'man, M. B.: Pairwise Nonlinear Interactions of Tollmien-Schlichting Waves in Flows of the Boundary-Layer Type. (Translated from Izvestiya Akademii Nauk SSSR, Mekhanika Zhidkosti i Gaza, No. 2, pp. 33-37, March-April 1977.) Fluid Dynamics, vol. 12, no. 2, Oct. 1977, pp. 192-196.

A78-22354

For a flow of the boundary-layer type, the method of a phase plane is used to investigate the joint evolution of pair of Tollmien-Schlichting waves as a function of the R numbers and the frequencies.

33. *Klineberg, J. M.: Technology for Aircraft Energy Efficiency. Presented at International Air Transportation Conference, Wash., D. C., Apr. 4-6, 1977, In the Proceedings, American Society of

Civil Engineers, (A79-14126), New York, 1977, pp. 127-171.

A79-14136

Six technology programs for reducing fuel use in U. S. commercial aviation are discussed. The six NASA programs are divided into three groups: Propulsion - engine component improvement, energy efficient engine, advanced turboprops; Aerodynamics - energy efficient transport, laminar flow control; and Structures - composite primary structures. Schedules, phases, and applications of these programs are considered, and it is suggested that program results will be applied to current transport derivatives in the early 1980s and to all-new aircraft of the late 1980s and early 1990s.

*NASA, Washington, D. C.

34. *Foss, R. L.: Very Large Aircraft - Technology and Operational Implications. Presented at International Air Transportation Conference, Wash., D. C., April 4-6, 1977, Proceedings (A79-14126), Amer. Soc. of Civil Engineers, New York, 1977, pp. 172-196.

A79-14137

This paper discusses future growth trends of commercial aircraft, starting with historical patterns that indicate the changes in airplane physical dimensions and weight that have occurred over the last several decades. Reasons for the observed growth are reviewed. Size of today's large aircraft is summarized for reference. Projections of commercial needs for the future are outlined. Their potential impact on future aircraft growth patterns is shown in terms of added range, payload, and change in cruise speed. The consequences and benefits of switching to alternate fuels, returning to turboprop power plants, adopting airships, or revitalizing sea planes is examined. Benefits of advanced technology considering new structural materials, laminar flow control, and advanced flight control systems is discussed. Typical aircraft of the future are illustrated. From this collection, a likely list of candidates that may be operational in 1995 is offered, together with the rationale for their selection.

*Lockheed-California Co., Burbank, Calif.

35. *Meier, H. U.: The Effect of Velocity Fluctuations and Nonuniformities in the Free Stream on the Boundary Layer Development. Presented at the Symposium on Turbulent Shear Flows, Univ. Park, Pa., April 18-20, 1977. In the Proceedings, Vol. I, (A77-33806), 1977, pp. 10.35-10.41.

A77-33853#

The influence of grid generated wind tunnel turbulence was studied. It was found that due to the position of the grids relative to the boundary layer start, a momentum loss in the boundary layer can be added. This effect of large fluctuation velocity components and nonuniformity of the flow at the start of the boundary layer was investigated in detail. The investigations led to some general remarks about the influence of the free stream turbulence level in low speed wind tunnel measurements.

*Aerodynamische Versuchsanstalt, Goettingen, West Germany

36. Laminar-Turbulent Transition. Fluid Dynamics Panel Symposium, held in Lyngby, Denmark, May 2-4, 1977, AGARD-CP-224, Oct. 1977, 380 pp.

N78-14316#

Stability theory and prediction methods applied to fluid dynamic processes in laminar-transitional flows were discussed. Twenty-eight papers were given. Citations of some selected papers follow. Morkovin gave the introductory address (no. 37 in this compilation) and also the evaluation report of the symposium (no. 83 in this compilation).

37. *Morkovin, M. V.: Instability, Transition to Turbulence and Predictability. Presented at AGARD Fluid Dynamics Panel Symposium on Laminar-Turbulent Transition (AGARD-CP-224), Lyngby, Denmark, May 2-4, 1977. AGARD-AG-236, July 28, 1978, 38 pp.

N78-31401#

A concise state of the art review on the phenomenon of transition which constituted the opening address is presented. Various instability mechanisms leading to transition are proposed and discussed. A variable insight is provided based on existing experimental evidence and postulated flow structures. Critical questions are asked relating to the conceptual foundation on which much of the transition effort is based. To enhance understanding of the basic mechanisms and processes, detailed microscopic experiments are encouraged to increase the data base.

*Illinois Institute of Technology, Chicago, Ill.

38. *Saric, W. S.; and *Nayfeh, A. H.: Nonparallel Stability of Boundary Layers with Pressure Gradients and Suction. In AGARD Laminar-Turbulent Transition. Lyngby, Denmark, May 2-4, 1977, AGARD-CP-224 (N78-14316#), Oct. 1977. 21 pp.

N78-14322#

An analysis is presented for the linear nonparallel stability of boundary layer flows with pressure gradients and suction. The effect of the boundary layer growth is included by using the method of multiple scales. The present analysis

is compared with those of Bouthier and Gaster and the roles of the different definitions of the amplification rates are discussed. The results of these theories are compared with experimental data for the Blasius boundary layer. Calculations are presented for stability characteristics of boundary layers with pressure gradients and non-similar suction distributions.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.
Grant NsG-1255

39. *Gougat, Pierre; and *Martin, Francoise: The Influence of a Periodic Wall Deformation on the Development of Natural Instabilities Leading to a Transition. (Influence d'une Deformation Periodique de Paroi sur le Development des Instabilities Naturelles conduisant a la Transition). In AGARD-CP-224, Laminar-Turbulent Transition, May 2-4, 1977, (N78-14316) Oct. 1977, 9 pp. (In French.)

N78-14333#

The natural instabilities which occur in the laminar boundary layer of a deformable wall are constituted by a series of intermittent waves. A spectral analysis of these fluctuations reveals the frequencies and coefficients of amplifications of natural instabilities are identical to those predicted by the stability theory. A deformation of the wall does not change the structure of the phenomena; it merely introduces a degree of exterior velocity which provokes an amplification or attenuation of the instabilities. The effect of a static deformation of the wall on the formation and amplifiction of boundary layer instabilities was studied in relation to the gradient of exterior speed.

*Laboratoire d'Aerothermique du C.N.R.S., Meudon, France.

40. *Vaningen, J. L.: Transition, Pressure Gradient, Suction, Separation and Stability Theory. In AGARD-CP-224, Laminar-Turbulent Transition, May 2-4, 1977, (N78-14316), Oct. 1977. 15 pp.

N78-14335#

A semi-empirical method is presented for the prediction of transition in two-dimensional incompressible flows with pressure gradient and suction. Included is the case of the laminar separation bubble, where transition is preceded by laminar separation. The method employs linear stability theory to calculate the amplification factor sigma for unstable disturbances in the laminar boundary layer (sigma is defined as the natural logarithm of the ratio between the amplitude of a disturbance at a given instant or position to the amplitude at neutral stability). It is found that at the experimentally determined transition position the calculated amplification factor for the critical disturbances attains nearly the same value (about 10) in many different cases for flows with low free stream turbulence levels. An attempt is made to include the effects of higher free stream turbulence levels by allowing the critical amplification factor to decrease with increasing free stream turbulence.

*Dept. of Aerospace Engineering, Technische Hogeschoal, Delft (The Netherlands)

41. Poll, D. I. A.: Leading Edge Transition on Swept Wings. In AGARD-CP-224, Laminar-Turbulent Transition, May 2-4, 1977, (N78-14316), Oct. 1977, 11 pp.

N78-14336#

The behavior of the swept wing attachment line boundary layer has been studied experimentally. Two dimensional trip wires and turbulent flat plate boundary layers have been used as sources of disturbance and a wide range of conditions has been covered, ensuring that the results are directly applicable to full scale flight situations. Simple criteria have been deduced and those allow the state of the attachment line boundary layer to be determined for a given geometry and free stream conditions. The validity of some of the principal results has been extended to high Mach numbers for the adiabatic wall case. Sample calculations show that most of the present generation of civil aircraft have turbulent attachment lines in the cruise condition. Although some benefit may be gained by a removal of root disturbances and the maintenance of a smooth leading edge the tolerable roughness heights are so small that it seems unlikely that turbulence can be prevented without some form of boundary layer suction.

42. *Finson, Michael L.: On the Application of Second-Order Closure Models to Boundary Layer Transition. In AGARD-CP-224, Laminar-Turbulent Transition, May 2-4, 1977, (N78-14316), Oct. 1977, 6 pp.

N78-14338#

Second-order closure models offer several potential advantages for the study and prediction of boundary layer transition. The required closure approximations can be formulated to represent an adequate physical description of the transition process. A five equation model is presented for fluctuating variables. It is argued that adequate closure techniques are available for the production, dissipation, and diffusion terms. Improved closure schemes are suggested, and a model is also presented for the manner by which surface roughness elements disturb the boundary layer. Calculations have been obtained for two by-pass situations where the initial fluctuation levels are relatively high, due either to free stream turbulence or surface roughness, and the

results are in reasonable agreement with wind tunnel observations on flat plates.

*Physical Sciences, Inc., Woburn, Mass.

43. *Whitfield, Jack D.; and *Dougherty, Sam N., Jr.: A Survey of Transition Research at AEDC. In AGARD-CP-224, Laminar-Turbulent Transition, May 2-4, 1977, (N78-14316), Oct. 1977. 20 pp.

N78-14340#

Experimental research on transition Reynolds numbers conducted in a large number of ground test facilities is surveyed. Facilities surveyed included primary wind tunnels used for aerodynamic testing at subsonic, transonic, supersonic, and hypersonic conditions. Measurements have been made on cones and planar bodies, flat plates and hollow cylinders. The primary motivation for this research spanning nearly 25 years has been to verify the adequacy of the facilities to simulate flight conditions. This necessarily entailed the study of free stream disturbances in wind tunnels and the role these disturbances play in altering transition Reynolds number which must be considered when scaling Reynolds number sensitivity data.

*Propulsion Wind Tunnel Facility, ARO, Inc., Arnold Air Force Station, Tenn.

Sponsored by AEDC

44. *Kelly, Robert E.: The Formation and Stability of Longitudinal Roll Vortices in Shear Flows. Final Rept. June 1, 1972-May 31, 1977, UCLA-Eng.-7737, May 31, 1977, 18 pp.

AD-A048691 N78-18367#

Longitudinal roll vortices occur frequently in shear flows. Although they are most commonly driven by body forces (either centrifugal or buoyant), they are also observed during transition in homogeneous boundary layers. Under the above grant, various investigations have been made of their formation and, for the case of thermally driven vortices, their own instability. This report summarizes the results obtained. More detailed results can be found in the journal publications referred to in the report.

*Univ. of California, Los Angeles, Calif.
Contract DA-ARO-D-31-124-72-G168

45. *MacDonald, I. S.: Commercial Aviation Future Progress, Programs, Proposals, and Problems - A Prognosis/W. Rupert Turnbull Lecture. Presented at the Canadian Aeronautics and Space Institute Annual General Meeting, Quebec City, Canada, May 17, 1977. Canadian Aeronautics and Space Journal, vol. 23, Nov.-Dec., 1977, pp. 338-345.

A78-18034#

The prospects for Canadian commercial airlines from the present to the end of the century are assessed. Noise regulation and retrofitting, active control technology, laminar flow control, regenerative turbines, and multi-blade turboprop with blades swept like wings are cited in discussing the processes of fleet replacement and acquisition. The likelihood that Canadian airlines will acquire the A300 Airbus, the Concorde, or the proposed McDonnell Douglas DC-9-55, the Boeing 7N7 and 7X7, or the British Aircraft Corporation BAC-X-11 is considered.

*Air Canada, Montreal, Canada

46. *Frisbee, L. E.; and *Hopps, R. H.: The Changing Horizons for Technical Progress - in Air Transportation. In "The Place of Aviation in Society"; Proceedings of the 15th Anglo-Amer. Aeronautical Conference, London, England, May 31-June 2, 1977, (A77-41926). Royal Aero. Society. 23 pp.

A77-41946#

Some of the most promising potential technological developments in the air transportation field are discussed, including improvements in airframe design, aircraft engines, and active controls hardware. Major obstacles to these relatively short term developments are considered. Special attention is given to the problem of fuel economy. Technologies requiring a longer time-scale for research and development, including advanced turboprop engines, all-wing concepts, and laminar flow control, are outlined. The potential impact of hydrogen-based power plants on the development of super- and hypersonic transports is examined.

*Lockheed-California Co., Burbank, Calif.

47. *Kachanov, Yu. S.; *Kozlov, V. V.; and *Levchenko, V. Ya.: Nonlinear Development of a Wave in a Boundary Layer. (Translated from Izvestiya Akademii Nauk SSSR, Mekhanika Zhidkosti i Gaza, No. 3, pp. 49-58, May-June, 1977.) Fluid Dynamics, Jan. 1978, pp. 383-390.

In recent years definite progress has been achieved in the construction of theoretical models of nonlinear wave processes which lead to a transition from laminar to turbulent flow. At the same time, there is a shortage of actual experimental material, especially for flows in a boundary layer. Fairly thorough experimental studies have been carried out only on the initial stage of the development of disturbances in a boundary layer, which is satisfactorily describable by the linear theory of hydrodynamic stability. In evaluating the theoretical models of subsequent stages of the transition, investigators have been forced to turn chiefly to much earlier experiments carried out by the United States National Bureau of Standards, in which the main attention was concentrated on the three-dimensional structure of the transition region.

The present investigation was undertaken for the purpose of obtaining detailed data on the structure of the flow in the transition region when there is disturbance in the laminar boundary layer of a two-dimensional wave. In order to make the two-dimensional nonlinear effects stand out more clearly, the amplitude of the wave was specified to be fairly large from the very outset. In contrast to earlier investigations, the main attention was centered on the study of the spectral composition of the disturbance field.

*Institute of Theoretical and Appied Mechanics, Siberian Division of the Academy of Sciences, USSR

48. *Pfenninger, Werner: Laminar Flow Control Laminarization. Special Course on Concepts for Drag Reduction. Held at the von Karman Inst., Rhode-St-Genese, Belgium, Mar. 28-Apr. 1, 1977. AGARD-R-654, June 1977, p. 3-1 - 3-75.

N77-32094#

A practical aerodynamically and structurally reasonably efficient laminar flow control (LFC) suction method, removing the slowest boundary layer particles through many closed spaced fine slots, was developed and subsequently applied to a second F94 LFC wing glove in flight: 100 percent laminar flow was observed up to the F94 test limit. Laminar flow on LFC wings in flight is thus possible at a much higher Reynolds number than even in the best low turbulence tunnels as a result of the negligible influence of the atmospheric microscale turbuence on transition. The F94 LFC glove comparison experiments, with suction starting at 0.03c and 0.4c, verified the theoretically predicted bounday layer stabilization by suction starting at 0.08c, thus maintaining laminar flow at substanially higher C_L as compared to boundary layer stabilization by flow acceleration; i.e., geometry alone without suction upstream of 0.4c.

*NASA, Langley Research Center, Hampton, Va.

49. *Kaups, Kalle; and *Cebeci, Tuncer: Compressible Laminar Boundary Layers With Suction on Swept and Tapered Wings. Journal of Aircraft, vol. 14, July 1977, pp. 661-667.

A77-37940#

In this paper we present a numerical method for solving the compressible laminar boundary-layer equations with suction on swept and tapered wings. The method employs an efficient two-point finite-difference method to solve the governing equations, and a very convenient similarity transformation which removes the wall normal velocity as a boundary condition and places it into the governing equations as a parameter. In this way the awkward nonlinear boundary condition which couples all the variables is avoided. To test and demonstrate the method, we present a sample calculation for a typical laminar-flow-control (LFC) wing.

*Douglas Aircraft Co., Inc., Long Beach, Calif.
Contract NAS1-14498

Note: There is a "User's Guide for Program Main to Calculate Compressible Laminar Boundary Layers with Suction on Swept and Tapered Wings" which perhaps could be obtained from the authors or from Douglas Aircraft Co.

50. *Lange, R. H.; and *Bradley, E. S.: Parametric Study of Advanced Long Range Military/Commercial Cargo Transports. Presented at the AIAA Aircraft Systems & Technology Meeting, Seattle, Wash., Aug. 22-24, 1977, 8 pp.

AIAA-77-1221 A77-44322

This paper describes the results of Lockheed parametric design studies of the performance and economics of advanced technology military/commercial cargo transports envisioned for operation in the 1985 and 1995 time period. The design parameters investigated include payloads from 220,000 to 550,000 pounds and ranges from 3,500 to 5,500 nautical miles. All configurations have supercritical wings, advanced composite materials, relaxed static stability, and low noise levels. The application of laminar flow control (LFC) technology on the performance of an advanced military transport is also presented.

*Lockheed-Georgia Co., Marietta, Ga.

51. *Srokowski, A. J.; and **Orszag, S. A.: Mass Flow Requirements for LFC Wing Design. AIAA Aircraft Systems and Technology Meeting, Seattle, Wash., Aug. 22-24, 1977, 16 pp.

AIAA-77-1222 A77-44323#

The problem of determining optimum suction mass flow requirements for LFC wings is addressed. Some previous methods for predicting the extent of laminar flow over swept wings with suction are briefly reviewed. These range from the purely empirical to those utilizing tabulated linear stability computations. The present method is described. This method solves the linear, incompressible stability equations by spectral techniques. The maximum temporal amplification of boundary layer crossflow and 2-D disturbances is determined for waves of a given frequency. Group velocities are used to integrate these amplification rates along the wing to yield the logarithmic amplitude ratio or "N factor" of the disturbance. The "N factor" calibration of a computer code utilizing this method is described, using experimentally determined transition data. The method is shown to be as consistent as previously used "fixed wavelength" methods.

*NASA, Langley Research Center, Hampton, Va.
**Mass. Inst. of Tech., Cambridge, Mass.

52. *Hopps, R. H.: Fuel Efficiency - Where We are Heading in the Design of Future Jet Transports. In Proceedings of the Canadian Symposium on Energy Conserving Transport Aircraft, Ottawa, Canada, Oct. 3, 4, 1977, (A78-31301), pp. 6-1 to 6-16.

A78-31307#

Consideration is given to the 1980s jet-transport market with emphasis on narrow-body vs wide-body aircraft, the benefits of increased size and capacity and the feasibility of superlarge aircraft. Technology of the 1980s relating to span, active controls and composites is briefly reviewed. Three potential technologies for the 1990s are discussed: laminar flow control, advanced turboprops and liquid hydrogen. It is noted that the technology of the 1980s will not offer dramatic improvements over all the aircraft flown today; large improvements can be offered only in comparison with the older narrow-body aircraft.

*Lockheed-California Co., Burbank, Calif.

53. *Klineberg, J. M.: The NASA Aircraft Energy Efficiency Program. In Proceedings of the Canadian Symposium on Energy Conserving Transport Aircraft, Ottawa, Canada, Oct. 3-4, 1977, (A78-31301), pp 1-1 to 1-32.

A78-31302#

The objective of the NASA Aircraft Energy Efficiency Program is to accelerate the development of advanced technology for more energy-efficient subsonic transport aircraft. This program will have application to current transport derivatives in the early 1980s and to all-new aircraft of the late 1980s and early 1990s. Six major technology projects were defined that could result in fuel savings in commercial aircraft: (1) Engine Component Improvement, (2) Energy Efficient Engine, (3) Advanced Turboprops, (4) Energy Efficiency Transport (aerodynamically speaking), (5) Laminar Flow Control, and (6) Composite Primary Structures.

*NASA, Washington, D.C.

54. *Meade, L. E.: Material Development for Laminar Flow Control Wing Panels. Presented at the 9th National Technical Conference of the Soc. for the Advancement of Material and Process Engineering, "Materials and Processes, In Service Performance" (A78-25176), Atlanta, Ga., Oct. 4-6, 1977, pp. 305-312.

A78-25200

The absence of suitable porous materials or techniques for the economic perforation of surface materials has previously restricted the design of laminar flow control (LFC) wing panels to a consideration of mechanically slotted LFC surfaces. A description is presented of a program which has been conducted to exploit recent advances in materials and manufacturing technology for the fabrication of reliable porous or perforated LFC surface panels compatible with the requirements of subsonic transport aircraft. Attention is given to LFC design criteria, surface materials, surface concepts, the use of microporous composites, perforated composites, and perforated metal. The described program was successful in that fabrication processes were developed for producing predictable perforated panels both of composite and of metal.

*Lockheed-Georgia, Marietta, Ga.
NAS1-14409

55. *Bonner, Tom F., Jr.; *Pride, Joseph D., Jr.; and *Fernald, William W.: Aircraft Energy Efficiency Laminar Flow Control Wing Design Study. NASA TM-78634, Oct. 1977, 34 pp.

N78-13042#

An engineering design study was performed in which Laminar Flow Control (LFC) was integrated into the wing of a commercial passenger transport aircraft. A baseline aircraft configuration was selected and the wing geometry was defined. The LFC system, with suction slots, ducting, and suction pumps was integrated with the wing structure. The use of standard aluminum technology and advanced Superplastic Formed-Diffusion Bonded (SFDB) titanium technology was evaluated. The results of the design study show that the LFC system can be integrated with the wing structure to provide a structurally and aerodynamically efficient wing for a commercial transport aircraft.

*NASA, Langley Research Center, Hampton, Va.

56. *Kobayashi, R.; and *Kohama, Y.: Taylor-Görtler Instability of Compressible Boundary Layers. AIAA Journal, vol. 15, no. 12, Dec. 1977, pp. 1723-1727.

The purpose of this paper is to consider analytically how compressibility of a fluid will affect the instability of laminar boundary layers along slightly concave walls leading to the onset of longitudinal vortices. Neutral stability curves representing the relation of the Görtler parameter to the dimensionless wavenumber of the longitudinal vortices and also distributions of the disturbances at the onset of the vortices are presented. The results show that the critical value of the Görtler parameter increases about 1.6 times as the freestream Mach number varies from 0 to 5 in the case of a thermally insulated wall. Effects of temperature ratio (wall temperature to freestream temperature) in cases of an isothermal wall are also discussed.

*Tohoku Univ., Sendai, Japan

57. Advancing Transport Aircraft Technology Towards 2000. Interavia, vol. 32, Dec. 1977, pp. 1219-1223.

A78-17135

Innovations in commercial aircraft are forecast for the 1980s and 1990s: attention is given to improvements in aerofoil design, the use of composites to reduce airframe weight, the reduction of specific fuel consumption, and reconsideration of the turboprop. Active ailerons, wing tip extensions, high-aspect ratio wings, supercritical wing designs, and laminar flow control are discussed. Advanced powerplants under investigation, in addition to turboprops, include improved high bypass ratio engines, variable cycle engines, and liquid hydrogen power systems.

58. *Benney, David J.; and *Orszag, Steven A.: Stability Analysis for Laminar Flow Control - Part I. NASA CR-2910, Oct. 1977, 90 pp.

N78-12363

This report develops the basic equations for the stability analysis of flow over three-dimensional swept wings and then surveys numerical methods for their solution. The equations for nonlinear stability analysis of three-dimensional disturbances in compressible, three-dimensional, non-parallel flows are given. Efficient and accurate numerical methods for the solutions of the equations of stability theory are surveyed and analyzed.

*Cambridge Hydrodynamics, Inc., Cambridge, Mass. Contract NAS1-14427

(Note: For Part II, see citation #184 in this bibliography.)

59. Kozlov, V. V.; Levchenko, V. Ya.; Maksimov, V. P.; Rudnitskii, A. L.; and Shcherbakov, V. A.: Investigation of Viscous Fluid Flow at a Suction Slit. Tsagi Uch. Zap., vol. 8, no. 1, 1977, pp. 130-135. (Russian text.)

A79-12142

The flow of a viscous incompressible fluid along a plate with a narrow suction slit is studied theoretically and experimentally. A numerical solution of the Navier-Stokes equations is obtained, treating the mainstream simultaneously with the flow within the slit, and taking the stabilized flow as the boundary condition within the slit. In the experimental part of the study, a laser anemometer is used to measure the longitudinal velocity component at various distances from the slit and for various suction modes and various mainstream conditions. Good agreement between theory and experiment is noted.

60. *Lekoudis, S. G.: Stability of Boundary Layers Over Permeable Surfaces. AIAA 16th Aerospace Sciences Meeting, Huntsville, Ala., Jan. 16-18, 1978, 9 pp.

AIAA-78-203 A78-22597

The stability of a two-dimensional, incompressible boundary layer over a perforated surface is examined. The spacing of the perforations is assumed to be small compared to the wavelength of the disturbances. If, under the perforations, there exists a chamber that permits traveling waves to exist, it can, under certain conditions, stabilize the flow. If instead there exist small chambers that sustain compressible waves created by the disturbance in the boundary layer, their effect on the stability of the flow is negligible, for the range of frequencies of interest.

*Lockheed-Georgia, Marietta, Ga.

61. *Sturgeon, R. F.: The Development and Evaluation of Advanced Technology Laminar-Flow-Control Subsonic Transport Aircraft. AIAA 16th Aerospace Sciences Meeting, Huntsville, Ala., Jan. 16-18, 1978, 9 pp.

AIAA-78-96 A78-52626

A study was conducted to evaluate the technical and economic feasibility of applying laminar flow control (LFC) to the wings and empennage of long-range subsonic transport aircraft for initial operation in 1985. For a design mission range of 5500 n.mi., advanced technology LFC and turbulent-flow aircraft were developed for a 200-passenger payload, and compared on the basis of production costs, direct operating costs, and fuel efficiency. Parametric analyses were conducted to establish optimum geometry, advanced system concepts were evaluated, and configuration variations maximizing the effectiveness of LFC were developed. The final comparisons include consideration of maintenance costs and procedures, manufacturing costs and procedures, and operational considerations peculiar to LFC aircraft.

*Lockheed-Georgia Co., Marietta, Ga. Contract NAS1-13694

62. *Hage, R. E.; and *Stern, J. A.: The Challenge of Advanced Fuel-Conservative Aircraft - A Manufacturer's View. 14th Annual AIAA Meeting and Technical Display, Wash. D.C., Feb. 7-9, 1978, 18 pp.

AIAA-78-362 A78-24034#

Costs and technological problems associated with advanced fuel-conservative aircraft are discussed, with particular attention given to the current NASA Aircraft Energy Efficiency (ACEE) program, which focuses on engine component improvement, turboprops, laminar flow control and composites. In addition to the results of the ACEE program, aircraft manufacturers will need to deal during the next decade with the noise requirements established by FAR Part 36. Due to

high costs and noise considerations, DC-8 and B707 fleets are expected to be replaced by the 1980s, and the demand for fuel-efficient aircraft in the 100- to 200-seat category will be significant. Fuselage cross-sections for such a category are considered; a comparison of the effectiveness of twin-jets and tri-jets for medium-range transport is also reported.

*Douglas Aircraft Co., Long Beach, Calif.

63. *Wilson, S. D. R.; and *Gladwell, I.: The Stability of a Two-Dimensional Stagnation Flow to Three-Dimensional Disturbances. Journal of Fluid Mechanics, vol. 84, Part 3, Feb. 13, 1978, pp. 517-527.

A78-25168

Experiments have shown that the two-dimensional flow near a forward stagnation line may be unstable to three-dimensional disturbances. The growing disturbance takes the form of secondary vortices, i.e. vortices more or less parallel to the original streamlines. The instability is usually confined to the boundary layer and the spacing of the secondary vortices is of the order of the boundary-layer thickness. This situation is analysed theoretically for the case of infinitesimal disturbances of the type first studied by Görtler and Hämmerlin. These are disturbances periodic in the direction perpendicular to the plane of the flow, in the limit of infinite Reynolds number. It is shown that the flow is always stable to these disturbances.

*Department of Mathematics, Univ. of Manchester, England

64. CTOL Transport Technology - 1978. A conference held at Langley Research Center, Hampton, Va., Feb. 28 - March 3, 1978.
NASA CP-2036, Pt. I, June 1978, 516 pp.
N78-27046#
NASA CP-2036, Pt. II, June 1978, 468 pp.
N79-10097#

Technology generated by NASA and specifically associated with advanced conventional takeoff and landing transport aircraft is reported. Topics covered include: aircraft propulsion; structures and materials; and laminar flow control.

A session on laminar flow control addressed insect contamination and alleviation; suction prediction techniques; porous materials; and laminar flow applications.

Note: Selected papers from this conference follow.

65. *Muraca, Ralph J.: Laminar Flow Control Overview. Presented at the CTOL Transport Technology Conference, Langley Research Center, Hampton, Va., Feb. 28 - Mar. 3, 1978.
NASA CP-2036, Part I, pp. 349-356, June 1978.

N78-27066#

Application of laminar flow control technology to future CTOL long range transport aircraft was considered. Topics covered include: (1) airfoil development and test; (2) development and improvement of design methods; (3) evaluation of leading edge contamination; and (4) laminar flow control system definition and concept evaluation.

*NASA, Langley Research Center, Hampton, Va.

66. *Peterson, John B., Jr.; and **Fisher, David F.: Flight Investigation of Insect Contamination and Its Alleviation. Presented at the CTOL Transport Technology Conference, Langley Research Center, Hampton, Va., Feb. 28 - Mar. 3, 1978. NASA CP-2036, Part I, pp. 357-373, June 1978.

N78-27067#

An investigation of leading-edge contamination by insects was conducted at the NASA Dryden Flight Research Center with a JetStar airplane instrumented to detect transition on the outboard leading-edge flap and equipped with a system to wash the leading edge in flight. The results of airline-type flights with the JetStar indicated that insects can contaminate the leading edge during takeoff and climbout at large jet airports in the United States. The results also showed that the insects collected on the leading edges at 180 knots did not erode at cruise conditions for a laminar flow control airplane and caused premature transition of the laminar boundary layer. None of the superslick and hydrophobic surfaces tested showed any significant advantages in alleviating the insect contamination problem. While there may be other solutions to the insect contamination problem, the results of these tests with a washer system showed that a continuous water spray while encountering the insects is effective in preventing insect contamination of the leading edges.

*NASA, Langley Research Center, Hampton, Va.
**NASA, Dryden Flight Research Center, Edwards, Calif.

67. *Srokowski, Andrew J.: Development of Advanced Stability Theory Suction Prediction Techniques for Laminar Flow Control. Presented at the CTOL Transport Technology Conference, Langley Research Center, Hampton, Va., Feb. 28 - Mar. 3, 1978. NASA CP-2036, Pt. I, pp. 375-394, June 1978.

N78-27068#

The problem of obtaining accurate estimates of suction requirements on swept laminar flow control wings was discussed. A fast accurate computer code developed to predict suction requirements by integrating disturbance amplification rates was described. Assumptions and approximations used in the present computer code are

examined in light of flow conditions on the swept wing which may limit their validity.

*NASA, Langley Research Center, Hampton, Va.

68. *Allison, Dennis O.; and *Dagenhart, John R.: Design of a Laminar-Flow-Control Supercritical Airfoil for a Swept Wing. Presented at the CTOL Transport Technology Conference, Langley Research Center, Hampton, Va., Feb. 28 - Mar. 3, 1978. NASA CP-2036, Part I, pp. 395-408, June 1978.

N78-27069#

An airfoil was analytically designed and analyzed for a combination of supercritical flow and laminar flow control (LFC) by boundary layer suction. A shockless inverse method was used to design an airfoil and an analysis method was used in lower surface redesign work. The laminar flow pressure distributions were computed without a boundary layer under the assumption that the laminar boundary layer would be kept thin by suction. Inviscid calculations showed that this 13.5 percent thick airfoil has shockless flows for conditions at and below the design normal Mach number of 0.73 and the design section lift coefficient of 0.60, and that the maximum local normal Mach number is 1.12 at the design point. The laminar boundary layer instabilities can be controlled with suction but the undercut leading edge of the airfoil provides a low velocity, constant pressure coefficients region which is conducive to laminar flow without suction. The airfoil was designed to be capable of lift recovery with no suction by the deflection of a small trailing edge flap.

*NASA, Langley Research Center, Hampton, Va.

69. *Gratzer, L. B.; and *George-Falvy, D.: Application of Laminar Flow Control Technology to Long-Range Transport Design. Presented at the CTOL Transport Technology Conference, Hampton, Va., Feb. 28 - March 3, 1978, NASA CP-2036, Part I, pp. 409-447, June 1978.

N78-27070#

The impact of laminar flow control (LFC) technology on aircraft structural design concepts and systems was discussed and the corresponding benefits were shown in terms of performance and fuel economy. Specific topics discussed include: (1) recent advances in laminar boundary layer development and stability analysis techniques in terms of suction requirements and wing suction surface design; (2) validation of theory and realistic simulation of disturbances and off-design conditions by wind tunnel testing; (3) compatibility of aerodynamic design of airfoils and wings with LFC requirements; (4) structural alternatives involving advanced alloys or composites in combinations made possible by advanced materials processing and manufacturing techniques; (5) addition of suction compressor and drive units and their location on the aircraft; and (6) problems associated with operation of LFC aircraft, including accumulation of insects at low altitudes and environmental considerations.

*Boeing Commercial Airplane Co., Seattle, Wash.

70. *Sturgeon, R. F.: Toward a Laminar-Flow-Control Transport. Presented at the CTOL Transport Technology Conference, Langley Research Center, Hampton, Va., Feb. 28 - Mar. 3, 1978. NASA CP-2036, Part I, pp. 449-495, June 1978.

N78-27071#

Analyses were conducted to define a practical design for an advanced technology laminar flow control (LFC) transport for initial passenger operation in the early 1990's. Mission requirements, appropriate design criteria, and level of technology for the study aircraft were defined. The characteristics of the selected configuration were established, aircraft and LFC subsystems compatible with the mission requirements were defined, and the aircraft was evaluated in terms of fuel efficiency. A wing design integrating the LFC ducting and metering system into advanced composite wing structure was developed, manufacturing procedures for the surface panel design were established, and environmental and structural testing of surface panel components were conducted. Test results revealed a requirement for relatively minor changes in the manufacturing procedures employed, but have shown the general compatibility of both the selected design and the use of composite materials with the requirements of LFC wing surface panels.

*Lockheed-Georgia Co., Marietta, Ga.
Contract NAS1-14631

71. *Pearce, Wilfred E.: Application of Porous Materials for Laminar Flow Control. Presented at the CTOL Transport Technology Conference, Langley Research Center, Hampton, Va., Feb. 28 - Mar. 3, 1978. NASA CP-2036, Part I, pp. 497-522, June 1978.

N78-27072#

Fairly smooth porous materials were elected for study: Doweave; Fibermetal; Dynapore; and perforated titanium sheet. Factors examined include: surface smoothness; suction characteristics; porosity; surface impact resistance; and strain compatibility. A laminar flow control suction glove arrangement was identified with material combinations compatible with thermal expansion and structural strain.

*Douglas Aircraft Co., Inc., Santa Monica, Calif.

72. *Nagel, A. L.: Studies of Advanced Transport Aircraft. Presented at the CTOL Transport Technology Conference, Langley Research Center,

Hampton, Va., Feb. 28 - Mar. 3, 1978. NASA CP-2036, Part II, pp. 951-982, June 1978.

N78-29064#

Studies have been made of several concepts for possible future airplanes, including all-wing distributed-load airplanes, multi-body airplanes, a long-range laminar flow control airplane, a nuclear-powered airplane designed for towing conventionally powered airplanes during long-range cruise, and an aerial transportation system comprised of continuously flying "liner" airplanes operated in conjunction with short-range "feeder" airplanes. The studies indicate that each of these concepts has the potential for important performance and economic advantages, provided certain suggested research tasks are successfully accomplished. Indicated research areas include all-wing airplane aerodynamics, aerial rendezvous, nuclear aircraft engines, air-cushion landing systems, and laminar flow control, as well as the basic research discipline areas of aerodynamics, structures, propulsion, avionics, and computer applications.

*NASA, Langley Research Center, Hampton, Va.

73. Advanced Technology Airfoil Research. A conference held at NASA, Langley Research Center, Hampton, Va., March 7-9, 1978.
NASA CP-2045, Vol. I. Pt. 1, Mar. 1979, 468 pp.
N79-20030#
NASA CP-2045, Vol. I. Pt. 2, Mar. 1979, 304 pp.
N79-19989#
NASA CP-2045, Vol. II, Mar. 1979, 263 pp.
N80-21283#

This conference provided a comprehensive review of all NASA airfoil research, conducted in-house and under grant and contract. A broad spectrum of airfoil research outside of NASA was also reviewed. The major thrust of the technical sessions were in three areas: development of computational aerodynamic codes for airfoil analysis and design, development of experimental facilities and test techniques, and all types of airfoil applications. In addition, results of technical workshops were presented at a concluding round-table discussion.

Note: Selected papers from this conference follow.

74. *Bobbitt, Percy J.: Langley Airfoil-Research Program. In the "Advanced Technology Airfoil Research" conference held at Langley Research Center, March 7-9, 1978, NASA CP-2045, Vol. I, Part 1, March 1979, pp. 11-38.

N79-20032#

An overview of past, present, and future airfoil research activities at the Langley Research Center is given. The immediate past and future occupy most of the discussion; however, past accomplishments and milestones going back to the early NACA years are dealt with in a broad-brush way to give a better perspective of current developments and programs. In addition to the historical perspective, a short description of the facilities which are now being used in the airfoil program is given. This is followed by a discussion of airfoil developments, advances in airfoil design and analysis tools (mostly those that have taken place over the past 5 or 6 years), and tunnel-wall-interference predictive methods and measurements. Future research requirements are treated.

*NASA, Langley Research Center, Hampton, Va.

75. *Eppler, Richard; and **Somers, Dan M.: Low Speed Airfoil Design and Analysis. In the "Advanced Technology Airfoil Research" conference, Langley Research Center, Mar. 7-9, 1978. NASA CP-2045, Vol. I, Part 1, March 1979, pp. 73-99.

N79-20036#

A low speed airfoil design and analysis program was developed which contains several unique features. In the design mode, the velocity distribution is not specified for one but many different angles of attack. Several iteration options are included which allow the trailing edge angle to be specified while other parameters are iterated. For airfoil analysis, a panel method is available which uses third-order panels having parabolic vorticity distributions. The flow condition is satisfied at the end points of the panels. Both sharp and blunt trailing edges can be analyzed. The integral boundary layer method with its laminar separation bubble analog, empirical transition criterion, and precise turbulent boundary layer equations compares very favorably with other methods, both integral and finite difference. Comparisons with experiment for several airfoils over a very wide Reynolds number range are discussed. Applications to high lift airfoil design are also demonstrated.

*Stuttgart Univ., West Germany
**NASA, Langley Research Center, Hampton, Va.

76. *Newman, Perry A.; and **Anderson, E. C.: Analytical Design of a Contoured Wind-Tunnel Liner for Supercritical Testing. In the "Advanced Technology Airfoil Research" conference held at Langley Research Center, March 7-9, 1978, NASA CP-2045, Vol. I, Pt. 2, March 1979, pp. 499-509.

N79-19993#

The present analytical design procedure is being developed in order to determine the shape of a contoured nonporous wind-tunnel liner for use in the Ames 12-foot pressure wind tunnel test of a large-chord, laminar flow control, swept-wing panel which has a supercritical airfoil section. This procedure is applicable to the two-dimensional streamlined tunnel problem and a first

check on its validity would be a comparison of the calculated tunnel-wall shape with that found experimentally. Results for such a comparison are given and the favorable agreement is encouraging.

*NASA, Langley Research Center, Hampton, Va.
**DCW Industries, Inc., Studio City, Calif.
Contract NAS1-14517

77. *Meier, H. U.; and *Kreplin, H. P.: The Influence of Turbulent Velocity Fluctuations and Integral Length Scales of Low Speed Wind Tunnel Flow on the Boundary Layer Development. AIAA 10th Aerodynamic Testing Conference, San Diego, Calif., Apr. 19-21, 1978. In Technical Papers (A78-32326), 1978, pp. 232-238.

AIAA-78-800 A78-32355#

The influence of the wind tunnel turbulence on the development of a turbulent boundary was studied. The experiments were carried out in the Low Turbulence Wind Tunnel of the DFVLR-AVA at a free stream velocity of 20 m/s. The turbulence level (Tu(1) approximately equal to 0.06%) was increased up to Tu(1) approximately equal to 1% by means of various grids at different positions in the settling chamber or nozzle. For a fixed transition and constant distance from the nozzle throat the effect of the wind tunnel turbulence on the wall shear stress was investigated. In particular it was tried to separate the effects which result from the turbulence intensity and from the turbulence structure, which is different in each wind tunnel.

*Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt. Institut fuer Stroemungsmechanik, Goettingen, West Germany

78. *Gibeling, H. J.; *Shamroth, S. J.; and *Eiseman, P. R.: Analysis of Strong-Interaction Dynamic Stall for Laminar Flow on Airfoils. NASA CR-2969, April 1978, 71 pp.

N78-20464#

A compressible Navier-Stokes solution procedure is applied to the flow about an isolated airfoil. Two major problem areas were investigated. The first area is that of developing a coordinate system and an initial step in this direction has been taken. An airfoil coordinate system obtained from specification of discrete data points developed and the heat conduction equation has been solved in this system. Efforts required to allow the Navier-Stokes equations to be solved in this system are discussed. The second problem area is that of obtaining flow field solutions. Solutions for the flow about a circular cylinder and an isolated airfoil are presented. In the former case, the prediction is shown to be in good agreement with data.

*United Technologies Research Center, East Hartford, Conn.
Contract NAS1-13619

79. *Harvey, William D.: Influence of Free-Stream Disturbances on Boundary-Layer Transition. NASA TM-78635, April 1978, 33 pp.

N78-20460#

Considerable experimental evidence exists which shows that free-stream disturbances (the ratio of root-mean-square pressure fluctuations to mean values) in conventional wind tunnels increase with increasing Mach number at low supersonic to moderate hypersonic speeds. In addition to local conditions, the free-stream disturbance level influences transition behavior on simple test models. Based on this observation, existing noise-transition data obtained in the same test facility have been correlated for a large number of reference sharp cones and flat plates and are shown to collapse along a single curve. This result is a significant improvement over previous attempts to correlate noise-transition data.

*NASA, Langley Research Center, Hampton, Va.

80. *Newman, Perry A; and **Anderson, E. Clay: Numerical Design of Streamlined Tunnel Walls for a Two-Dimensional Transonic Test. NASA TM-78641, April 1978, 22 pp.

N78-23105#

An analytical procedure is discussed for designing wall shapes for streamlined nonporous two-dimensional transonic tunnels. It is based upon currently available 2-D inviscid transonic and boundary-layer analysis computer programs. Predicted wall shapes are compared with experimental data obtained from the NASA Langley 6- by 19-Inch Transonic Tunnel where the slotted walls were replaced by flexible nonporous walls. Comparisons are presented for the empty tunnel operating at a Mach number of 0.9 and for a supercritical test of an NACA 0012 airfoil at zero lift. Satisfactory agreement is obtained between the analytically and experimentally determined wall shapes. (Such a liner will be required for testing a large-cord, LFC, swept-wing panel, which has a supercritical airfoil section.)

*NASA, Langley Research Center, Hampton, Va.
**DCW Industries, Inc., Studio City, Calif.
Contract NAS1-14517

81. *El-Hady, N. M.; and *Nayfeh, A. H.: Nonparallel Stability of Two-Dimensional Heated Boundary-Layer Flows, Proceedings of the 12th Symposium on Naval Hydrodynamics, Wash., D.C., June 5-9, 1978.

The method of multiple scales is used to analyze the linear, nonparallel stability of two-dimensional heated liquid boundary layers. Included in the analysis are disturbances due to velocity, pressure, temperature, density and transport properties with temperature. An equation is derived for the modulation of the wave amplitude with streamwise distance. Although the

analysis is applicable to both uniform and non-uniform wall heating, numerical results are presented only for the uniform heating case. The numerical results are in good agreement with the experimental results of Strazisar, Reshotko and Prahl.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.
Grant NSG-1255

82. *Lovell, W. A.; *Price, J. E.; *Quartero, C. B.; *Turriziani, R. V.; and *Washburn, G. F.: Design of a Large Span-Distributed Load Flying-Wing Cargo Airplane with Laminar Flow Control. NASA CR-145376, June 1978, 45 pp.

N78-30045#

A design study was conducted to add laminar flow control to a previously designed span-distributed load airplane while maintaining constant range and payload. With laminar flow control applied to 100 percent of the wing and vertical tail chords, the empty weight increased by 4.2 percent, the drag decreased by 27.4 percent, the required engine thrust decreased by 14.8 percent, and the fuel consumption decreased by 21.8 percent. When laminar flow control was applied to a lesser extent of the chord (approximately 80 percent), the empty weight increased by 3.4 percent, the drag decreased by 20.0 percent, the required engine thrust decreased by 13.0 percent, and the fuel consumption decreased by 16.2 percent. In both cases the required take-off gross weight of the aircraft was less than the original turbulent aircraft.

*Vought Corp., Hampton, Va.
Contract NAS1-13500

83. *Morkovin, M. V.: Technical Evaluation Report of the Fluid Dynamics Panel Symposium on Laminar-Turbulent Transition. Symposium held at Lyngby, Denmark, May 2-4, 1977; AGARD Advisory Rept., AGARD-AR-122, 18 pp., June 1978. (See citation nos. 36-43 for selected papers from this symposium).

N78-27882#

The AGARD Fluid Dynamics Panel organized a three day symposium on laminar-turbulent transition to review the progress achieved during the last ten years and to bring to light the still unsolved problems. There were a total of twenty-nine papers presented in five sessions. The list of these papers heads the references at the end of the report. A second section of this report presents various considerations for evaluating theoretical and experimental analyses of the transition phenomena with particular concern to the improvement of methods for calculating (transition) onset and development on which emphasis was focused in the Call for Papers by the Program Committee. The subsequent sections then offer evaluative comments concerning individual papers and related groups of papers, primarily from the point of view of the specialist in the given subfield.

*Illinois Institute of Technology, Chicago, Ill.

84. *Jernell, Lloyd S.: Effects of Laminar Flow Control on the Performance of a Large Span-Distributed-Load Flying-Wing Cargo Airplane Concept. NASA TM-78715, June 1978, 23 pp.

N79-17851#

The effects of laminar flow control (LFC) on the performance of a large span-distributed-load flying-wing cargo airplane concept having a design payload of 2.669 MN and range of 5.93 Mm were determined. Two configurations were considered. One employed laminarized flow over the entire surfaces of the wing and vertical tails, with the exception of the estimated areas of interference due to the fuselage and engines. The other case differed only in that laminar flow was not applied to the flaps, elevons, spoilers, or rudders. The two cases are referred to as the 100 percent and 80 percent laminar configurations, respectively. The utilization of laminar flow control results in reductions in the standard day, sea level installed maximum static thrust per engine from 240 kN for the non-LFC configuration to 205 kN for the 100 percent laminar configuration and 209 kN for the 80 percent case. Weight increases due to the LFC systems cause increases in the operating empty weights of approximately 3 to 4 percent. The design takeoff gross weights decrease approximately 3 to 5 percent. The FAR-25 takeoff field distances for the LFC configurations are greater by about 6 to 7 percent. Fuel efficiencies for the respective configurations are increased 33 percent and 23 percent.

*NASA, Langley Research Center, Hampton, Va.

85. *Nayfeh, A. H.; and *Padhye, A.: The Relation Between Temporal and Spatial Stability in Three-Dimensional Flows. Presented at the AIAA 11th Fluid and Plasma Dynamics Conference, Seattle, Wash., July 10-12, 1978, 12 pp.

AIAA-78-1126 A78-45130

An analysis is presented of the nonparallel spatial or temporal stability of three-dimensional incompressible, isothermal boundary-layer flows taking into account the transverse velocity component as well as the axial and crossflow variations of the mean flow. The method of multiple scales is used to derive partial differential equations that describe the axial and crossflow variations of the disturbance amplitude, phase and wavenumbers. This equation is used to derive the expressions that relate the temporal and spatial instabilities. These relations are functions of the complex group velocities. Moreover, this equation is used to derive the expression that relates the spatial amplification in any direction to a calculated amplification in any other direc-

tion. These relations are verified by numerical results obtained for two- and three-dimensional disturbances in two- and three-dimensional flows.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Grant NSG-1255

86. *Kachanov, Yu. S.; *Kozlov, V. V.; and *Levchenko, V. Ya.: Experiments on Nonlinear Interaction of Waves in Boundary Layer. AIAA 11th Fluid and Plasma Dynamics Conference, Seattle, Wash., July 10-12, 1978, 12 pp. + 15 figures.

AIAA-78-1131

The results of an experimental study of the flow structure in a region of turbulent transition obtained when initiating two harmonic waves being introduced into the flat plate boundary layer are described. The quasi-stationary interpretation of the obtained results is presented. On the basis of the obtained results and the presented interpretation, some peculiarities of a "natural" transition process are discussed.

*Institute of Theoretical and Applied Mechanics, USSR Academy of Sciences, Novosibirsk.

Note: See pp. 135-144 in #139 in this bibliography for a symposium paper with the same title and the same authors.

87. *George-Falvy, D.: Summary Report of the Second Wind Tunnel Test of the Boeing LFC Model. NASA CR-157792, July 26, 1978, 27 pp.

N79-17799#

An 8-ft span, 20-ft chord, 30 deg swept wing section having provisions for laminar boundary control over the first 30% of the upper surface and the first 15% of the lower surface was tested in a 5-ft by 8-ft wind tunnel to explore the sensitivity of laminar flow to various forms of disturbances such as surface imperfections, contamination, off-design pressure distribution (increased crossflow), and imposed noise. The test equipment used and instrumentation of the model are described. Typical results obtained from configurations with spanwise ridges and spanwise rows of disk are discussed as well as suction flow characteristics at reduced incidence.

*Boeing Commercial Airplane Co., Seattle, Wash.

88. *Kramer, J. J.: Planning a New Era in Air Transport Efficiency. Astronautics and Aeronautics, vol. 16, July-Aug. 1978, pp. 26-28.

A78-43357#

The current status of the NASA Aircraft Energy Efficiency (ACEE) program is briefly reviewed with reference to CTOL aircraft. Attention is given to four basic technologies: turboprop, advanced aerodynamics and active controls, laminar flow control, and composites.

*NASA, Washington, D.C.

89. *Leonard, R. W.: Airframes and Aerodynamics - Aircraft Design in NASA Energy Efficient Transport Program. Astronautics and Aeronautics, vol. 16, July-Aug., 1978, pp. 38-46.

A78-43359#

The first part of the paper discusses the Energy Efficient Transport program of the Aircraft Energy Efficiency (ACEE) program, giving attention to the development of active aerodynamics and active controls. The second part of the paper deals with two other portions of the ACEE program: Composite Primary Structures and Laminar Flow Control.

*NASA, Langley Research Center, Hampton, Va.

90. *Gilbert, B.: Turbulent Flows Produced by Perforated Plate Generators in Wind Tunnels. Rept. no. LOG-J10987, Aug. 11, 1978, 18 pp.

N79-29473#

An application of perforated sheet metal plates was shown to provide an efficient method of producing a large range of turbulent flows for experimental investigation. Fabrication of a standard uniformly perforated grid was done quickly, with ordinary machine shop equipment. Different flow geometries were produced accurately without the use of special equipment. The standard grid and two geometric variations were investigated giving isotropic flow, wake flow, and uniform shear flow. Although the degree of isotropy was excellent, the variation in mean velocity profiles was slightly poorer than found for other grid generators. The wake and shear flows were comparable in quality to similar flows produced experimentally by other methods.

*Grumman Aerospace Corp., Bethpage, N.Y.

91. *Fisher, David F.; and **Peterson, John B., Jr.: Flight Experience on the Need and Use of Inflight Leading Edge Washing for a Laminar Flow Airfoil. Presented at AIAA, Aircraft Systems and Technology Conference, Los Angeles, Calif., Aug. 21-24, 1978, 11 pp.

AIAA-78-1512 A78-47947

An investigation of leading-edge contamination by insects was conducted at the NASA Dryden Flight Research Center with a JetStar airplane instrumented to detect transition on the outboard leading-edge flap and equipped with a system to wash the leading edge in flight. The results of airline-type flights with the JetStar indicated that insects can contaminate the leading edge during takeoff and climbout at large jet airports in

the United States. The results also showed that the insects collected on the leading edges at 180 knots did not erode at cruise conditions for a laminar flow control airplane and caused premature transition of the laminar boundary layer. None of the superslick and hydrophobic surfaces tested showed any significant advantages in alleviating the insect contamination problem. While there may be other solutions to the insect contamination problem, the results of these tests with a washer system showed that a continuous water spray while encountering the insects is effective in preventing insect contamination of the leading edges.

*NASA, Dryden Flight Research Center, Edwards, Calif.
**NASA, Langley Research Center, Hampton, Va.

92. *Braslow, A. L.; and *Muraca, R. J.: A Perspective of Laminar-Flow Control. Paper presented at AIAA Conference on Air Transportation: Technical Perspectives and Forecasts, Los Angeles, Calif., Aug. 21-24, 1978, 40 pp.

AIAA-78-1528 A78-46503#

A historical review of the development of laminar flow control technology is presented with reference to active laminar boundary-layer control through suction, the use of multiple suction slots, wind-tunnel tests, continuous suction, and spanwise contamination. The ACEE laminar flow control program is outlined noting the development of three-dimensional boundary-layer codes, cruise-noise prediction techniques, airfoil development, and leading-edge region cleaning. Attention is given to glove flight tests and the fabrication and testing of wing box designs.

*NASA, Langley Research Center, Hampton, Va.

93. *Shevell, R. S.: The Technological Development of Transport Aircraft - Past and Future. AIAA Conference on Air Transportation: Technical Perspectives and Forecasts, Los Angeles, Calif., Aug. 21-24, 1978, 19 pp.

AIAA-78-1530 A78-46505#

The speed history of transport aircraft is examined. From 1928 to 1958 speed increased five fold. However, the beginning of the jet age in 1958 established speed levels which have shown little change in the past 20 years. It is pointed out that successful aircraft have almost always had equal or lower operating cost compared to their predecessor while offering service improvement in either speed, range comfort, or combinations of them. The technological development of the future is discussed, taking into account laminar flow control, nuclear powered aircraft, short takeoff and landing aircraft, supersonic transports, hydrogen-fueled aircraft, prop-fan powered aircraft, and hypersonic transport. A description of near term technological advances is also presented. Attention is given to active control technology, improved transonic airfoils, advanced filamentary composite materials, induced drag improvements, propulsion, and the next generations of transport aircraft.

*Stanford Univ., Stanford, Calif.

94. *Singh, P.; *Sharma, V. P.; and *Misra, U. N.: Three Dimensional Fluctuating Flow and Heat Transfer Along a Plate With Suction. Int. J. Heat and Mass Transfer, vol. 21, Aug. 1978, pp. 1117-1123.

A79-18970

The flow and heat transfer along a porous plate are investigated when a transverse sinusoidal suction velocity distribution fluctuating with time is applied. Due to this tranverse velocity the flow of fluid is three dimensional. For asymptotic flow conditions, wall shear stress and rate of heat transfer are obtained. When frequency parameter $\alpha \to 0$, it is found that the phase lead of the skin friction in the cross-flow direction is $\pi/2$.

*India Institute of Technology, Kharagpur, India.

95. *Nayfeh, A. H.; and *Bozatli, A. N.: Secondary Instability in Boundary-Layer Flows. VPI-E-78-19, Aug., 1978, 35 pp. (For a journal article with the same title see #129 in this bibliography.)

AD-A058804 N79-13315#

The stability of a secondary Tollmien-Schlichting wave, whose wavenumber and frequency are nearly one half of those of a fundamental Tollmien-Schlichting instability wave (T-S wave), is analyzed by using the method of multiples. Under these conditions, the fundamental wave acts as a parametric excitor for the secondary wave. When the amplitude of the fundamental wave is small, the amplitude of the secondary wave deviates slowly from its unexcited state. However, as the amplitude of the fundamental wave increases, so does the amplitude of the secondary wave even in the regions where it is damped in the unexcited state.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Contract N00014-75-C-9381

96. Ryzhenko, A. I.; and Yasinskiy, F. G.: Problem Statement in Planning and Analysis of Variants of Mass-Production Designs of Boundary Layer Suction Systems. NASA TM-75269, August 1978. (U.S. Gov't. Agencies and Their Contractors only.)

Translation of "Postanovka zadacha proyektirovaniya i analiza variantov seriynykh knostruktsiy sistema otsosa pograniehnogo sloya," Samoletostroyeniye - Tekhnika Vozdushnogo Flota, No. 40, 1976, pp. 73-77.

X78-10024 (English Translation)
A77-32713 (Original Russian)

This paper deals with the need to work out a set of design solutions for boundary layer suction (BLS) systems to minimize drag on airframes, and to pass the problem (achieve the milestone) of selecting the best variants of such BLS systems for mass production, on the basis of optimization studies. Soviet and foreign work on optimization of thin-walled aviation structural elements and applicable optimization techniques are reviewed briefly. Boundary-layer laminarization, airframe skin fabrication variants, and tradeoffs in the design of BLS surface are discussed.

97. *Gibson, J. S.: The Effects of Noise on Laminar Flow Control Drag Reduction Systems. Presented at 11th Congress of the International Council of the Aeronautical Sciences, Lisbon, Portugal, Sept. 10-16, 1978, Proceedings. Volume 2, 1980, pp. 33-39, 24 refs.

A81-14390#

The nature of boundary layer transition from laminar to turbulent flow and the problem of noise as a transition triggering mechanism are described. For historical perspective, the noise sources and laminar flow/noise criteria relative to the X-21A laminar flow control (LFC) research aircraft are reviewed. A more detailed review is given for a passenger LFC transport aircraft, which includes the definition of noise sources, noise predictions on aircraft LFC surfaces, and critically affected LFC areas. Current activities in the area of noise effects on laminar flow are briefly discussed, as are conclusions regarding needed research.

*Lockheed-Georgia Co., Marietta, Ga.

98. *Turriziani, R. V.; *Lovell, W. A.; *Price, J. E.; *Quartero, C. B.; and *Washburn, G. F.: Preliminary Design Characteristics of a Subsonic Business Jet Concept Employing Laminar Flow Control. NASA CR-158958, Sept. 1978, 48 pp.

N78-33087#

Aircraft configurations were developed with laminar flow control (LFC) and without LFC. The LFC configuration had approximately eleven percent less parasite drag and a seven percent increase in the maximum lift-to-drag ratio. Although these aerodynamic advantages were partially offset by the additional weight of the LFC system, the LFC aircraft burned from six to eight percent less fuel for comparable missions. For the transatlantic design mission with the gross weight fixed, the LFC configuration would carry a greater payload for ten percent fuel per passenger mile.

*Vought Corp., Hampton, Va.
Contract NAS1-13500

99. *Pope, G. G.: Prospects for Reducing the Fuel Consumption of Civil Aircraft. In: Energy and Aerospace; Proceedings of the Anglo/American Conference, London, England, Dec. 5-7, 1978, (A79-31908). Royal Aeron. Soc., 1979, 21 pp.

A79-31911

An outline is provided of technological advances that will contribute to the reduction of fuel consumption. Attention is concentrated mainly on advances being made in the UK. The emphasis is on developments that can be exploited in the generation of aircraft which will succeed the more recent of the transport aircraft types now in service and those which will reach the airlines in the early 1980s. Advances in powerplants are examined along with developments in aerodynamics, taking into account advances in design techniques, experimental facilities, wing tip design, drag reduction, and laminar flow control. Attention is also given to materials and structures, active control technology, and operational considerations.

*Royal Aircraft Establishment, Farnborough, Hants, England

100. *Klineberg, J. M.: The NASA Aircraft Energy Efficiency Program. In: Energy and Aerospace; Proceedings of the Anglo/American Conference, London, England, Dec. 5-7, 1978, (A79-31908). Royal Aero. Soc., 1979, 21 pp.

A79-31912#

A review is provided of the goals, objectives, and recent progress in each of six aircraft energy efficiency programs aimed at improved propulsive, aerodynamic and structural efficiency for future transport aircraft. Attention is given to engine component improvement, an energy efficient turbofan engine, advanced turboprops, revolutionary gains in aerodynamic efficiency for aircraft of the late 1990s, laminar flow control, and composite primary aircraft structures.

*NASA, Washington, D.C.

101. *BCAC Preliminary Design Dept.: Evaluation of Laminar Flow Control System Concepts for Subsonic Commercial Transport Aircraft, Final Rept., Sept. 1976 - Sept. 1978. NASA CR-158976, D6-47109, Dec. 1978, 269 pp.

N79-15942#

A two-year study conducted to establish a basis for industry decisions on the application of laminar flow control (LFC) to future commercial transports was presented. Areas of investigation included: (1) mission definition and baseline selection; (2) concepts evaluations; and (3) LFC transport configuration selection and component design. The development and evaluation of competing design concepts was conducted in the areas of aerodynamics, structures and materials, and

systems. The results of supporting wind tunnel and laboratory testing on a full-scale LFC wind panel, suction surface opening concepts and structural samples were included. A final LFC transport was configured in incorporating the results of concept evaluation studies and potential performance improvements were assessed. Remaining problems together with recommendations for future research are discussed.

*Boeing Commercial Airplane Co., Seattle, Wash.
Contract NAS1-14630

102. *El-Hady, N. M.: Effect of Compressibility, Suction, and Heat Transfer on the Nonparallel Stability of Boundary Layer Flows. VPI and SU Ph.D. Thesis, 1978, 215 pp. (Available from Univ. Microfilms, Order no. 7921029.)

N79-32494

The effects of heating, suction, and compressibility on the stability characteristics of boundary layer flows within the framework of a complete nonparallel, linear, spatial stability theory was investigated. Included in the theory are disturbances due to velocity, pressure, temperature, density, and transport properties as well as variations of the fluid properties with temperature. The method of multiple scales is used to account for the nonparallelism of the mean flow and an equation is derived for the modulation of the wave amplitude with position. Stability characteristics are examined for boundary layer flows over an adiabatic flat plate to study the effect of a slight compressibility of the mean flow. The feasibility of controlling boundary layers by suction through porous strips is investigated and the results are compared with the case of continuous area suction.

Dissertation Abstracts.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

103. *Weeks, D. J.; and *Hodges, J.: An Experimental Investigation into the Influence of Acoustic Disturbances on the Development of a Turbulent Boundary Layer. ARC-R/M-3825, BR64877, DCAF E010257, (supersedes RAE-TR-77035 and ARC-37524), 1978, 41 pp.

N79-16238#

The effects of acoustic disturbances on the mean flow in a turbulent boundary layer developing in a mildly favorable pressure gradient are discussed. A Hartmann generator, mounted on the center line of a transonic wind tunnel, was used as a noise source, and the mean flow in the boundary layer on the tunnel sidewall was examined for any effects of the noise. It was not possible to identify any effect of the noise itself on the boundary layer. It is concluded that the acoustic disturbances generally found in the working sections of transonic wind tunnels are likely to exert a measurable influence on the development of turbulent boundary layers.

*Royal Aircraft Establishment, Bedford, England

104. *Nayfeh, A. H.: Stability of Three-Dimensional Boundary Layers. Presented at the 17th Aerospace Sciences Meeting, New Orleans, La., Jan. 15-17, 1979, 10 pp. Also AIAA Journal, vol. 18, no. 4, pp. 406-416, 1980.

AIAA-79-0262 A79-23565#

A theory is developed for the linear stability of three-dimensional growing boundary layers. The method of multiple scales is used to derive partial-differential equations describing the temporal and spatial evolution of the complex amplitudes and wavenumbers of the disturbances. In general, these equations are elliptic, unless certain conditions are satisfied. For a monochromatic disturbance, these conditions demand that the ratio of the components of the complex group velocity be real, thereby relating the direction of growth of the disturbance to the disturbance wave angle. For a nongrowing boundary layer, this condition reduces to $d\alpha/d\beta$ being real, where α and β are the complex wavenumbers in the streamwise and crosswise directions, in agreement with the result obtained by using the saddle-point method. For a wavepacket, these conditions demand that the components of the complex group velocity be real. In all cases, the evolution equations are reduced to inhomogeneous ordinary-differential equations along real group velocity directions.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Grant NSG-1255

105. *Cebeci, Tuncer; and **Stewartson, Keith: On Stability and Transition in Three-Dimensional Flows. Presented at the AIAA 17th Aerospace Sciences Meeting, New Orleans, La., Jan. 15-17, 1979, 9 pp. Also AIAA Journal, vol. 18, April 1980, pp. 398-405.

AIAA-79-0263 A79-19630#

The usefulness of the e^n method for predicting transition in two-dimensional and axially symmetric flows is well established. In order to extend the method to three-dimensional parallel shear flows, it is first necessary to establish a relationship between α and β, the complex wave numbers in two perpendicular directions in the plane of flow. We suggest that this may be done by making use of group velocity concepts which lead to the requirement $\partial\alpha/\partial\beta = -\tan\phi$, where ϕ is real and denotes the direction of propagation of centered disturbances. As a paradigm of this approach, the rotating disk is studied. It is established that the critical Reynolds number is 176, that the principal disturbances to the laminar flow travel outwards and at an angle ≈ -8 deg to the direction of motion of the disk, while the appropriate value of n is ~ 20. The observed

direction of propagation of disturbance is at ≈−13 deg to the direction of motion of the disk. The generally accepted value of n is ~9, much less than that found here.

*California State Univ., Long Beach, Calif.
**University College, London, England
ONR Contract N00014-76-C-0927

106. *Mack, L. M.: On the Stability of the Boundary Layer on a Transonic Swept Wing. AIAA 17th Aerospace Sciences Meeting, New Orleans, La., Jan. 15-17, 1979, 17 pp.

AIAA-79-0264 A79-23563#

Both incompressible and compressible linear stability theory are applied to the three-dimensional compressible boundary layer on a particular transonic sweptback wing of infinite span. A spatial stability theory is used which identifies the growth direction with the real part of the complex angle of the group velocity. It is found that in the forward, but not the rear, crossflow instability region, the maximum amplification rates of the steady disturbances may be calculated to within about 10% by the incompressible stability theory. There is little difference between the sixth and eighth-order compressible theories. The maximum amplification rate of the steady disturbances at any chordwise station is closely related to the maximum cross-flow at that station independent of the Reynolds number. For other than crossflow instability, there can be large differences between the incompressible and compressible theories, both as to the amplification rate and the angle of the wave-number vector for maximum instability. Amplitude ratios of individual wave components are obtained by integrating the spatial amplification rate along the growth direction subject to the constraint that the wavenumber vector is irrotational. This procedure yields steady disturbances aligned with the local potential flow direction whose wavelengths are nearly independent of downstream distance.

*California Inst. of Tech., Jet Propulsion Lab., Pasadena, Calif.
Contract NAS7-100

107. *Lekoudis, Spyridon G.: Stability of Three-Dimensional Compressible Boundary Layers over Wings with Suction. Presented at AIAA 17th Aerospace Sciences Meeting, New Orleans, La., Jan. 15-17, 1979, 12 pp.

AIAA-79-0265 A79-19631#

The problem of the propagation of three-dimensional laminar instabilities in a three-dimensional compressible boundary layer is examined using linear stability theory. The theory is applied to the case of a swept wing with suction. Compressibility is stabilizing especially when the disturbance is of the Tollmien-Schlichting type. When compressibility is neglected the calculations of the amplification rates and the group velocities agree with existing results, obtained from incompressible theory.

*Consultant, Lockheed-Georgia Co., Marietta, Ga.
Research supported by Lockheed-Georgia's IR and D Program.

108. *Runyan, L. J.; and *George-Falvy, D.: Amplification Factors at Transition on an Unswept Wing in Free Flight and on a Swept Wing in Wind Tunnel. Presented at AIAA 17th Aerospace Sciences Meeting, New Orleans, La., Jan. 15-17, 1979, 18 pp.

AIAA-79-0267 A79-23564#

Theoretically predicted amplification characteristics of Tollmien-Schlichting and crossflow disturbances are correlated with experimental data on transition location. A modified version of the MACK linear stability program was used to analyze two specific cases: an unswept sailplane wing of high quality surface finish in free flight at low Reynolds number, and a swept wing section in a low turbulence wind tunnel. For the sailplane wing, where transition was caused by Tollmien-Schlichting type instability, the amplification factor corresponding to transition was found to be about e to the 15th power. For the swept wing model, where transition was caused by crossflow instability, the amplification factor corresponding to transition was about e to the 12th power.

*Boeing Commercial Airplane Co., Seattle, Wash.

109. *Boeing Preliminary Design Department: Evaluation of Laminar Flow Control System Concepts for Subsonic Commercial Transport Aircraft, Summary Rept., Sept. 1976 - Sept. 1978. NASA CR-158998, Jan. 1979, 79 pp.

N79-21043#

Results of a 2-year study are reported which were carried out to extend the development of laminar flow control (LFC) technology and evaluate LFC systems concepts. The overall objective of the LFC program is to provide a sound basis for industry decisions on the application of LFC to future commercial transports. The study was organized into major tasks to support the stated objectives through application of LFC systems concepts to a baseline LFC transport initially generated for the study. Based on competitive evaluation of these concepts, a final selection was made for incorporation into the final design of an LFC transport which also included other advanced technology elements appropriate to the 1990 time period.

*Boeing Commercial Airplane Co., Seattle, Wash.
Contract NAS1-14630

110. *Boeing Preliminary Design Dept.: Aircraft Surface Coatings Study: Energy Efficient Trans-

port Program - Sprayed and Adhesive Bonded Coatings for Drag Reduction. Final Rept., D6-46699, NASA CR-158954, Jan. 1979, 115 pp.

N81-12225#

Surface coating materials for application on transport type aircraft to reduce drag, were investigated. The investigation included two basic types of materials: spray on coatings and adhesively bonded films. A cost/benefits analysis was performed, and recommendations were made for future work toward the application of this technology.

*Boeing Commercial Airplane Co., Seattle, Wash.
NAS1-14742

111. *Keefe, Laurence R.: A Study of Acoustical Fluctuations in the Langley 8-Foot Transonic Pressure Tunnel. NASA CR-158983 Jan. 1979, 29 pp. (U.S. Gov't. and Their Contractors Only.)

X79-10022#

*Wyle Labs, Inc., Hampton, Va.
NASA L-67019-A

112. *Barger, Raymond L.: A Theoretical Investigation of Forebody Shapes Designed for Natural Laminar Boundary-Layer Flow. NASA TP-1375, Jan. 1979, 18 pp.

N79-15903#

The design of forebody shapes for natural laminar flow is discussed. For subsonic flow, computed results for three shapes of different fineness ratios indicate that laminar flow can be attained under conditions that approximate those on the forebody of a cruise missile flying at a low altitude at a high subsonic Mach number. For supersonic (Mach 2.00) design, a one-parameter family of hyperbolic arcs was used to generate forebody shapes having a favorable pressure gradient over the forebody length. Computed results for these shapes indicated laminar and transitional flow over the range of Reynolds numbers considered.

*NASA, Langley Research Center, Hampton, Va.

113. *McQuilkin, F. T.: Study of the Application of Superplastically Formed and Diffusion Bonded (SPF/DB) Titanium Structure to Laminar Flow Control (LFC) Wing Design. NASA CR-158979, Jan. 1979, 101 pp.

N79-20070

Eighteen design concepts for a LFC wing cover, using various SPF/DB approaches, were developed. After evaluation of producibility, compatibility with LFC requirements, structural efficiency and fatigue requirements, three candidates were selected for fabrication of 15 × 23 cm (6 × 9 in.) demonstration panels. Included were both sandwich and stiffened semi-sandwich panels with slotted and perforated surfaces.

Subsequent to the evaluation of the three demonstration panels, one concept was selected for fabrication of a 0.3 × 1.0 meter (12 × 42 inch) feasibility panel. It was a stiffened, semi-sandwich panel with a slotted surface, designed to meet the requirements of the upper wing cover at the maximum wing bending moment of the baseline configuration.

*Rockwell International, Los Angeles, Calif.
Contract NAS1-14566

114. *Wright, Andrew S.: Aircraft Energy Efficiency Laminar Flow Control Glove Flight Conceptual Design Study. NASA TM-80054, Jan. 1979, 34 pp.

N79-20100#

A conceptual design study of a laminar flow control glove applied to the wing of a short to medium range jet transport with aft mounted engines has been completed. Two suction surfaces were studied--a slotted aluminum glove concept and a woven stainless steel mesh porous glove concept. The laminar flow control glove and a dummy glove with a modified supercritical airfoil, ducting, modified wing leading and trailing edges, modified flaps and an LFC trim tab were applied to the wing after slot spacing suction parameters, and compression power were determined. The results of the study show that a laminar flow control glove can be applied to the wing of a jet transport with an appropriate suction system installed.

*NASA, Langley Research Center, Hampton, Va.

115. *Turriziani, R. V.; *Lovell, W. A.; *Price, J. E.; *Quartero, C. B.; and *Washburn, G. F.: Evaluation of a Long-Endurance-Surveillance Remotely-Piloted Vehicle With and Without Laminar Flow Control. NASA CR-159006, Feb. 1979, 56 pp.

N79-17852#

Two aircraft were evaluated, using a derated TF34-GE-100 turbofan engine one with laminar flow control (LFC) and one without. The mission of the remotely piloted vehicles (RPV) is one of high-altitude loiter at maximum endurance. With the LFC system maximum mission time increased by 6.7 percent, L/D in the loiter phase improved 14.2 percent, and the minimum parasite drag of the wing was reduced by 65 percent resulting in a 37 percent reduction for the total airplane. Except for the minimum parasite drag of the wing, the preceding benefits include the offsetting effects of weight increase, suction power requirements, and drag of the wing-mounted suction pods. In a supplementary study using a scaled-down, rather than derated, version of the engine, on the LFC configuration, a 17.6 percent increase in mis-

sion time over the airplane without LFC and an incremental time increase of 10.2 percent over the LFC airplane with derated engine were attained. This improvement was due principally to reductions in both weight and drag of the scaled engine.

*Vought Corp., Hampton, Va.
Contract NAS1-13500

116. *Mangiarotty, R. A.; and *Bohn, A. J.: Wind Tunnel Study on the Effects of Acoustical Disturbances on Controlled Laminar Flow. AIAA 5th Aeroacoustical Conference, Seattle, Wash., March 12-14, 1979, 11 pp.

AIAA-79-0629 A79-26922#

An exploratory study was conducted to investigate the sensitivity of laminar flow controlled (LFC) boundary layers to external acoustical disturbances using an 8-ft span, 20-ft chord, and 30-deg swept wing section with laminar flow control through spanwise slots. The objectives were to identify Tollmien-Schlichting and other amplification frequencies, critical disturbance levels in the boundary layer, the influence of suction rate on these disturbances, and the transfer function between an external sound field and the corresponding disturbance induced in the boundary layer.

*Boeing Commercial Airplane Co., Seattle, Wash.
Contract NAS1-14630

117. *Eggleston, B.; *Jones, D. J.; and **Elfstrom, G. M.: Development of Modern Airfoil Sections for High Subsonic Cruise Speeds. In: AIAA Technical Papers (A79-27351, pp. 9-16) of Atlantic Aeronautical Conference, Williamsburg, Va., Mar. 26-28, 1979, 8 pp.

AIAA-79-0687 A79-27353#

Some recent Canadian work on the design and test of airfoils for high subsonic aircraft is reviewed. Comparisons of theory and experiment are presented for two 16% thick airfoils. One airfoil was designed using numerical optimization while the other was designed by inverse methods with refinements to improve performance. The inverse design airfoil improved maximum lift coefficients 20% at all Mach numbers tested (0.2-0.80) and demonstrated that a concave pressure recovery was not detrimental. Anticipated improvements due to natural laminar flow were not realized at high subsonic Mach numbers and high Reynolds numbers (20×10^6).

*de Havilland Aircraft of Canada, Ltd., Downsview, Ontario, Canada
**National Research Council, Ottawa, Canada

118. *Eppler, R.: The Effect of Disturbances on a Wing. The Science and Technology of Low Speed and Motorless Flight, NASA CP-2085, Part I (N79-23889#), pp. 81-82, held at NASA, Langley Research Center, Hampton, Va., March 29-30, 1979.

N79-23893#

Disturbances such as flap and aileron hinges and poorly faired spoilers were simulated in a computer wind tunnel. The total drag of a single roughness element does not depend only on the size of that element. Its position on the wing has a surprisingly strong effect. In particular, a roughness element on the convex side of a deflected flap or aileron causes a very substantial increase in drag. Very few experimental data are available for comparison. Good agreement with experiment can be achieved, however, by adapting a fictive "step size." The correlation between the real roughness-element size and the drag increase remains to be determined. Simple, fundamental experiments are suggested which will allow a theoretical estimation of the drag increase due to roughness elements.

*Stuttgart Univ., Stuttgart, West Germany

119. *Eppler, R.: Some New Airfoils. The Science and Technology of Low Speed and Motorless Flight, NASA CP-2085, Pt. 1 (N79-23889#), pp. 131-154, held at NASA, Langley Research Center, Hampton, Va., March 29-30, 1979.

N79-23896#

A computer approach to the design and analysis of airfoils and some common problems concerning laminar separation bubbles at different lift coefficients are discussed briefly. Examples of application to ultralight airplanes, canards, and sailplanes with flaps are given.

*Stuttgart Univ., Stuttgart, West Germany

120. *Blackwelder, R. F.: Boundary Layer Transition. Physics of Fluids, vol. 22, no. 3, March 1979, pp. 583 and 584.

A79-28324

It is suggested that boundary layer transition on a flat plate may be considered as a cascade of at least three distinct instabilities. The oscillation frequency of the velocity "spike" is predicted by the growth of a localized free shear layer that is a result of the earlier instabilities.

*Dept. of Aerospace Engineering, Univ. of Southern Calif., Los Angeles, Calif.
Research supported by the Guggenheim Foundation and Max-Planck-Institut fuer Stroemungsforschung.

121. *Roache, P. J.: Semidirect Computation of Three-Dimensional Viscous Flows Over Suction Holes in Laminar Flow Control Surfaces. Final Report. NASA CR-159017, March 1979, 23 pp.

N79-21005#

A summary is given of the attempts made to apply semidirect methods to the calculation of three-dimensional viscous flows over suction holes in laminar flow control surfaces. The attempts were all unsuccessful, due to either (1) lack of resolution capability, (2) lack of computer efficiency, or (3) instability.

*Ecodynamics Research Associates, Inc., Albuquerque, N. Mex.
Contract NAS1-15045

122. *Nayfeh, Ali H.: Effect of Streamwise Vortices on Tollmien-Schlichting Waves. NASA CR-162654; VPI-E-79-12; March 1979, 20 pp.

N80-16294#

The method of multiple scales is used to determine a first order uniform expansion for the effect of counter rotating steady streamwise vortices in growing boundary layers on Tollmien-Schlichting waves. The results show that such vortices have a strong tendency to amplify three dimensional Tollmien-Schlichting waves having a spanwise wavelength that is twice the wavelength of the vortices. An analytical expression is derived for the growth rates of these waves. These growth rates increase linearly with increasing amplitudes of the vortices.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Contract N00014-75-C-03811
Grant NsG-1255

123. *Arata, W. H., Jr.: Very Large Vehicles, Aircraft Design Concepts. Astronautics and Aeronautics, vol. 17, April 1979, pp. 20-25, 33.

A79-30484#

Some of the concepts being studied for large aircraft are briefly discussed. Concepts for conventional takeoff and landing aircraft, distributed-load aircraft, wing-in-ground effect aircraft, multiple fuselages, the laminar-flow-control aircraft, nuclear powered tug, air-cushion-landing-system aircraft, blimp-helicopter combination, and surface-effect ships are mentioned.

*Northrop Corp., Los Angeles, Calif.

124. *Noggle, L. W.; and **Jobe, C. E.: Large-Vehicle Concepts - Aircraft Design. Astronautics and Aeronautics, vol. 17, April 1979, pp. 26-32.

A79-30485#

The paper briefly surveys most of the very large vehicle concepts examined by Air Force, Navy, NASA, and industry in recent study efforts. Some of these include a conventional aircraft capable of carrying a 400,000-lb load over a range of 6200 n.mi., a laminar flow control aircraft, where slotted wing and tail surfaces provide laminar flow to 70% chord to conserve fuel, nuclear-powered aircraft with active-controls technology, swept-wing space-distributed-load aircraft capable of carrying a million pounds of payload, wing-in-ground-effect vehicles, a power-augmented-ram/wing-in-ground-effect vehicle, and the heavy-lift airship.

*Aeronautical Systems Div., Wright-Patterson AFB, Ohio
**Flight Dynamics Lab., Wright-Patterson AFB, Ohio

125. *Meade, L. E.: Fabrication of Thick Graphite/Epoxy Wing Surface Structure - for Subsonic Transport Aircraft. In: "Enigma of the Eighties: Environment, Economics, Energy." Soc. for the Advancement of Material and Process Engineering, 24th National Symposium and Exhibition, San Francisco, Calif., May 8-10, 1979, Book I, (A79-43228), pp. 252-259.

A79-43245

The fabrication of thick structural laminates from Narmco 5208/T300 graphite/epoxy prepreg has presented problems of dimensional and void content control. This paper describes the fabrication process development conducted on Laminar Flow Control wing surfaces for passenger transport applications to achieve thick laminates of high quality. The steps addressed include prebleeding, layup, tooling aids, and curing to achieve the required laminate quality.

*Lockheed-Georgia Co., Marietta, Ga.

126. *Molloy, J. K.: Advanced Air Transport Concepts - Review of Design Methods for Very Large Aircraft. AIAA Student Journal, vol. 17, Spring 1979, pp. 12-16.

A79-31121#

The concepts of laminar flow control, very large all-wing aircraft, an aerial relay transportation system and alternative fuels, which would enable large improvements in fuel conservation in air transportation in the 1990's are discussed. Laminar boundary layer control through suction would greatly reduce skin friction and has been reported to reduce fuel consumption by up to 29%. Distributed load aircraft, in which all fuel and payload are carried in the wing and the fuselage is absent, permit the use of lighter construction materials and the elimination of fuselage and tail drag. Spanloader aircraft with laminar flow control could be used in an aerial relay transportation system which would employ a network of continuously flying liners supplied with fuel, cargo and crews by smaller feeder aircraft. Liquid hydrogen and methane fuels derived from coal are

shown to be more weight efficient and less costly than coal-derived synthetic jet fuels.

*NASA, Langley Research Center, Hampton, Va.

127. *Boeing Preliminary Design Department: Natural Laminar Flow Airfoil Analysis and Trade Studies, Final Rept. Aug. 1977 - June 1978. NASA CR-159029, May 1979, 84 pp.

N82-15018#

Recent development of advanced computer techniques for boundary layer analyses and airfoil design, and advances in manufacturing methods for low-cost, smooth-surfaced bonded structure have combined to provide new interest in natural laminar flow technology.

This document constitutes the final report of two of the subtasks, of Contract NAS1-14742. The first subtask was to define an airfoil for a large commercial transport cruising at Mach 0.8. The second subtask was to incorporate the airfoil into a natural laminar flow transport configuration and compare fuel requirements and operating costs to those of an equivalent turbulent flow transport.

A third subtask was pursued as a separate study and is reported in NASA CR-158954, "Aircraft Surface Coatings Study," which is no. 110 in this compilation.

*Boeing Commercial Airplane Co., Seattle, Wash.
Contract NAS1-14742

128. *Anderson, E. C.: User Guide for STRMLN: A Boundary-Layer Program for Contoured Wind-Tunnel Liner Design. Final Report. NASA CR-159058; DCW-R-15-02; May 1979, 52 pp.

N79-23114#

A 2-D boundary layer computer code developed to process data for an arbitrary number of streamlines is presented. Provisions are included for the computer code to determine either mass transfer rates necessary for an effective boundary layer displacement of zero thickness or the effective displacement thickness for a specified mass transfer-rate distribution. The computer code was developed to be compatible with other computer codes which are being modified and/or developed at the NASA-Langley Research Center in order to design the three dimensional, contoured, wind tunnel liner used in transonic testing of a laminar flow control system installed on a supercritical airfoil section. A brief description of the liner design procedure, representative liner calculations, adaptive-wall design for a two dimensional wind tunnel test, and other applications are reported.

*Dow Industries, Studio City, Calif.
Contract NAS1-14517

129. *Nayfeh, A. H.; and *Bozatli, A. N.: Secondary Instability in Boundary-Layer Flows. Physics of Fluids, Vol. 22, May 1979, pp. 805-813. (For a report with the same title see #95 in this bibliography.)

AD-A074792 A79-36401

The stability of a secondary Tollmien-Schlichting wave, whose wavenumber and frequency are nearly one half those of a fundamental Tollmien-Schlichting instability wave, is analyzed using the method of multiple scales. Under these conditions, the fundamental wave acts as a parametric exciter for the secondary wave. The results show that the amplitude of the fundamental wave must exceed a critical value to trigger this parametric instability. This value is proportional to a detuning parameter which is the real part of $k - 2K$, where k and K are the wavenumbers of the fundamental and its subharmonic, respectively. For the Blasius flow, the critical amplitude is approximately 29% of the mean flow, and hence many other secondary instabilities take place before this parametric instability becomes significant. For other flows where the detuning parameter is small, such as free-shear layer flows, the critical amplitude can be small; thus the parametric instability might play a greater role.

*Virginia Polytechnic Inst. and State Univ., Blacksburg, Va.
Grant NSG-1255

130. *Cousteix, J.; and *Pailhas, G.: Exploratory Study of a Laminar-Turbulent Transition Process Near the Point of Laminar Boundary Layer Separation. ONERA TP-1979-86. June 1979. La Récherche Aerospatiale, May-June 1979, pp. 213-218. (In French.)

A79-41308#

The point and nature of laminar-turbulent transition was studied systematically in a small subsonic wind tunnel, using models with various angles of sweep and a wide range of angles of attack. The technique employed was based on sublimitation of acenaphtene coatings and on hot-wire anemometer probings of the boundary layer. Transition was found to be a phenomenon whose characteristics are strongly influenced by such parameters as the pressure gradient. Further studies of the transition phenomenon are in progress.

*ONERA, Centre d'Etudes et de Récherches de Toulouse, Toulouse, France

131. *Hefner, Jerry N.; and *Bushnell, Dennis M.: Application of Stability Theory to Laminar Flow Control. Presented at the AIAA 12th Fluid and Plasma Dynamics Conference, Williamsburg, Va., July 23-25, 1979, 20 pp.

AIAA-79-1493 A79-46691#

The paper summarizes the state-of-the-art for application of stability theory to laminar flow control using suction, wall temperature and/or favorable pressure gradient ("natural laminar flow"). Discussions include current LFC problem areas requiring stability analyses, methods of relating stability theory to transition with results from data and theory comparisons available thus far, and a summary of low disturbance data available for theory calibration on swept wings. Critical issues highlighted are problems peculiar to suction LFC on high performance transonic wings and application of the e-to-the-n-power method to both low and high speed flight data.

*NASA, Langley Research Center, Hampton, Va.

132. *Nayfeh, A. H.; and *El-Hady, N. M.: An Evaluation of Suction Through Porous Strips for Laminar Flow Control. AIAA 12th Fluid and Plasma Dynamics Conference, Williamsburg, Va., July 23-25, 1979, 14 pp.

AIAA-79-1494

An evaluation is presented of suction through porous strips for laminar flow control. The linear stability theory and the exp(N) criterion are used to investigate the case of suction through porous strips and compare it with the case of continuous area suction. A number of calculations have been performed for strips of various widths and spacings subject to the constraint of constant total mass flow through the strips. The amount of suction required to keep the factor N below some semi-empirical value is determined. The effect of suction through a strip is not limited to the region over the strip but extends both upstream (upstream influence) and downstream (downstream influence). The effectiveness of a strip can be increased considerably by increasing the extent of the upstream influence (sink effect). The results show that the number of strips and their widths and spacings can be optimized so that the total suction levels needed are about 5-10% larger than those needed to achieve the same stability characteristics using continuous area suction.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.
Grant NSG-1255

133. *Lekoudis, Spyridon G.: The Stability of the Boundary Layer on a Swept Wing With Wall Cooling. Presented at AIAA 12th Fluid and Plasma Dynamics Conference, July 23-25, 1979, Williamsburg, Va., 10 pp.

AIAA-79-1495 A79-46692#

Linear stability theory is used to examine the propagation of laminar instabilities in the leading edge region of a transonic swept wing with wall cooling. Before this could be done, the effects of computing real group velocity ratios for monochromatic waves needed investigation. When crossflow disturbances were computed using spatial theory and for a limited range of angles of wavegrowth direction, the growth rate in the direction formed by the real ratio of the group velocities and the direction itself were insensitive to the orientation of the wave growth. When temporal theory was used, this condition resulted in a single wave of maximum amplification. It is found that wall cooling has a stabilizing effect on crossflow disturbances, but the stabilization is mild compared to the stabilizing effect that wall cooling has on Tollmien-Schlichting waves.

*Lockheed-Georgia Co., Marietta, Ga.
Research supported by Lockheed-Georgia's IR&D Program.

134. *Nayfeh, A. H.; and **Bozatli, A. N.: Nonlinear Wave Interactions in Boundary Layers. Presented at AIAA 12th Fluid and Plasma Dynamics Conference, Williamsburg, Va., July 23-25, 1979, 18 pp.

AIAA-79-1496

A model is proposed for the excitation of three-dimensional waves in two-dimensional boundary-layer flows. The model is an interaction of four waves: two two-dimensional waves having the frequencies ω and 2ω and two three-dimensional waves having the frequency ω. Numerical results for nonparallel spatially growing waves are obtained for the experimental conditions of Klebanoff, Tidstrom, and Sargent. The results show that the proposed model is capable of predicting the growth of the three-dimensional waves.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
**Univ. of Arkansas, Fayetteville, Arkansas
ONR Contract N000 14-75-C-0381 and NASA Grant NSG-1255

135. *Floryan, Jerzy M.; and *Saric, William S.: Stability of Görtler Vortices in Boundary Layers With Suction. AIAA 12th Fluid and Plasma Dynamics Conference, Williamsburg, Va., July 23-25, 1979, 18 pp. AIAA Journal, vol. 20, March 1982, pp. 316-324.

AIAA-79-1497 A82-23830#

The formal analysis of Görtler-type instability is presented. The boundary-layer and the disturbance equations are formulated in a general, orthogonal, curvilinear system of coordinates constructed from the inviscid flow over a curved surface. Effects of curvature on the boundary-layer flow are analyzed. The basic approximation for the disturbance equations is presented and solved numerically. Previous analyses are discussed and compared with our analysis. Effects of suction are introduced and discussed, and the results show that the stability characteristics depend on the normal-velocity terms. Stabilization due to suction is not noticeable until the suction exceeds a certain critical value. It is

found that large suction is required for the stabilization of the boundary layer over a curved surface.

*Virginia Polytechnic and State Univ., Blacksburg, Va.
Grant NSG-1255

136. *Owen, F. K.; **Stainback, P. C.; and **Harvey, W. D.: Evaluation of Flow Quality in Two NASA Transonic Wind Tunnels. AIAA 12th Fluid and Plasma Dynamics Conf., Williamsburg, Va., July 23-25, 1979, 11 pp.

AIAA-79-1532 A79-46714#

Tests have been conducted in the Langley Research Center 8-Foot Transonic Pressure Tunnel and the Ames Research Center 12-Foot Pressure Wind Tunnel in order to measure characteristic disturbance levels and energy spectra in their respective settling chambers, test sections, and diffusers and to determine the sources of these disturbances. Results are presented and discussed along with some specific recommendations.

*Complere Inc., Palo Alto, Calif.
**NASA Langley Research Center, Hampton, Va.
Contracts NAS1-14833 and NAS1-15223.

137. *Swift, G.; and *Mungur, P.: A Study of the Prediction of Cruise Noise and Laminar Flow Control Noise Criteria For Subsonic Air Transports, Final Rept., May 1977-June 1978; LG78ER0218; NASA CR-159104, Aug. 1979, 262 pp.

N80-12818#

General procedures for the prediction of component noise levels incident upon airframe surfaces during cruise are developed. Contributing noise sources are those associated with the propulsion system, the airframe and the laminar flow control (LFC) system. Transformation procedures from the best prediction base of each noise source to the transonic cruise condition are established. Two approaches to LFC/acoustic criteria are developed. The first is a semi-empirical extension of the X-21 LFC/acoustic criteria to include sensitivity to the spectrum and directionality of the sound field. In the second, the more fundamental problem of how sound excites boundary layer disturbances is analyzed by deriving and solving an inhomogeneous Orr-Sommerfeld equation in which the source terms are proportional to the production and dissipation of sound induced fluctuating vorticity. Numerical solutions are obtained and compared with corresponding measurements. Recommendations are made to improve and validate both the cruise noise prediction methods and the LFC/acoustic criteria.

*Lockheed-Georgia Co., Marietta, Ga.
Contract NAS1-14946

138. *Tibbetts, J. G.: Near-Field Noise Prediction For Aircraft in Cruising Flight: Methods Manual-Laminar Flow Control Noise Effects Analysis. Final Report, May 1977-June 1978. LG78ER0219; NASA CR-159105, Aug. 1979, 97 pp.

N80-12819#

Methods for predicting noise at any point on an aircraft while the aircraft is in a cruise flight regime are presented. Developed for use in laminar flow control (LFC) noise effects analyses, they can be used in any case where aircraft generated noise needs to be evaluated at a location on an aircraft while under high altitude, high speed conditions. For each noise source applicable to the LFC problem, a noise computational procedure is given in algorithm format, suitable for computerization. Three categories of noise sources are covered: (1) propulsion system, (2) airframe, and (3) LFC suction system. In addition, procedures are given for noise modifications due to source soundproofing and the shielding effects of the aircraft structure wherever needed. Sample cases, for each of the individual noise source procedures, are provided to familiarize the user with typical input and computed data.

*Lockheed-Georgia Co., Marietta, Ga.
Contract NAS1-14946.

139. *Eppler, R.; and *Fasel, H., Editors: Laminar-Turbulent Transition, Sept. 16-22, 1979. Proceedings of the Symposium sponsored by IUTAM, DFG, Universität, Stuttgart, et al. Berlin, Springer-Verlag, 1980, 451 pp., 34 papers.

A81-18101

The studies contained in this volume provide an overview of the current research in the field of hydrodynamic stability and transition to turbulence. Papers are presented on the local criteria of hydrodynamic stability, the transition mechanics of an oscillating boundary layer, three-dimensional waves in a boundary layer, and the generation of a Tollmien-Schlichting wave by a sound wave. Other studies include the laminar-turbulent transition in Taylor-Couette flow, a visual study of the growth and entrainment of turbulent spots, and numerical studies of transition in planar shear flows.

*Stuttgart Universität, Stuttgart, West Germany

140. *Nayfeh, A. H.: Three-Dimensional Stability of Growing Boundary Layers. Proceedings of the International Union of Theoretical and Applied Mechanics Symposium on Laminar-Turbulent Transition, held at Stuttgart, Germany, Sept. 16-22, 1979, (A81-18101, pp. 201-217), Springer-Verlag, 1980.

A81-18117

A theory is developed for the linear stability of three-dimensional growing boundary layers. The method of multiple scales is used to derive partial-differential equations describing the temporal and spatial evolution of the complex amplitudes and wavenumbers of the disturbances. In general, these equations are elliptic unless certain conditions are satisfied. For a monochromatic disturbance, these conditions demand that the ratio of the components of the complex group velocity be real and thereby relate the direction of growth of the disturbance to the disturbance wave angle. For a nongrowing boundary layer, this condition reduces to $d\alpha/d\beta$ being real, in agreement with the result obtained by using the saddle-point method. For a wavepacket, these conditions demand that the components of the group velocity be real.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Grant NSG-1255 (Navy supported research.)

141. *Bushnell, Dennis M.; and **Tuttle, Marie H.: Survey and Bibliography on Attainment of Laminar Flow Control in Air Using Pressure Gradient and Suction - Vol. I. NASA RP-1035, Sept. 1979, 346 pp., 616 refs.

N79-33438#

This survey and bibliography on attainment of laminar flow in air through the use of favorable pressure gradient and suction consists of two volumes. Volume I contains the survey, summaries of data for both ground and flight experiments, and abstracts of referenced reports. Volume II, NASA TM-80108 (X79-10184#) comprises a bibliography and abstracts of the restricted and classified laminar flow control (LFC) literature. The first author conducted the survey and compiled summaries of data, and the second author conducted the literature search and compiled the bibliography. A third selected bibliography of laminar flow control reports, available to NASA personnel only, can be secured from the Scientific and Technical Information Facility by asking for NASA TM-80157 (X79-10185#).

*NASA, Langley Research Center, Hampton, Va.
**NASA, Langley Research Center, Hampton, Va. (retired)

142. *Wigeland, R. A.; *Tan-Atichat, J.; and *Nagib, H. M.: Evaluation of a New Concept for Reducing Free-Stream Turbulence in Wind Tunnels. NASA CR-3196, Oct. 1979, 49 pp.

N79-33440#

The feasibility of using of a 45 deg-honeycomb for improving the flow quality in wind tunnels was investigated. The results of the experiments indicate that the turbulence levels in a wind tunnel using the 45 deg-honeycomb would be comparable to those obtainable using a conventional honeycomb, i.e., a honeycomb which is positioned normal to the mean flow in the settling chamber. However, this is true only when a 45 deg-screen is mounted immediately downstream of the honeycomb, and when some distance is provided between the trailing edges of the corner turning vanes and the upstream side of the 45 deg-honeycomb. This distance is required for adequate decay of the turning-vane wakes, thereby providing a reasonably uniform mean flow entering the honeycomb. Results demonstrate that this distance should be at least twice the spacing between the turning vanes. Even though the resulting turbulence intensity is the same downstream of both the 45 deg-honeycomb and the conventional honeycomb, there would have to be a significant improvement in the test-section turbulence intensity, using the 45 deg-honeycomb to justify the additional expense in fabricating and installing this type of honeycomb.

*Illinois Inst. of Tech., Chicago, Ill.
Grant NSG-1451

143. *Hough, G. R. (ed.): Viscous Flow Drag Reduction. Symposium held at Vought Advanced Technology Center, Dallas, Texas, Nov. 7 and 8, 1979. AIAA Technical Papers, "Progress in Astronautics and Aeronautics," Volume 72, 1980, 481 pp.

A81-26501

The symposium focused on laminar boundary layers, boundary layer stability analysis of a natural laminar flow glove on the F-111 TACT aircraft, drag reduction of an oscillating flat plate with an interface film, electromagnetic precipitation and ducting of particles in turbulent boundary layers, large eddy breakup scheme for turbulent viscous drag reduction, blowing and suction, polymer additives, and compliant surfaces. Topics included influence of environment in laminar boundary layer control, generation rate of turbulent patches in the laminar boundary layer of a submersible, drag reduction of small amplitude rigid surface waves, and hydrodynamic drag and surface deformations generated by liquid flows over flexible surfaces.

*Vought Advanced Technology Center, Dallas, Texas
Supported by: U.S. Navy, U.S. Air Force, NSF, and NASA.
(Note: Selected papers from this symposium follow.)

144. *Leehey, P.: Influence of Environment in Laminar Boundary Layer Control. In: Viscous Flow Drag Reduction, Symposium, Dallas, Texas, Nov. 7-8, 1979. AIAA Technical Papers (A81-26501), 1980, Vol. 72, pp. 4-16.

A81-26502#

Transition Reynolds number is not a unique function of stream turbulence percentage, but is influenced by the frequency spectra, spatial scales, and other physical properties of the dis-

turbance environment of the particular test facility and by the physical characteristics of the test plate. Hot-wire measurements of boundary layer disturbances show that the response to stream turbulence, to downstream traveling acoustic waves, and to test plate vibration is primarily in the Tollmien-Schlichting (T-S) fundamental eigenmode. Growth rates of T-S waves are initially greater under two-dimensional acoustic wave excitation than under three-dimensional stream turbulence excitation in accordance with predictions from spatial stability theory. Conversion of environmental disturbances to T-S waves is found to occur primarily in the vicinity of the test plate leading edge. Analytical, numerical and experimental results suggest strongly that the efficiency of conversion increases with increased bluntness of the leading edge.

*Mass. Inst. of Tech., Cambridge, Mass.
NSF-Navy-supported research.

145. *Runyan, L. J.; and **Steers, L. L.: Boundary Layer Stability Analysis of a Natural Laminar Flow Glove on the F-111 TACT Airplane. In: Viscous Flow Drag Reduction, Symposium, Dallas, Texas, Nov. 7-8, 1979, AIAA Technical Papers (A81-26501), 1980, Vol. 72, pp. 17-32.

A81-26503#

A natural laminar flow airfoil has been developed as a part of the aircraft energy efficiency program. A NASA flight program incorporating this airfoil into partial wing gloves on the F-111 TACT airplane was scheduled to start in May, 1980. In support of this research effort, an extensive boundary layer stability analysis of the partial glove has been conducted. The results of that analysis show the expected effects of wing leading-edge sweep angle, Reynolds number, and compressibility on boundary layer stability and transition. These results indicate that it should be possible to attain on the order of 60% laminar flow on the upper surface and 50% laminar flow on the lower surface for sweep angles of at least 20 deg, chord Reynolds numbers of 25×10^6 and Mach numbers from 0.81 to 0.85.

*Boeing Commercial Airplane Co., Seattle, Wash.
**NASA, Dryden Flight Research Center, Edwards, Calif.

146. *Mask, R. L.: Low Drag Airfoil Design Utilizing Passive Laminar Flow Control and Coupled Diffusion Control. In: "Viscous Flow Drag Reduction" Symposium at Dallas, Texas, Nov. 7-8, 1979. AIAA Technical Papers (A81-26501), 1980, Vol. 72 of "Progress in Astronautics and Aeronautics," pp. 212-232.

A81-26512#

A two-dimensional high-chord Reynolds number passive laminar airfoil was designed for lift coefficient = 0.73 at freestream M = 0.6 and $Re = 4 \times 10^7$ (evaluated for chord length) providing an extremely high L/D = 240. This laminar airfoil design concept integrates passive laminar flow stabilization, by pressure gradient shaping, with active diffusion control techniques on the airfoil trailing edge. A discussion of the design concept and the predicted performance is given. Full scale Reynolds number experiments defining maximum transition Reynolds number and environment influence on transition are presented.

*Vought Advanced Technology Center, Dallas, Tex.
Contracts N62269-77-C-0442 and N62269-79-C-0277
(Note: For this work in report form, see #200 in this bibliography.)

147. *Pfenninger, W.; **Reed, H. L.; and ***Dagenhart, J. R.: Design Considerations of Advanced Supercritical Low Drag Suction Airfoils. In: Viscous Flow Drag Reduction; Symposium at Dallas, Texas, Nov. 7-8, 1979. AIAA Technical Papers (A81-26501), 1980, Vol. 72 of "Progress in Astronautics and Aeronautics," pp. 249-271.

A81-26514#

Supercritical low drag suction laminar flow airfoils were laid out for shock free at design freestream Mach = 0.76, design lift coefficient = 0.58, and t/c = 0.13. The design goals were the minimization of suction laminarization problems and the assurance of shock-free flow at freestream Mach not greater than design freestream Mach (for design lift coefficient) as well as at lift coefficient not greater than design lift coefficient (for design freestream Mach); this involved limiting the height-to-length ratio of the supersonic zone at design to 0.35. High design freestream Mach numbers result with extensive supersonic flow (over 80% of the chord) on the upper surface, with a steep Stratford-type rear pressure rise with suction, as well as by carrying lift essentially in front- and rear-loaded regions of the airfoil with high static pressures on the carved out front and rear lower surface.

*George Washington Univ., Wash., D. C.
**Virginia Polytechnic Institute, Blacksburg, Va.
***NASA, Langley Research Center, Hampton, Va.

148. *Poll, D. I. A.: Transition in the Infinite Swept Attachment Line Boundary Layer. The Aeronautical Quarterly, vol. 30, Nov. 1979, pp. 607-629.

A80-13573

The transition behavior of the boundary layer which is formed along an infinite swept attachment line has been studied experimentally. Circular trip wires and turbulent flat plate boundary layers have been used as sources of disturbance and the range of parameters covered has been such that the results are directly applicable to full scale flight conditions. Simple criteria have been deduced which allow the state of the boundary layer to be determined for given geometric and

free stream properties. Sample calculations for typical swept wing configurations suggest that the majority of civil aircraft will have turbulent attachment lines in the cruise and that subsequent relaminarization in regions of favorable pressure gradient is unlikely.

*College of Aeronautics, Cranfield Institute of Technology, Beds., England
Research supported by the Ministry of Defence.

149. *Pugh, P. G.; **Grauer-Carstensen, H.; and ***Quemard, C.: An Investigation of the Quality of the Flow Generated by Three Types of Wind Tunnels. In: AGARD "Towards New Transonic Wind-Tunnels" (N80-19137), Nov. 1979, 23 pp.

N80-19138#

Flow quality in three wind tunnels with differing drive systems is examined. The investigation included measurements of (1) fluctuating static pressure on the sidewall of the test section; (2) turbulence immediately upstream of the contraction and in the test section; (3) fluctuations of flow angle (both pitch and yaw) in the test section; and (4) fluctuations of both pitot and static pressures in the test section flow. Factors important to the description of wind tunnel flow quality are also discussed. It is shown that the use of fluctuating static pressure as an index of flow quality is invalid when comparing wind tunnels having different forms of drive system or, possibly, even widely different types of test section. Fluctuations in flow angle are of much more direct consequence to the gathering of the usual types of data and can be measured using either appropriately designed yawmeters or with hot-film probes.

*Royal Aircraft Establishment, Bedford, England
**DFVLR, Goettingen, West Germany
***CERT, Toulouse, France

150. *Koegler, John A., Jr.: A Parametric Wing Design Study for a Modern Laminar Flow Wing. NASA-TM-80154, Dec. 1979, 44 pp.

N80-15050#

The results of a parametric wing design study using a modern laminar flow airfoil designed to exhibit desirable stall characteristics while maintaining high cruise performance are presented. It was found that little is sacrificed in cruise performance when satisfying the stall margin requirements if a taper ratio of 0.65 or greater is used.

*NASA, Langley Research Center, Hampton, Va.

151. *Ragab, S. A.; and *Nayfeh, A. H.: On Goertler Instability. VPI-E-79-41, Dec. 1979, 81 pp.

AD-A081255 N80-23602#

Goertler instability for boundary-layer flows over generally curved walls is considered. The full linearized disturbance equations are obtained in an orthogonal curvilinear coordinate system. A perturbation procedure to account for second-order effects is used to determine the effects of the displacement thickness and the variation of the streamline curvature on the neutral stability of the Blasius flow. The pressure gradient in mean flow is accounted for by solving the non-similar boundary-layer equations. Growth rates are obtained for the actual mean flow and compared with those for the Blasius flow and the Falkner-Skan flows. The results demonstrate the strong influence of the pressure gradient and the nonsimilarity of the basic flow on the stability characteristics.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Contract N00014-75-C-0381.

152. *Winoto, S. H.; *Durão, D. F. G.; and *Crane, R. I.: Measurements Within Görtler Vortices. Journal of Fluids Engineering, Dec. 1979, vol. 101, pp. 517-520.

A80-20750#

Local measurements of streamwise velocity component have been made in the laminar boundary layer on the concave surface of a water channel, supported by flow visualization. Details of the naturally-occurring Görtler vortex pattern are presented.

*Dept. of Mechanical Engineering, Imperial College of Science and Technology, London, England
Research supported by Science Research Council.

153. *Bozatli, A. N.: Effects of Wall Waviness and Nonlinear Wave Interactions on the Stability of Boundary-Layer Flows. Ph.D. Thesis, Virginia Polytechnic Institute and State University, 1979, 186 pp. (Available from University Microfilms, Order no. 7924092.)

N80-12992

The effects of wall undulations on the stability of and nonlinear mode-mode interactions of disturbance waves in boundary layer flows are investigated by using a combination of perturbation and numerical methods. Nonparallel flow effects are retained in most of the cases treated. The waviness on a plate which can stabilize or destabilize the flow, depending on the flow and waviness parameters is discussed. Stabilizing the flow by transferring energy from the unstable Tollmien-Schlichting mode to a higher stable mode through a resonant wave coupling mechanism is

examined. First order linear secondary instabilities associated with a time dependent flow consisting of the superposition of a basic flow and a finite amplitude fundamental wave are analyzed.

Dissertation Abstracts.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.

154. *Aircraft Energy Efficiency Program: Laminar Flow Control Technology. NASA-TM-82352, NF-86/8-79, 1979, 8 pp.

N81-24389#

Laminar flow control system design is analyzed with emphasis on surface and structural concepts, wing structures, leading edge contamination and suction unit configurations.

(This type of publication is known as a "NASA FACT.")
*NASA, Wash., D.C.

155. *Nayfeh, A. H.; and *El-Hady, N. M.: Nonparallel Stability of Two-Dimensional Nonuniformly Heated Boundary-Layer Flows. NASA CR-162309, VPI-E-79-1; 1979, 37 pp. Also, Physics of Fluids, vol. 23, 1980, pp. 10-18.

N79-32499#

An analysis is presented for the linear stability of water boundary-layer flows over nonuniformly heated flat plates. Included in the analysis are disturbances due to velocity, pressure, temperature, density, and transport properties as well as variations of the liquid properties with temperature. The method of multiple scales is used to account for the nonparallelism of the mean flow. In contrast with previous analyses, the nonsimilarity of the mean flow is taken into account. No analysis agrees, even qualitatively, with the experimental data when similar profiles are used. However, both the parallel and nonparallel results qualitatively agree with the experimental results of Strazisar and Reshotko when nonsimilar profiles are used.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

156. *Ragab, S. A.: Interacting Inviscid and Laminar Viscous Flow, and Some Aspects of the Stability. VPI and SU Ph.D. Thesis, 1979, 207 pp. (Available from University Microfilm, Order no. 8020226.)

N80-30679

The method of matched asymptotic expansions is used to obtain a second order triple deck solution for the case of constant wall temperature. It includes the problem of an adiabatic wall as a special case. A second order accurate finite difference scheme is developed for solving the lower deck equations. The theory is applied to supersonic flows past compression ramps and incompressible flows over small humps with small bubble separation. Also a numerical method for integrating the interacting boundary layer equations for incompressible flows is developed. For incompressible flows over small humps the first order theory is in good agreement with the interacting boundary layer. By including the second order terms in the triple deck theory, better agreement is obtained. For supersonic flows past corners, the agreement between the triple deck theory and solutions of the full Navier-Stokes equations is improved only in the free interaction region for an adiabatic wall. The second order theory breaks down for cold walls.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

157. *Dougherty, N. S., Jr.; and **Fisher, D. F.: Boundary-Layer Transition on a 10-Deg. Cone-Wind Tunnel/Flight Correlation. AIAA 18th Aerospace Science Meeting, Pasadena, Calif., Jan. 14-16, 1980, 17 pp.

AIAA-80-0154 A80-22737#

Boundary-layer transition location measurements were made on a 10-deg sharp cone in 23 wind tunnels of the U.S. and Europe and in flight. The data were acquired at subsonic, transonic, and supersonic Mach numbers over a range of unit Reynolds numbers to obtain an improved understanding of wind tunnel flow quality influence. Cone surface microphone measurements showed Tollmien-Schlichting waves present. Transition location defined by pitot probe measurements showed transition Reynolds number to be correlatable to cone surface disturbance amplitude within + or - 20 percent for the majority of tunnel and flight data.

*ARO, Inc., Arnold Air Force Station, Tenn.
*NASA, Dryden Flight Research Center, Edwards, Calif.

158. *Mercer, J. E.; *Geller, E. W.; *Johnson, M. L.; and **Jameson, A.: A Computer Code to Model Swept Wings in an Adaptive Wall Transonic Wind Tunnel. Flow Research Rept. no. 164, May 1980. Presented at the AIAA 18th Aerospace Sciences Meeting, Pasadena, Calif., Jan. 14-16, 1980, 7 pp.

AIAA-80-0156 A80-19287#

A computer program has been developed to calculate inviscid transonic flow over a swept wing in a wind tunnel with specified normal flow at the walls. An approximately orthogonal computational grid which conforms to the wing and the tunnel walls was developed for application of the Jameson-Caughey finite volume algorithm. The code solves the full potential equations in fully conservative form using line relaxation. This pro-

gram is to be used in place of the wind tunnel for preliminary studies of the adaptive wall concept for three dimensional configurations. It can also be used to assess the magnitude of wall interference in a conventional tunnel.

*Flow Research Co., Kent, Wash.
**New York Univ., New York, N. Y.
Contract No. F40600-79-C-001.

159. *El-Hady, N. M.; and *Nayfeh, A. H.: Nonparallel Stability of Compressible Boundary-Layer Flows. Presented at the AIAA 18th Aerospace Sciences Meeting, Pasadena, Calif., Jan. 14-16, 1980.

AIAA-80-0277

The effect of compressibility on the stability characteristics of boundary-layer flows is investigated within the framework of a complete nonparallel, linear, spatial stability theory. The method of multiple scales is used to account for the nonparallelism of the mean flow and an equation is derived for the modulation of the wave amplitude with position. Stability characteristics are examined for boundary-layer flows over an adiabatic flat plate. A nearly constant increment in the growth rate due to nonparallel effects is found for subsonic flows. For supersonic flows, this effect is a function of wave angle. Oblique first-mode waves are more unstable than two-dimensional waves according to both parallel and nonparallel theories. For the second-mode the most unstable frequency predicted by the nonparallel theory for a given Reynolds number is higher than that predicted by the parallel theory, in contrast with the first-mode results where they are equal. The nonparallel results are in better agreement with the experimental results of Laufer and Vrebalovitch and Kendall than the parallel results for $M \leq 2.2$.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

160. *Wray, Alan; and **Hussaini, M. Y.: Numerical Experiments in Boundary-Layer Stability. AIAA 18th Aerospace Sciences Meeting, Pasadena, Calif., Jan. 14-16, 1980, 9 pp.

AIAA-80-0275 A80-23957#

Numerical solution of the three-dimensional incompressible Navier-Stokes equations is used to study the instability of a flat-plate boundary layer in a manner analogous to the vibrating-ribbon experiments. Flow-field structures are observed which are very similar to those found in the vibrating-ribbon experiment to which computational initial conditions have been matched. Streamwise periodicity is assumed in the simulation so that the evolution occurs in time, but the events which constitute the instability are so similar to the spatially occurring ones of the laboratory that it seems clear the physical processes involved are the same. A spectral and finite difference numerical algorithm is employed in the simulation.

*NASA, Ames Research Center, Moffett Field, Calif.
**ICASE, NASA, Langley Research Center, Hampton, Va.

161. *Wilcox, D. C.: Development of an Alternative to the e^9 Procedure for Predicting Boundary Layer Transition. Presented at the AIAA 18th Aerospace Sciences Meeting, Pasadena, Calif., Jan. 14-16, 1980, 14 pp.

AIAA-80-0278 A80-18289#

A method has been devised which can be used in conjunction with linear-stability theory for predicting boundary-layer transition. As with the classical "e^9" procedure, for a given frequency the growth of a disturbance is computed downstream of the initial point of instability using the linearized equations of motion. In contrast to the e^9 procedure in which the linearized equations are used all the way to the inferred transition point, an approximate set of long-time averaged equations which account for nonlinearity is used to describe the ultimate nonlinear growth of the disturbance. Because the new method accounts for nonlinear processes it holds promise as a more physically sound procedure than the e^9 method for determining the point at which a boundary layer undergoes transition to turbulence.

*DCW Industries, Inc., Studio City, Calif.
Contracts NOR N00014-77-C-0259 and N00014-78-C-0799.

162. Cotta, R.: Increasing Aircraft Efficiency Through Laminar Flow Control. Aviation Engineering and Maintenance, vol. 4, Jan. 1980, pp. 12-15.

A80-24899

The article discusses recent work in improving laminar flow in order to reduce drag and thereby overall fuel consumption. Attention is given to NASA's laminar flow control project (LFC), the object of which is to demonstrate that the technology required to incorporate LFC into long-range commerical jet transports of the 1990's is available. Discussion covers LFC aircraft configurations proposed by Boeing, Lockheed, and Douglas. Also covered are computer aided design, possible materials, and compromises for maintenance access. Finally, attention is given to losses in aerodynamic efficiency which stem from insect accumulation on wing leading edges, dents, mismatched surface panels, and leaking pressurization of aerodynamic seals.

163. *Mabey, Dennis G.: Resonance Frequencies of Ventilated Wind Tunnels. AIAA Journal, vol. 18, no. 1, Jan. 1980, pp. 7-8 (Synoptic).

N79-30245 (full paper)

Experiments suggest that the theory widely used to predict the transverse resonance frequencies in slotted tunnels is in error in the 0-0.05 Mach number range. One reason for the error is that the theory is based on an unrepresentative wall boundary condition. Moreover, the theory implies that the plenum chamber depth is generally less than twice the tunnel height. An improved theory is developed which shows that the resonance frequencies of ventilated tunnels are influenced by the depth of the plenum chamber for Mach numbers up to about M = 0.6. Although the theory is approximate, it agrees well with experiments for slotted and perforated walls (with both normal and 60 deg inclined holes) in a small pilot wind tunnel (100 × 100 mm). The earlier theory was only valid for slotted working sections. The results are consistent with other experiments, which show that plenum chamber design can influence the flow unsteadiness within the working section of a ventilated tunnel.

*Royal Aircraft Establishment, Bedford, England

164. *Lekoudis, S. G.: Resonant Wave Interactions on a Swept Wing. AIAA Journal, vol. 18, Jan. 1980, pp. 122-124.

A80-17006#

The nonlinear stability of a three-dimensional boundary layer flow on a swept wing with laminar flow control is considered in terms of resonant wave interactions. For a locally parallel, three dimensional boundary layer flow consisting of a steady mean part and an unsteady disturbance part consisting of wave triads, it is found that the disturbance is governed by the Orr-Somerfeld problem for the case of a three-dimensional boundary layer. A set of quasi-linear, first-order, partial differential equations for the slowly varying disturbance amplitudes is then derived from the resonance conditions. It is shown that the necessary conditions for resonant interaction exist for crossflow instability waves on a typical laminar flow control wing, and implications for the prediction of transitions on swept wings are discussed.

*Lockheed-Georgia Co., Marietta, Ga.

165. *Orszag, S. A.: Advanced Stability Theory Analyses for Laminar Flow Control. Final Report. NASA CR-3233, Feb. 1980, 50 pp.

N80-17396#

Recent developments of the SALLY computer code for stability analysis of laminar flow control wings are summarized. Extensions of SALLY to study three dimensional compressible flows, non-parallel and nonlinear effects are discussed.

*Cambridge Hydrodynamics, Inc., Cambridge, Mass.
Contract NAS1-15372

166. *Klopfer, G. H.; and **Hussaini, M. Y.: A Study of Formation of Intense Shear Layers in Transitional Boundary Layers. ICASE Rept. No. 80-5, NASA CR-165,909, Jan. 31, 1980, 31 pp.

The present study is an analytical investigation of the initial stages to turbulence in an incompressible boundary layer on a flat plate. An attempt is made to obtain a conceptual picture of the development of laminar instability with particular reference to three-dimensional nonlinear phenomena. The analytical study is based on certain physical assumptions, and some comparisons with experiments are carried out to test these assumptions. The agreement between the two establishes confidence in the final results.

It is shown that the development of a two-dimensional disturbance into a three-dimensional configuration associated with streamwise vortices is a nonlinear phenomenon, at least in the cases investigated. Its subsequent evolution to intense shear layers is essentially an inviscid linear phenomenon, though nonlinear effects modify the magnitude of the relevant characteristic properties. The influence of various initial perturbation profiles on the development of high shear layers is brought out.

*Nielsen Engineering and Research, Inc., Mountain View, Calif.
**Institute for Computer Applications in Science and Engineering (ICASE) NASA, Langley Research Center, Hampton, Va.
Contracts NAS1-14101 and NAS1-14472.

167. *Goglia, G. L.; and *Wilkinson, S. P.: Experimental Study of Flow Due to an Isolated Suction Hole and a Partially Plugged Suction Slot. Final Report, Feb. 1, 1978 - Jan. 31, 1980. NASA CR-162808, Feb. 1980, 36 pp.

N80-18340#

Details for construction of a model of a partially plugged, laminar flow control, suction slot and an isolated hole are presented. The experimental wind tunnel facility and instrumentation is described. Preliminary boundary layer velocity profiles (without suction model) are presented and shown to be in good agreement with the Blasius laminar profile. Recommendations for the completion of the study are made. An experimental program for study of transition on a rotating disk is described along with preliminary disturbance amplification rate data.

*Old Dominion Univ., Norfolk, Va.
Grant NSG-1491

168. *El-Hady, Nabil M.: Nonparallel Stability of Three-Dimensional Compressible Boundary Layers. Part I - Stability Analysis. Final Rept. NASA CR-3245, Feb. 1980, 38 pp.

N80-16296#

A compressible linear stability theory is presented for nonparallel three-dimensional boundary-layer flows, taking into account the normal velocity component as well as the streamwise and spanwise variations of the basic flow. The method of multiple scales is used to account for the nonparallelism of the basic flow, and equations are derived for the spatial evolution of the disturbance amplitude and wavenumber. The numerical procedure for obtaining the solution of the nonparallel problem is outlined.

*Old Dominion Univ., Norfolk, Va.
Grant NSG-1645

169. *Schairer, Edward T.: Turbulence Measurements in the Boundary Layer of a Low-Speed Wind Tunnel Using Laser Velocimetry. NASA TM-81165, Feb. 1980, 25 pp.

N80-16300#

Laser velocimeter measurements in an incompressible, turbulent boundary layer along the wall of a low-speed wind tunnel are presented. The laser data are compared with existing hot-wire anemometer measurements of a flat plate, incompressible, turbulent, boundary layer with zero pressure gradient. An argument is presented to explain why previous laser velocimeter measurements in zero pressure gradient, turbulent boundary layers have shown an unexpected decrease in turbulent shear stresses near the wall.

*NASA, Ames Research Center, Moffett Field, Calif.

170. *Nayfeh, A. H.; and *Padhye, A.: Neutral Stability Calculations for Boundary-Layer Flows. Physics of Fluids, vol. 23, Feb. 1980, pp. 241-245.

A80-25852

An analysis is presented of the parallel neutral stability of three-dimensional incompressible, isothermal boundary-layer flows. A Taylor-series expansion of the dispersion relation is used to derive the general eigenvalues. These equations are functions of the complex group velocity. These relations are verified by numerical results obtained for two- and three-dimensional disturbances in two- and three-dimensional flows.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Grant NSG-1255

171. *Orszag, Steven A.: Advanced Stability Theory Analyses for Laminar Flow Control. NASA CR-3233, February 1980, 48 pp.

N80-17396#

Recent developments of the SALLY computer code for stability analysis of laminar flow control wings are summarized. Extensions of SALLY to study three dimensional compressible flows, nonparallel and nonlinear effects are discussed.

*Cambridge Hydrodynamics, Inc., Cambridge, Mass.
Contract NAS1-15372

172. *Batill, S. M.; and *Mueller, T. J.: Visualization of the Laminar-Turbulent Transition in the Flow over an Airfoil Using the Smoke-Wire Technique. AIAA 11th Aerodynamic Testing Conference, Colorado Springs, Colo., March 18-20, 1980. In Technical Papers (A80-26929), 1980, pp. 45-53.

AIAA-80-0421 A80-26935#

A flow visualization technique, referred to as the smoke-wire, was used for visualization of the transition of the free shear layer associated with the laminar separation bubble of a NACA 66_{3-018} airfoil section at low Reynolds number (50,000-130,000). The smoke-wire technique allows the introduction of fine smoke streaklines into the flow field through the electrical resistive heating of a very fine wire which has been coated with oil and which is located upstream from the leading edge of the airfoil section. Streakline data were collected using both high speed still and motion picture photography.

*Notre Dame Univ., Notre Dame, Ind.
Grant NSG-1419

173. *Pate, S. R.: Effects of Wind Tunnel Disturbance on Boundary-Layer Transition with Emphasis on Radiated Noise: A Review. (Invited paper), AIAA 11th Aerodynamic Testing Conference, Colorado Springs, Colo., March 18-20, 1980, 22 pages + 80 figures.

AIAA-80-0431

Effects of wind tunnel free-stream disturbances on boundary-layer transition are reviewed. Experimental results show that free-stream disturbances dominate the transition process as determined by the experimentally measured transition Reynolds numbers on simple geometries (flat plates and sharp cones). Principal modes of disturbance are turbulence ($\tilde{u}/U_\infty$) and acoustic sound ($\tilde{p}/q_\infty$) at subsonic speeds; hole/slot acoustic resonance at transonic speeds ($\tilde{p}/q_\infty$); and tunnel wall turbulent-boundary-layer radiated noise at supersonic-hypersonic speeds ($\tilde{p}/q_\infty$). Data correlations and resulting empirical equations that show the direct relationship between transition Reynolds numbers and free-stream disturbance levels are presented and discussed.

*ARO, Inc., AEDC Division, Arnold Air Force Station, Tenn.

174. *Wigeland, R. A.; *Tan-Atichat, J.; and *Nagib, H. M.: Evaluation of a New Concept for Reducing Free-Stream Turbulence in Wind Tunnels. AIAA 11th Aerodynamic Testing Conference,

Colorado Springs, Colo., March 18-20, 1980. In Technical Papers (A80-26929), AIAA, Inc., 1980, pp. 117-128. Also, Journal of Aircraft, vol. 18, July 1981, pp. 528-536.

AIAA-80-0432 A80-26942#

A 45 deg-honeycomb flow manipulator, mounted parallel to the corner turning vanes, was investigated for improving the flow quality in wind tunnels with little or no settling chamber length. This manipulator permits increased turbulence decay distance in comparison to a conventional honeycomb arrangement. The resulting turbulence levels in a wind tunnel using the 45 deg-honeycomb are comparable to those obtained using a conventional honeycomb, but only when a 45 deg-screen is mounted immediately downstream of the honeycomb and when some separation distance between the turning vanes and the 45 deg-honeycomb is provided for adequate decay of the turning vane wakes (at least twice the spacing between the turning vanes).

*Illinois Institute of Technology, Chicago, Ill.
Grant NsG-1451.

175. *Scheiman, James; and *Brooks, J. D.: A Comparison of Experimental and Theoretical Turbulence Reduction from Screens, Honeycomb and Honeycomb-Screen Combinations. AIAA 11th Aerodynamic Testing Conference, Colorado Springs, Colo., March 18-20, 1980, Technical Papers, 1980, pp. 129-137.

AIAA-80-0433-CP A80-26943#

A 1/2-scale model of a portion of the NASA Langley 8-Foot Transonic Pressure Tunnel was used to conduct some turbulence reduction research. The experimental results are correlated with various theories. Screens alone reduce axial turbulence more than the lateral turbulence; whereas, honeycomb alone reduces lateral turbulence more than axial turbulence. Because of this difference, the physical mechanism for decreasing turbulence for screens and honeycomb must be completely different. Honeycomb with a downstream screen is an excellent combination for reducing turbulence.

*NASA, Langley Research Center, Hampton, Va.
(Note: A revised version of this paper was published in the Aug. 1981 issue of the Journal of Aircraft, pp. 638-643, #241 in this bibliography.)

176. *Brooks, J. D.; *Stainback, P. C.; and *Brooks, C. W., Jr.: Additional Flow Quality Measurements in the Langley Research Center 8-Foot Transonic Pressure Tunnel. Presented at the AIAA 11th Aerodynamic Testing Conference, Colorado Springs, Colo., March 18-20, 1980. Technical Papers, 1980, pp. 138-145.

AIAA-80-0434-CP A80-26944#

Additional tests were conducted to further define the disturbance characteristics of the Langley 8-Foot Transonic Pressure Tunnel. Measurements were made in the settling chamber with hot wire probes and in the test section with pressure transducers when various methods were used to choke the flow. In addition to presenting rms values measured at various locations and tunnel condition, autocorrelations and cross correlation data are also presented.

*NASA, Langley Research Center, Hampton, Va.

177. *Nayfeh, A. H.; *Bozatli, A. N.: Nonlinear Interaction of Two Waves in Boundary-Layer Flows. Physics of Fluids, vol. 23, March 1980, pp. 448-458.

A80-30535

First-order nonlinear interactions of Tollmien-Schlichting waves of different frequencies and initial amplitudes in boundary-layer flows are analyzed using the method of multiple scales. Numerical results for flow past a flat plate show that the spatial detuning wipes out resonant interactions unless the initial amplitudes are very large. Thus, a wave having a moderate amplitude has little influence on its subharmonic although it has a strong influence on its second harmonic. Moreover, two waves having moderate amplitudes have a strong influence on their difference frequency. The results show that the difference frequency can be very unstable when generated by the nonlinear interaction, even though it may be stable when introduced by itself in the boundary layer.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Contract N00014-75-C-0381.
Grant NSG-1255.

178. *Quast, Armin: Laminar Airfoils for Transport Aircraft. "Laminarprofile fuer verkehrsflugzeuge" Rept. DFVLR-Mitt-80-07, March 1980, 34 pp. Translation into English ESA-TT-680 by European Space Agency. Paris, France, Oct. 1981, 33 pp.

N81-13952# (In German)
N82-18190# (In English)

The development of laminar airfoils in order to save fuel by reducing drag is discussed. Laminarization through shaping is considered. Laminar and turbulent boundary layer theory and subjective assessment indicate that laminar airfoils for high Reynolds numbers are feasible, with a 22% fuel saving. The reduced cruising speeds, required, however, decrease passenger comfort, making them more suitable for freight carrying.

*Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (West Germany)

179. *Dougherty, N. S., Jr.: Influence of Wind Tunnel Noise on the Location of Boundary Layer Transition on a Slender Cone at Mach Numbers from 0.2 to 5.5, Vol. II: Tabulated and Plotted Data. AEDC-TR-78-44, vol. 2. Final Rept., Jan. 26, 1970 - Apr. 28, 1977. March 1980, 246 pp.

AD-A083166 N80-26280#

A study was conducted to investigate the effects of wind tunnel test section noise on the location of boundary-layer transition. The study was carried out by conducting experiments on a slender, highly polished cone with an included angle of 10 deg. Wind tunnel test section noise was measured by microphones flush-mounted on the cone surface. In most of the experiments, boundary-layer transition was measured with a surface-mounted, traversing pitot pressure probe. The experiments were conducted in 23 different subsonic, transonic, and supersonic wind tunnels over a Mach number range from 0.2 to 5.5 and a unit Reynolds number range from 1.0×10^6 to 7.0×10^6 per foot, the bulk of the data being obtained between 2.0×10^6 and 4.0×10^6 per foot. The results show an influence of wind tunnel noise on boundary-layer transition for most of the wind tunnels.

*ARO Inc., a Sverdrup Corp., Co., Arnold Air Force Station, Tenn.

180. Zhigulev, V. N.; Kirkinskiy, A. T.; Sidorenko, N. V.; and Tumin, A. M.: The Mechanism of Secondary Instability and Its Role in the Generation of Turbulence. Fluid Mechanics - Soviet Research, vol. 9, no. 2, Mar./Apr. 1980, pp. 96-114.

The development of disturbances in the boundary layer after loss of stability is analyzed, concentrating on the three-dimensional nonlinear perturbing wave. A mechanism of secondary instability of the perturbing wave in the boundary layer is suggested and the role of this mechanism in generation of turbulence is examined. The calculations made are compared with experimental data and a statistical approach to the problem of hydrodynamic instability to reveal the role of secondary instability in the development of flow turbulence.

181. *Nayfeh, Ali H.: Stability of Three-Dimensional Boundary Layers. Presented as AIAA-79-0262 at the 17th Aerospace Sciences Meeting, New Orleans, La., Jan. 15-16, 1979. AIAA Journal, vol. 18, no. 4, April 1980, pp. 406-416.

AIAA-79-0262R

(For abstract see citation #104 in this bibliography.)

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Grant NSG-1255

182. *Cebeci, Tuncer; and **Stewartson, Keith: On Stability and Transition in Three-Dimensional Flows. Presented as AIAA-79-0263 at the 17th Aerospace Sciences Meeting, New Orleans, La., Jan. 15-16, 1979. AIAA Journal, vol. 18, no. 4, April 1980, pp. 398-405.

AIAA-79-0263R

(For abstract see citation #105 in this bibliography.)

*California State Univ., Long Beach, Calif.
**University College, London, England

183. *Hefner, J. N.; and *Bushnell, D. M.: Status of Linear Boundary-Layer Stability and the e^n Method, with Emphasis on Swept-Wing Applications. NASA TP-1645, April 1980, 50 pp.

N80-22633#

The state-of-the-art for the application of linear stability theory and the e^n method for transition prediction and laminar flow control design are summarized, with analyses of previously published low disturbance, swept wing data presented. For any set of transition data with similar stream disturbance levels and spectra, the e^n method for estimating the beginning of transition works reasonably well; however, the value of n can vary significantly, depending upon variations in disturbance field or receptivity. Where disturbance levels are high, the values of n are appreciably below the usual average value of 9 to 10 obtained for relatively low disturbance levels. It is recommended that the design of laminar flow control systems be based on conservative estimates of n and that, in considering the values of n obtained from different analytical approaches or investigations, the designer explore the various assumptions which entered into the analyses.

*NASA, Langley Research Center, Hampton, Va.

184. *Orszag, Steven A.: Stability Analysis for Laminar Flow Control - Part II, Final Report. NASA CR-3249, April 1980, 20 pp.

N80-21703#

Topics covered include: (1) optimization of the numerics of the SALLY stability analysis code; (2) relation between temporal and spatial stability theory; (3) compressible flow stability calculations; (4) spectral methods for the boundary layer equations; and (5) numerical study of nonlinear, nonparallel stability of incompressible flows.

*Cambridge Hydrodynamics, Inc., Cambridge, Mass.
Contract NAS1-14907
(Note: For Part I, see citation #58 in this bibliography.)

185. *Beall, R. T.: Fabrication of a Graphite/Epoxy Composite Leading Edge for Laminar Flow Control. In the Society for the Advancement of Material and Process Engineering (SAMPE) Proceedings of the 25th National Symposium and Exhibition, San Diego, Calif., May 6-8, 1980, (A81-22636), pp. 243-250.

A81-22652

Lockheed has recently completed the first phase of a program to evaluate laminar flow control concepts for transport aircraft. Achievement of laminar flow over a wing surface requires a system of slots, metering holes, ducts and pumps to be used to remove the turbulent air adjacent to the surface. This requirement poses severe restrictions on conventional metallic structure. Graphite/expoxy composite with its unique properties appears to be the material that might solve the very complex structural problems associated with a laminar flow control aircraft. A six-foot span graphite/epoxy test article incorporating provisions for leading edge cleaning, deicing and laminar flow control was designed, fabricated and tested.

*Lockheed-Georgia Co., Marietta, Ga.
NASA-supported research.

186. *Chan, Y. Y.: Boundary Layer Controls on the Sidewalls of Wind Tunnels for Two-Dimensional Tests. Journal of Aircraft, vol. 17, May 1980, pp. 380-382.

A80-33281#

The side wall boundary layer in a transonic wind tunnel test section for a two-dimensional airfoil is turbulent and compressible in general. The present note provides some results of the side wall boundary layer developments corresponding to two specified boundary layer growth control methods. A detailed examination gives a better understanding of the phenomena with which the merits or inadequacy of the control methods can be assessed. In summary, by applying suction at an area of the side wall around the model, one can actively control the boundary layer growth, and consequently the inviscid flow outside the boundary layer can be made practically parallel to the side wall. Suction applied ahead of the model is much less effective in controlling the boundary layer development, as the boundary layer recovers rapidly after the suction area and responds to the pressure field in a manner similar to that without suction.

*High-Speed Aeronautics Lab., National Aeronautical Establishment, Ottawa, Canada

187. *Wilson, Vernon, E.: Design Studies of Laminar Flow Control (LFC) Wing Concepts Using Superplastics Forming and Diffusion Bonding (SPF/DB). Final Report, NASA CR-159220, Aug. 1978 - Sept. 1979, May 1980, 114 pp.

N80-26293#

Alternate concepts and design approaches were developed for suction panels, and techniques were defined for integrating these panel designs into a complete LFC 200R wing. The design concepts and approaches were analyzed to assure that they would meet the strength, stability, and internal volume requirements. Cost and weight comparisons of the concepts were also made. Problems of integrating the concepts into a complete aircraft system were addressed. Methods for making splices both chordwise and spanwise, fuel light joints, and internal duct installations were developed. Manufacturing problems such as slot alignment, tapered slot spacing, production methods, and repair techniques were addressed. An assessment of the program was used to develop recommendations for additional research in the development of SPF/DB for LFC structure.

*Rockwell International Corp., Aircraft Div., Los Angeles, Calif.
Contract NAS1-15488

188. *Tan-Atichat, Jimmy: Effects of Axisymmetric Contractions on Turbulence of Various Scales. Illinois Inst. of Tech., Chicago, Ph.D. Thesis, 1980, 393 pp. (Order No. 8026159 from University Microfilms.)

N81-13055

The present study examines digitally acquired and processed results from an experimental investigation of grid-generated turbulence of various scales through and downstream of nine matched cubic axisymmetric contractions ranging in area ratio from 2 to 36, and in length-to-inlet diameter ratio from 0.25 to 1.50. In addition, a fifth order contraction was utilized for studying the contour shape effect. Key features of this experiment included powering the wind tunnel with compressed air to eliminate minute extraneous velocity fluctuations caused by the blower fan blades which amplify and affect the components of turbulent kinetic energy unequally in a contracting stream, and the concurrent utilization of both digital and analog instrumentation to achieve a higher quality of the recorded data. Results indicate that the extent to which the turbulence is altered by the contraction depends on the incoming turbulence scales, and the total strain experienced by the fluid as well as the contraction ratio and the strain rate.

Dissertation Abstracts.

*Illinois Institute of Technology, Chicago, Ill.

189. *Winblade, R. L.: Advanced Transport Aircraft Technology. Airport Forum, vol. 10, June 1980, pp. 44-48, 50.

A80-44114

Various elements of the NASA aircraft energy efficiency program are described. Regarding composite structures, the development of three secondary and three medium-primary components to validate structural and fabrication technology is discussed. In laminar flow control, the design of advanced airfoils having large regions of supercritical flow with features which simplify laminarization are considered. Emphasis is placed on engine performance improvement, directed at developing advanced components to reduce fuel comsumption in current production engines, and engine diagnostics aimed at identifying the sources and causes of performance deterioration in high-bypass turbofan engines. In addition, the results of propeller aerodynamic and acoustic tests have substantiated the feasibility of achieving the propeller efficiency goal of 80% and confirmed that the effect of blade sweep on reducing propeller source noise was 5-6 dB.

*NASA, Transport Aircraft Office, Washington, D.C.

190. *Malik, M. R.: Transition Prediction Using Three Dimensional Stability Analysis. NASA CR-159277; R-SAL-6/80-01. June 1980, 31 pp.

N80-26621#

Several methods of transition prediction by linear stability analysis are compared. The spectral stability analysis code SALLY is used to analyze flows over laminar flow control wings. It is shown that transition by the envelope method and a new modified wave packet method are comparable in reliability but that the envelope method is more efficient computationally.

*Systems and Applied Sciences Corp., Hampton, Va.
Contract NAS1-15604

191. *El-Hady, N. M.: On the Stability of Three-Dimensional Compressible Nonparallel Boundary Layers. Presented at AIAA 13th Fluid and Plasma Dynamics Conference, Snowmass, Colo., July 14-16, 1980, 15 pp.

AIAA-80-1374 A80-44144#

A compressible linear stability theory is presented for three-dimensional nonuniform boundary layers. The amplitude, phase, and wavenumber equation which govern the motion of the disturbance are obtained by using the method of multiple scales. Group velocity trajectories are used to identify the disturbance growth direction. The spatial stability theory is applied to the flow on a laminar flow control supercritical sweptback wing of infinite span. Three different methods are used to calculate the absolute maximum logarithmic amplitude ratio N. In the front crossflow instability region, the method of maximum spatial growth rate predicts large difference in N compared with the method of fixed wavelength and the method of fixed spanwise component of wavelength. This difference decreases in the middle streamwise instability region, and almost vanishes in the rear crossflow instability region. Compressibility of the medium reduces N by about 15% in both the front and rear regions, and by about 40% in the middle region of the wing. Nonuniformity of the medium has large effects especially in the rear region.

*Old Dominion Univ., Norfolk, Va.
Grant NSG-1645
(Note: NASA CR-3245, Feb. 1980 has the same title.)

192. *Floryan, J. M.; and *Saric, W. S.: Wavelength Selection and Total Growth of Görtler Vortices. AIAA 13th Fluid and Plasma Dynamics Conference, Snowmass, Colo., July 14-16, 1980, 18 pp.

AIAA-80-1376 A80-44145#

This paper investigates a wavelength selection mechanism under ideal and nonideal flow conditions. The conditions of the total streamwise growth of Görtler vortices generated under ideal and nonideal flow conditions and its effect on the laminar-turbulent transition process is also examined. The stabilizing effects of suction on the total growth of these vortices are analyzed. It is demonstrated that the wavelength selection mechanism and the total growth of the vortices are affected by the departures from ideal flow conditions. It is shown that under ideal flow conditions, a wavelength selection mechanism can be based on the maximum amplification rate of the disturbances. However, this mechanism is easily affected by the departures from ideal flow. The case of streamwise vorticity in the basic flow is analyzed and is shown to affect disturbances through a subharmonic resonance.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.
Grant NsG-1255

193. *Ragab, S. A.; and *Nayfeh, A. H.: Effect of Pressure Gradients on Görtler Instability. AIAA 13th Fluid and Plasma Dynamics Conference, Snowmass, Colo., July 14-16, 1980, 26 pp.

AIAA-80-1377 A80-44146#

Görtler instability for boundary-layer flows over generally curved walls is considered. The full linearized disturbance equations are obtained in an orthogonal curvilinear coordinate system. A perturbation procedure to account for second-order effects is used to determine the effects of the displacement thickness and the variation of the streamline curvature on the neutral stability of the Blasius flow. The pressure gradient in the mean flow is accounted for by solving the nonsimilar boundary-layer equations. Growth rates are obtained for the actual mean flow and the Falkner-Skan flows. The results demonstrate the strong

influence of the pressure gradient and the nonsimilarity of the basic flow on the stability characteristics.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.
Navy supported research.
Grant NsG-1255

194. *Nayfeh, A. H.; *Reed, H. L.; and **Ragab, S. A.: Flow Over Plates With Suction Through Porous Strips. AIAA 13th Fluid and Plasma Dynamics Conference, Snowmass., Colo., July 14-16, 1980, 24 pp.

AIAA-80-1416 A80-44157#

This paper addresses the steady, incompressible, two-dimensional flow past a flat plate with suction through porous strips. Closed-form solutions for each flow quantity are developed in the context of linearized triple-deck theory using Fourier transforms. To demonstrate the validity of these closed-form solutions, we compare the wall shear stress and pressure coefficients and the streamwise velocity profiles from the linearized theory with those obtained by the numerical integration of both interacting and nonsimilar boundary-layer equations. The agreement between the linearized triple-deck and interacting boundary-layer equations is good; however, the nonsimilar boundary layers, which fail to account for upstream influence, are shown to be in poor agreement with both interacting boundary layers and the linearized triple deck. The linearized closed-form solutions will therefore be very useful in future stability calculations.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
**Lockheed-Georgia Co., Marietta, Ga.
Work supported by ONR and NASA Grant NSG-1255.

195. *Comptroller General of the United States: A Look at NASA's Aircraft Energy Efficiency Program. PSAD-80-50, July 28, 1980, 94 pp.

N81-26149#

The status of the program, the coordination effectiveness between NASA and the Department of Defense, the need for periodic reporting to the Congress on efforts such as ACEE, and NASA's role in aeronautical research and development were examined. Emphasis is placed on the development of technologies which would make future transport aircraft up to 50% more fuel efficient than current models.

*Washington, D.C.

196. *Malik, M. R.; and **Orszag, S. A.: Comparison of Methods for Prediction of Transition by Stability Analysis. AIAA Fluid and Plasma Dynamics Conference, 13th, Snowmass, Colo., July 14-16, 1980, 7 pp.

AIAA-80-1375 A80-41588#

The paper compares several methods of transition prediction of linear stability analysis. The spectral stability analysis code SALLY is used to analyze flows over laminar flow control wings. It is shown that transition prediction by the envelope method and a new modified wave packet method are comparable in reliability, but that the envelope method is more efficient computationally. This is based on the results which show that the wave packet method provides N factors which are at best as consistent as those of the envelope method; since the wave packet method is at least 3 times as expensive as the envelope method, the latter is recommended for engineering design calculations.

*Systems and Applied Sciences Corp., Hampton, Va.
**MIT, Cambridge, Mass.
Contracts NAS1-15604 and NAS1-15894

197. *Philipp, V. M.: Development of Natural Disturbances/Perturbations in a Laminar Boundary Layer. Translation into English from UCh. Zap. (Available to U.S. Gov't. agencies and their contractors only.)

AD-B0507610 X81-72147

*Air Force Systems Command, Wright-Patterson AFB, Ohio

198. *Eppler, R.; and **Somers, D. M.: A Computer Program for the Design and Analysis of Low-Speed Airfoils. NASA TM-80210, August 1980, 145 pp.

N80-29254#

A conformal-mapping method for the design of airfoils with prescribed velocity-distribution characteristics, a panel method for the analysis of the potential flow about given airfoils, and a boundary-layer method have been combined. With this combined method, airfoils with prescribed boundary-layer characteristics can be designed and airfoils with prescribed shapes can be analyzed. All three methods are described briefly. A FORTRAN IV computer program for the numerical evaluation of these methods is available through COSMIC. The program and its input options are described in detail. A complete listing is given as an appendix.

Note: For a supplement to this report see #210 in this bibliography.

*Stuttgart Univ., West Germany
**NASA, Langley Research Center, Hampton, Va.

199. *Hawkins, W. M.: Liquid Hydrogen - An Outstanding Alternate Fuel for Transport Aircraft. In: Safe and Efficient Management of Energy; Proceedings of the 33rd Annual International Air Safety Seminar, Christchurch, New Zealand, Sept. 15-18, 1980, (A82-17276), pp. 270-295.

influence of the pressure gradient and the nonsimilarity of the basic flow on the stability characteristics.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.
Navy supported research.
Grant NsG-1255

194. *Nayfeh, A. H.; *Reed, H. L.; and **Ragab, S. A.: Flow Over Plates With Suction Through Porous Strips. AIAA 13th Fluid and Plasma Dynamics Conference, Snowmass., Colo., July 14-16, 1980, 24 pp.

AIAA-80-1416 A80-44157#

This paper addresses the steady, incompressible, two-dimensional flow past a flat plate with suction through porous strips. Closed-form solutions for each flow quantity are developed in the context of linearized triple-deck theory using Fourier transforms. To demonstrate the validity of these closed-form solutions, we compare the wall shear stress and pressure coefficients and the streamwise velocity profiles from the linearized theory with those obtained by the numerical integration of both interacting and nonsimilar boundary-layer equations. The agreement between the linearized triple-deck and interacting boundary-layer equations is good; however, the nonsimilar boundary layers, which fail to account for upstream influence, are shown to be in poor agreement with both interacting boundary layers and the linearized triple deck. The linearized closed-form solutions will therefore be very useful in future stability calculations.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
**Lockheed-Georgia Co., Marietta, Ga.
Work supported by ONR and NASA Grant NSG-1255.

195. *Comptroller General of the United States: A Look at NASA's Aircraft Energy Efficiency Program. PSAD-80-50, July 28, 1980, 94 pp.

N81-26149#

The status of the program, the coordination effectiveness between NASA and the Department of Defense, the need for periodic reporting to the Congress on efforts such as ACEE, and NASA's role in aeronautical research and development were examined. Emphasis is placed on the development of technologies which would make future transport aircraft up to 50% more fuel efficient than current models.

*Washington, D.C.

196. *Malik, M. R.; and **Orszag, S. A.: Comparison of Methods for Prediction of Transition by Stability Analysis. AIAA Fluid and Plasma Dynamics Conference, 13th, Snowmass, Colo., July 14-16, 1980, 7 pp.

AIAA-80-1375 A80-41588#

The paper compares several methods of transition prediction of linear stability analysis. The spectral stability analysis code SALLY is used to analyze flows over laminar flow control wings. It is shown that transition prediction by the envelope method and a new modified wave packet method are comparable in reliability, but that the envelope method is more efficient computationally. This is based on the results which show that the wave packet method provides N factors which are at best as consistent as those of the envelope method; since the wave packet method is at least 3 times as expensive as the envelope method, the latter is recommended for engineering design calculations.

*Systems and Applied Sciences Corp., Hampton, Va.
**MIT, Cambridge, Mass.
Contracts NAS1-15604 and NAS1-15894

197. *Philipp, V. M.: Development of Natural Disturbances/Perturbations in a Laminar Boundary Layer. Translation into English from UCh. Zap. (Available to U.S. Gov't. agencies and their contractors only.)

AD-B0507610 X81-72147

*Air Force Systems Command, Wright-Patterson AFB, Ohio

198. *Eppler, R.; and **Somers, D. M.: A Computer Program for the Design and Analysis of Low-Speed Airfoils. NASA TM-80210, August 1980, 145 pp.

N80-29254#

A conformal-mapping method for the design of airfoils with prescribed velocity-distribution characteristics, a panel method for the analysis of the potential flow about given airfoils, and a boundary-layer method have been combined. With this combined method, airfoils with prescribed boundary-layer characteristics can be designed and airfoils with prescribed shapes can be analyzed. All three methods are described briefly. A FORTRAN IV computer program for the numerical evaluation of these methods is available through COSMIC. The program and its input options are described in detail. A complete listing is given as an appendix.

Note: For a supplement to this report see #210 in this bibliography.

*Stuttgart Univ., West Germany
**NASA, Langley Research Center, Hampton, Va.

199. *Hawkins, W. M.: Liquid Hydrogen - An Outstanding Alternate Fuel for Transport Aircraft. In: Safe and Efficient Management of Energy; Proceedings of the 33rd Annual International Air Safety Seminar, Christchurch, New Zealand, Sept. 15-18, 1980, (A82-17276), pp. 270-295.

A82-17290

Liquid hydrogen is proposed as an excellent alternate aircraft fuel, owing to its worldwide availability, low cost, ability to be transported and stored without difficulty, and minimum impact on the environment. NASA compared the characteristics and performance of three aircraft using (1) synthetic Jet A, (2) liquid methane, and (3) liquid hydrogen. The liquid hydrogen aircraft was found to weigh considerably less than the others, thereby reducing the take-off gross weight. Every pound of hydrogen produces 51,590 BTU's, whereas a pound of Jet A produces only 18,400 BTU's. Moreover the liquid hydrogen aircraft uses the least energy in spite of aerodynamic disadvantages of the aircraft and high energy needs for liquefaction and the manufacturing process. Liquid hydrogen also has a flyover noise level of 89 decibels compared to the 94 decibels for the Synjet aircraft. A simple system of laminar flow maintenance using liquid hydrogen is discussed, and several safety features of the fuel are noted.

*Flight Safety Foundation, Inc., Arlington, Va.

200. *Mask, R. L.: Low Drag Airfoil Design Utilizing Passive Laminar Flow and Coupled Diffusion Control Techniques. Final Rept., 30 Sept. 1977 - 1 Dec. 1979, Sept. 1980, 84 pp. (ATC-R-91100/9 CR-71, NADC-79119-60).

AD-A090778 N81-12024#

A two dimensional high chord Reynolds number passive laminar airfoil was designed for $C_L = 0.73$ at $M_\infty = 0.06$ and $Re_c = 4 \times 10^7$ providing an extremely high L/D = 240. This laminar airfoil design concept integrates passive laminar flow stabilization, by pressure gradient shaping, with active diffusion control techniques on the airfoil trailing edge. A discussion of the airfoil design concept and the predicted performance is presented. Full scale Reynolds number passive laminar flow/transition experiments defining maximum transition Reynolds number and real flow environment influence on transition are presented. Examination of wind tunnel scaling influences and real flow environment effects on the ATC/laminar airfoil performance are discussed and summarized for typical low turbulence tunnels.

*Vought Corp., Dallas, Texas
Contracts N62269-77-C-0442
N62269-79-C-0277

(Note: For another form of this work see #146 in this bibliography.)

201. *Sturgeon, R. F.: Evaluation of Laminar Flow Control System Concepts for Subsonic Commercial Transport Aircraft. Final Rept. LG80ER-15; NASA CR-159253, Sept. 1980, 316 pp.

N80-33394#

Alternatives in the design of laminar flow control (LFC) subsonic commercial transport aircraft for operation in the 1980's period were studied. Analyses were conducted to select mission parameters and define optimum aircraft configurational parameters for the selected mission, defined by a passenger payload of 400 and a design range of 12,038 km (6500 n mi). The base-line aircraft developed for this mission was used as a vehicle for the evaluation and development of alternative LFC system concepts. Alternatives in the areas of aerodynamics, structures and materials, LFC systems, leading-edge region cleaning, and integration of auxiliary systems were studied. Relative to a similarly-optimized advanced technology turbulent transport, the final LFC configuration is approximately equal in DOC but provides decreases of 8.2% in gross weight and 21.7% in fuel consumption.

*Lockheed-Georgia Co., Marietta, Ga.
Contract NAS1-14631

202. Lockheed-Georgia Co., Marietta: Evaluation of Laminar Flow Control System Concepts for Subsonic Commercial Transport Aircraft. Summary Rept. Lockheed No. LG80ER0149; NASA CR-159254, Sept. 1980, 100 pp.

N80-31384#

A study was conducted to evaluate alternatives in the design of laminar flow control (LFC) subsonic commercial transport aircraft for operation in the 1980's period. Analyses were conducted to select mission parameters and define optimum aircraft configurational parameters for the selected mission, defined by a passenger payload of 400 and a design range of 12,038 km (6500 n. mi.). The baseline aircraft developed for this mission was used as a vehicle for the evaluation and development of alternative LFC system concepts. Alternatives were evaluated in the areas of aerodynamics, structures, materials, LFC systems, leading-edge region cleaning and integration of auxiliary systems. Based on these evaluations, concepts in each area were selected for further development and testing and ultimate incorporation in the final study aircraft. Relative to a similarly-optimized advanced technology turbulent transport, the final LFC configuration is approximately equal in direct operating cost but provides decreases of 8.2% in gross weight and 21.7% in fuel consumption.

Contract NAS1-14631

203. Bogdevich, V. G.; Kobets, G. F.; Koziuk, G. S.; Migirenko, G. S.; Mikuta, V. I.; Mironov, B. P.; Novikov, B. G.; Tetianko, V. A.; and Shtatnov, Iu. V.: Some Questions Relating to the Control of Flows Near a Wall. (PMTF-Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki, Sept.-Oct. 1980, pp. 99-109.) Translation in Journal of Applied Mechanics and Technical Physics, vol. 21, no. 5, March 1981, pp. 657-665, 44 refs.

A81-46784 (English)
A81-21061 (Russian)

A review is presented of cavitation flows in heavy liquids, characteristics of transition of laminar to turbulent flows, and laminarization of wall-boundary flows on permeable surfaces. The interaction of gas bubbles and polymer additions on the structure of wall-boundary turbulence is examined.

204. Levchenko, V. Ya.; and Solov'ev, A. S.: Interaction of Wave Disturbances in an Oscillating Boundary Layer. Fluid Dynamics, vol. 15, no. 5, March 1981, pp. 756-760. Translated from Izvestiya, Akademii Nauk SSSR, Mekhanika Zhidkosti i Gaza, no. 5, pp. 154-158, Sept.-Oct. 1980.

A theoretical analysis is made of the interaction of wave disturbances of small finite amplitude in a boundary layer in the case when the velocity distribution contains a periodic component that oscillates in time in accordance with a harmonic law. It is shown that it is in principle possible for there to be a four-wave synchronous (resonance) interaction in a cubic nonlinearity; equations are obtained for the amplitudes. Calculations made to test the effectiveness of the resonance phenomena have shown that the coupling coefficients are not sufficiently large for the superimposed oscillations to change significantly the nature of the interaction of the waves.

205. *Steers, Louis L.: Natural Laminar Flow Flight Experiment. In NASA CP-2172, (N81-19001), pp. 135-144, "Advanced Aerodynamics and Active Controls." Selected NASA Research, Feb. 1981. Presented at the 4th Ann. Status Rev. of the NASA Aircraft Energy Efficiency (ACEE) Energy Efficient Transport Program, Mountain View, Calif., Oct. 7-9, 1980.

N81-19010#

A supercritical airfoil section was designed with favorable pressure gradients on both the upper and lower surfaces. Wind tunnel tests were conducted in the Langley 8 Foot Transonic Pressure Tunnel. The outer wing panels of the F-111 TACT airplane were modified to incorporate partial span test gloves having the natural laminar flow profile. Instrumentation was installed to provide surface pressure data as well as to determine transition location and boundary layer characteristics. The flight experiment encompassed 19 flights conducted with and without transition fixed at several locations for wing leading edge sweep angles which varied from 10 to 26 at Mach numbers from 0.80 to 0.85 and altitudes of 7620 meters and 9144 meters. Preliminary results indicate that a large portion of the test chord experienced laminar flow.

*NASA, Hugh L. Dryden Flight Research Center, Edwards, Calif.

206. *Gaster, M.: On Transition to Turbulence in Boundary Layers. In: Proceedings of the Symposium on "Transition and Turbulence" in fluids, Madison, Wisconsin, Oct. 13-15, 1980, pp. 95-112 (A82-12438), New York, Academic Press, 1981.

A82-12443

Transition processes that occur in boundary layer flows such as those that arise on the surface of smooth aerofoils are analyzed by examining the idealized problem of transition in the boundary layer of a flat plate at zero incidence to the flow. The type of stability problem involved is defined, and parallel flows are analyzed. Wave-packets in a parallel flow and in a growing boundary layer are discussed, and experimental work on the evolution of wave packets in a laminar boundary layer on a flat plate is reported.

*National Maritime Institute, Teddington, Middx., England

Grant AF-AFOSR-80-0272
Contract F49620-78-C-0062

207. *Cunnington, G. R., Jr.; and *Parmley, R. T.: Aerodynamic Surface Cooling for Laminar Flow Control for Hydrogen-Fueled Subsonic Aircraft. SAE, Aerospace Congress and Exposition, Los Angeles, Calif., Oct. 13-16, 1980, 9 pp.

SAE-80-1155

A81-34245

The nature and magnitude of the potential of cryogenic-fueled aircraft designs for laminar flow control, by use of the sensible heat of the stored fuel to cool aerodynamic surfaces, are explored. It is shown that cooling the boundary layer below adiabatic wall conditions delays turbulent region transition and reduces frictional drag, with preliminary design calculations promising, for the case of liquid hydrogen and nitrogen heat-transfer fluid, 20% fuel requirement reductions in a M 0.85-cruise, 400-passenger aircraft on a 12,000 km flight. The cooling system entailed is a simple, current-technology design which does not adversely affect safety or normal operational factors. It is estimated that the fuel weight savings will be greater than the added cooling system weight, although further, experimental studies are needed to verify the accuracy of drag-reduction predictions.

*Lockheed Research Labs., Palo Alto, Calif.

208. Brykina, I. G.; Gershbein, E. A.; and Peigin, S. V.: Laminar Boundary Layer on Sweptback Wings of Infinite Span at an Angle of Attack. (Akademiia Nauk SSSR, Izvestiia, Mekhanika Zhidkosti i Gaza, May-June 1980, pp. 27-39.) Fluid Dynamics, vol. 15, no. 3, Nov. 1980, pp. 344-354. (Translation.)

A81-17656

In the present paper, the compressible boundary layer flow on swept wings of infinite span is studied for various angles of attack under the assumption of an impermeable or BLC wing surface. A first-approximation analytical solution is obtained (also for axisymmetric flow) by an integral method of successive approximations. Asymptotic solutions of the boundary layer equations are obtained for large values of the BLC parameter.

209. *Harvey, W. D.; *Stainback, P. C.; and **Owen, F. K.: Evaluation of Flow Quality in Two Large NASA Wind Tunnels at Transonic Speeds. NASA TP-1737, Dec. 1980, 76 pp.

N81-13303#

Wind-tunnel testing of low-drag airfoils and basic transition studies at transonic speeds are designed to provide high quality aerodynamic data at high Reynolds numbers. This requires that the flow quality in facilities used for such research be excellent. To obtain a better understanding of the characteristics of facility disturbances and identification of their sources for possible facility modification, detailed flow quality measurements were made in two prospective NASA wind tunnels. This paper presents experimental results of an extensive and systematic flow-quality study of the settling chamber, test section, and diffuser in the Langley 8-Foot Transonic Pressure Tunnel (TPT) and the Ames 12-Foot Pressure Wind Tunnel (PWT). Results indicate that the free stream velocity and pressure fluctuation levels in both facilities are low (<0.1 percent) at subsonic speeds and are so high as to make it difficult to conduct meaningful boundary-layer control and transition studies at transonic speeds.

*NASA, Langley Research Center, Hampton, Va.
**COMPLERE, Inc., Palo Alto, Calif.

210. *Eppler, R.; and **Somers, D. M.: A Computer Program for the Design and Analysis of Low-Speed Airfoils, Supplement. NASA TM-81862, Dec. 1980, 30 pp.

N81-13921#

Three new options were incorporated into an existing computer program for the design and analysis of low speed airfoils. These options permit the analysis of airfoils having variable chord (variable geometry), a boundary layer displacement iteration, and the analysis of the effect of single roughness elements. All three options are described in detail and are included in the FORTRAN IV computer program.

Note: For the main report see citation #198 Aug. '80 in this bibliography.

*Stuttgart Univ., Stuttgart, West Germany
**NASA, Langley Research Center, Hampton, Va.

211. Padhye, A.: Nonparallel Stability of Three-Dimensional Flows. Ph.D. Thesis, Virginia Polytechnic Institute and State Univ., 1980, 140 pp. (Available from University Microfilms, Order No. 8110471.)

N81-26070

An analysis of linear stability of three dimensional boundary layer flows is presented. Both temporal and spatial stabilities are considered. The method of multiple scales is used to account for the nonparallelism of the mean flow, and to derive amplitude and wave-number modulation equations. The wavenumber modulation equation is used to develop a formal method for obtaining neutral stability. The amplitude modulation equation is used to develop a transformation relating the temporal and spatial stabilities. In the case of three dimensional flows, the calculations are performed in temporal stability which is then transformed to be the spatial along the direction of group velocity. The most amplified disturbance at any given frequency is oriented almost normal to the direction of the potential flow. The corresponding group velocity is directed almost along the direction of the potential flow.

Dissertation Abstracts.

212. *Floryan, J. M.: Stability of Boundary-Layer Flows Over Curved Walls. Ph.D. Thesis, 1980, Virginia Polytechnic Institute and State Univ., 175 pp.

N80-30668
Avail.: Univ. Microfilms
Order No. 8020206

The formal analysis of the Görtler-type instability is presented. The boundary layer equations and the disturbance equations are formulated in a general, orthogonal, curvilinear system of coordinates constructed from the inviscid flow over a curved surface. Effects of the curvature of the wall on the boundary layer flow are analyzed and are shown to be insignificant for the intended stability analysis. The basic approximation for the disturbance equations is presented and solved numerically. Previous analyses are discussed and compared with the present one. Results show the importance of the boundary layer growth and are in a good agreement with the experimental data. Effects of suction are introduced and are shown to stabilize the boundary layer.

Dissertation Abstracts.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.

213. *Owen, F. K.: Measurements of Flow Quality in the Ames 2 × 2 Ft Transonic Wind Tunnel. AIAA 19th Aerospace Sciences Meeting, St. Louis, Mo., Jan. 12-15, 1981, 7 pp.

AIAA-81-0156

A81-20636#

For decades, wind tunnel testing has been conducted in test section environments which have not been adequately documented. However, with the advent of the energy shortage, the need for improved fuel-efficient transports employing supercritical or LFC airfoils has increased the awareness of the possible influence of freestream turbulence on advanced experimental testing. This has already lead to detailed flow quality measurements in NASA transonic wind tunnels. The purpose of this paper is to present results of a study in the Ames 2 × 2 ft transonic wind tunnel.

*Complere, Inc., Palo Alto, Calif., U.S. Air Force supported research.
Contract NAS2-10352

214. *Thomas, A. S. W.; and *Cornelius, K. C.: An Experimental Investigation of the Flow of a Laminar Boundary Layer into a Suction Slot. AIAA 19th Aerospace Sciences Meeting, St. Louis, Mo., Jan. 12-15, 1981, 12 pp.

AIAA-81-0194 A81-20665#

The problem of the flow of a laminar boundary layer into a suction slot has been examined experimentally in a low turbulence water channel. A dimensional analysis is used to determine the variables that are important to the problem and these are found to be the slot Reynolds number and a new parameter that is introduced to describe the mean velocity gradient in the flow above the slot. Measurements are then reported of the characteristics of the separation region within the slot and the slot pressure loss. These data show unique collapse when expressed in terms of these similarity variables and may now be used as a predictive design tool. The flow in the region above the slot, in both the upstream and downstream directions, has also been examined. The upstream flow development can be likened to that of a boundary layer that develops from some displaced effective origin. The possibility of a Taylor-Goertler rational instability occurring just downstream of the slot has been studied and is not found to be critical to the subsequent flow development. Finally, some brief discussion is given to the implications of these findings in the design of suction slots for Laminar Flow Control applications.

*Lockheed-Georgia Co., Marietta, Ga.

215. *Mack, L. M.: Compressible Boundary-Layer Stability Calculations for Sweptback Wings with Suction. Presented at the 19th AIAA Aerospace Sciences Meeting, St. Louis, Mo., Jan. 12-15, 1981, 10 pp.

AIAA-81-0196 A81-20840#

The stability of the laminar boundary layers on two transonic wings of infinite span with distributed suction is investigated with the compressible, parallel-flow stability theory. Both wings have supercritical airfoil sections; one has a sweep angle of 23 deg, the other of 35 deg. Zero-frequency disturbances are used to represent cross-flow instability, and disturbances with the wavenumber vector aligned with the local flow direction represent traveling-wave instability. In both cases, the maximum spatial amplification rate is used as a measure of the instability. For the suction, distributions with constant mass flux downstream of the starting point are used. The main objective is to determine how the maximum amplification rate varies with the magnitude and starting point of the suction. It is found for both types of disturbances that the maximum amplification rate varies almost linearly with the suction magnitude up to at least the point where the amplification rate is halved. Different starting locations for the suction in the first 4% of the chord were found to affect cross-flow instability, but to have little influence on traveling-wave instability.

*California Institute of Technology, Jet Propulsion Lab., Pasadena, Calif.
Contract NAS7-100

216. *Sonoda, T.; and *Aihara, Y.: Effects of Pressure Gradients on the Secondary Instability of Gortler Vortices. AIAA 19th Aerospace Sciences Meeting, St. Louis, Mo., Jan. 12-15, 1981, 12 pp.

AIAA-81-0197 A81-20666#

The paper discusses the experimental results on the secondary instability of Görtler vortices in low speed boundary layers under the influence of pressure gradient. It is found that the secondary instability in the form of horseshoe type vortices is important to the transition of the boundary layer. The effects of pressure gradient are observed to appear through a changing of the high shear layer in three-dimensional mean velocity field. Influence of pressure gradient on the upstream region is noticed.

*Tokyo University, Tokyo, Japan

217. *Nastrom, G. D.; **Holdeman, J. D.; and ***Davis, R. E.: Cloud Encounter and Particle Density Variabilities from GASP data. Paper presented at AIAA 19th Aerospace Sciences Meeting, St. Louis, Mo., Jan. 12-15, 1981, 7 pp. Also, Journal of Aircraft, vol. 19, no. 4, April 1982, pp. 272-277.

AIAA-81-0308 A81-20742#

Summary statics and variability studies are presented for cloud encounter and particle number density data taken as part of the NASA Global Atmospheric Sampling Program (GASP) aboard commercial Boeing 747 airliners. On the average, cloud encounter is shown on about 15% of the 52,164 data samples available, but this value varies with season, latitude, synoptic weather situation, and distance from the tropopause. The number density

of particles (diameter greater than 3 μm) also varies with time and location, and depends on the horizontal extent of cloudiness.

Clouds are also of interest for proposed laminar flow control (LFC) wing aircraft. This interest, which provided the motivation for this study, is due to some evidence that the low drag characteristics of LFC wings are lost, albeit temporarily, whenever visible clouds are encountered and sometimes in cirrus hazes, thereby influencing the economic feasibility of LFC.

*Control Data Corp., Minneapolis, Minn.
**NASA, Lewis Research Center, Cleveland, Ohio
***NASA, Langley Research Center, Hampton, Va.

218. *Kong, Fred Y.; and *Schetz, Joseph A.: Turbulent Boundary Layer Over Solid and Porous Surfaces with Small Roughness. Paper presented at AIAA 19th Aerospace Sciences Meeting, St. Louis, Mo., Jan. 12-15, 1981, 13 pp.

AIAA-81-0418

A81-20820#

Experimental studies were conducted to obtain direct measurements of skin friction, mean velocity profiles, axial and normal turbulence intensity profiles, and Reynolds stress profiles in the boundary layer on a large-diameter, axisymmetric body with a solid, smooth surface, a sandpaper-roughened, solid surface and a porous, sintered metal surface in the same nominal roughness range as the sandpaper. The roughness values were in the low range just above what is normally considered "hydraulically smooth". Measurements were taken at four different axial locations (except for the porous surface, for which measurements were made only at the last station) and two different freestream velocities corresponding to dynamic pressures of 12.7 and 17.8 cm H_2O, which gives a Re_L range of 4.96×10^6 to 6.11×10^6. For the Law of the Wall, the Defect Law, and the turbulence quantities, good agreement exists between the present results and those from well-established studies for solid, smooth surfaces. The sandpaper-roughened wall tests showed an increase in local skin friction and a slight shift in the log region of the Wall Law, as well as an increase in turbulence quantities. These results were in accord with classical results for uniform sand grain roughness. For the porous wall case, a higher increase in local skin friction and marked downward shift of the log region of the Wall Law were observed. All the turbulence quantities also showed a definite increase in magnitudes, which were greater than those observed from the sandpaper-roughened wall. These results indicate that the porosity and non-uniformity of the porous surface influences the turbulent boundary layer more strongly than a uniformly sand-roughened, solid surface in the same nominal range.

*Virginia Polytechnic Inst. and State Univ., Blacksburg, Va.
Work supported by NASA, LaRC.

219. *Somers, Dan M.: NASA Research Related to Sailplane Airfoils. In: Proceedings of 1981 S.S.A. (Soaring Society of America) National Soaring Convention, Phoenix, Ariz., Jan. 14-18, 1981, pp. 99-109. (Published by the Arizona Soaring Assoc. (ASA) 1981.)

The theoretical methods and experimental facilities at the NASA Langley Research Center have been employed to conduct investigations of sailplane airfoils. The unique and powerful capabilities of the Eppler Program have been used to design and analyze many airfoils and to smooth several Wortmann airfoils. Wind-tunnel investigations of two sailplane airfoils have been conducted in the Langley low-turbulence pressure tunnel. A procedure for sailplane performance improvement has been outlined.

*NASA, Langley Research Center, Hampton, Va.

220. *Wazzan, A. R.; *Gazley, C., Jr.; and *Smith, A. M. O.: The H-R Method for Predicting Transition. RAND/P-6581, Jan. 1981, 14 pp.

N81-25328#

A shortcut method, the H-R_x method, for predicting transition in a wide class of boundary layer flows, including the effects of pressure gradient, surface heat transfer, and suction is described. Here H and R_x are the body shape factor and the Reynolds number, based on distance x measured in the direction of the flow, respectively. The method is extremely simple to use and a good substitute to the well known but rather complicated e to the 9th power method.

*California Univ., Los Angeles, Calif.

221. *Orszag, S. A.: Advanced Stability Analysis for Laminar Flow Control. Final Rept. CHI-43; NASA CR-165661, Feb. 1981, 126 pp.

N81-17381#

Five classes of problems are addressed: (1) the extension of the SALLY stability analysis code to the full eighth order compressible stability equations for three dimensional boundary layer; (2) a comparison of methods for prediction of transition using SALLY for incompressible flows; (3) a study of instability and transition in rotating disk flows in which the effects of Coriolis forces and streamline curvature are included; (4) a new linear three dimensional instability mechanism that predicts Reynolds numbers for transition to turbulence in planar shear flows in good agreement with experiment; and (5) a study of the stability of finite amplitude disturbances in axisymmetric pipe flow showing the stability of this flow to all nonlinear axisymmetric disturbances.

*Cambridge Hydrodynamics, Inc., Mass.
Contract NAS1-15894

222. *Jagger, D. H.: Design Possibilities for Improved Fuel Efficiency of Civil Transport Aircraft. In: Symposium on Energy Management and Its Impact on Avionics, London, March 19, 1981, (A82-20513), Royal Aeronautical Society. 9 pp.

A82-20514

The possible application and potential benefits of various technical advances in aerodynamics, structures, and propulsion for the reduction of fuel usage in future Airbus aircraft are discussed. In particular, technical comparisons and tradeoffs in terms of fuel economy are considered for a hypothetical medium-range project aircraft of the 1980's. Improvements in fuel used per passenger at 1,000 n.m. range over two successive periods of 20 years are estimated. A breakdown of the objectives, time-scales, and costs of various parts of the current NASA Aircraft Energy Efficiency Program is also given. This features such improvement as propulsion/aerodynamic integration winglets, the use of advanced composite materials, drag cleanup, structural-duct integration, minimum suction-natural laminar flow, reduction of engine performance losses, and active controls for load alleviation.

*Airbus Industrie, Blagnac, Haute-Garonne, France

223. *Demetriades, A.: Roughness Effects on Boundary-Layer Transition in a Nozzle Throat. AIAA Journal, vol 19, no. 3, March 1981, pp. 282-289.

AIAA-81-4057 A81-25511#

A boundary-layer transition study was carried out in the throat region of the DeLaval nozzle of a supersonic wind tunnel. The study was motivated equally by the need to find thresholds for laminar boundary-layer flow in the tunnel walls when roughness is present and by the desire to simulate transition on roughened blunt bodies in supersonic and hypersonic flow. Detailed inviscid and viscous flow measurements were done from the low subsonic to the supersonic regions of the nozzle throat. The roughness was caused by attaching distributed roughness overlays on the nozzle surface. Transition, detected by hot-film anemometers, was found to move upstream as the flow Reynolds number and/or the roughness height increased. Cast in the coordinates of some of the empirical blunt-body transition correlations currently in use, the present transition data agree with the available blunt-body data when the nondimensional roughness exceeds unity and support the concept of a constant roughness Reynolds number for transition in that regime. At the lower roughness heights, the results show that the transition Reynolds number departs from the aforementioned correlations and approaches a limit insensitive to roughness but characteristic of the experimental facility.

*Montana State Univ., Bozeman, Mont.
Contract F04701-77-C-0113

224. *Jenkins, M. W. M.: In-Flight Research - At Low Cost. Lockheed Horizons, Spring 1981, pp. 32-39.

A81-29208

An overview is presented of a flight test program in which a manned, jet-powered sailplane has been used in conjunction with several remotely controlled 0.3-scale research vehicles for advanced aerodynamics technology research. Among the concerns of the program have been the effects of wing spanwise blowing, laminar flow control by slot-suction methods, leading-edge insect strikes, vortex diffusers, airframe noise, command augmentation, and fiber-optic flight controls. A description is also given of the fully integrated ground monitoring facilities at which test aircraft telemetry is gathered, reduced, and analyzed.

*Lockheed-Georgia Co., Marietta, Ga.

225. *Holmes, Bruce J.; and *Croom, Cynthia C.: Aerodynamic Design Data for a Cruise-Matched High Performance Single Engine Airplane. Presented at the Business Aircraft Meeting and Exposition, Wichita, Kansas, April 7-10, 1981, 12 pp.

SAE-81-0625 A81-42779

Design data are presented for a class of high-performance single-engine business airplanes. The design objectives include a cruise speed of 300 knots, a cruise altitude of 10,700 m (35,000 ft), a cruise payload of six passengers (including crew and baggage), and a no-reserves cruise range of 1300 n.mi. Two unconventional aerodynamic techologies were evaluated: the individual and combined effects of cruise-matched wing loading and of a natural laminar flow airfoil were analyzed. The tradeoff data presented illustrate the ranges of wing geometries, propulsion requirements, airplane weights, and aerodynamic characteristics which are necessary to meet the design objectives. Very large design and performance improvements resulted from use of the aerodynamic technologies evaluated. It is shown that the potential exists for achieving more than 200-percent greater fuel efficiency than is achieved by current airplanes capable of similar cruise speeds, payloads, and ranges.

*NASA, Langley Research Center, Hampton, Va.

226. *Papenfuss, H.-D.; and *Niehuis, R.: Grenzschichteffekte 2. Ordnung bei der kompressiblen Stromung mit starkem Absaugen. (Boundary-Layer Effects of the Second Order in a Compressible Flow with Hard Suction. Deutsche Gesellschaft für Luft- und Raumfahrt, Jahrestagung, Aachen, West Germany, May 11-14, 1981, 19 pp. Paper 81-018. (In German.)

A81-47571#

An approach involving suction from the wall can be used to reduce drag. The effects of suction are related to a displacement of the separation point and the laminarization of the boundary layer. Up to now, this approach has been rarely used in practical applications because of technical difficulties. The considered investigation is concerned with hard suction. In increasing suction intensity, the limits of the validity of the Prandtl boundary layer concept are approached. Particular attention is given to second-order boundary-layer effects, taking into account the effects of displacement, longitudinal and transversal curvature, and external rotation. The laminar flow around planar and axisymmetrical bodies is studied, taking into account compressible fluids. Second-order boundary-layer theory provides the result that curvature and rotation effects disappear for the limiting case of hard suction. Only the displacement effect remains. It is pointed out that solely the quantities of frictionless displacement flow are needed for calculating the wall gradients of second-order boundary-layer flow.

*Bochum, Ruhr-Universität, Bochum, West Germany

227. *Creel, Theodore R., Jr.; and *Beckwith, Ivan E. (inventors): A Rectangular Rod-Wall Sound Shield, Patent Application. Filed May 28, 1981, 12 pp. NASA-Case-LAR-12883-1, U.S. Patent Application-SN-267935.

N81-29138#

A test section for a supersonic or hypersonic wind tunnel is described. The section is shielded from the noise normally radiated by the turbulent tunnel wall boundary layer. A vacuum plenum surrounds spaced rod elements making up the test chamber. Some of the boundary layer formed along the rod elements during a test is thereby extracted to delay the tendency of the rod boundary layers to become turbulent. Novel rod construction involves bending. Each rod is bent prior to machining, providing a flat segment on each rod for connection with the flat entrance fairing. Rods and fairing are secured to provide a test chamber incline on the order of 1 deg outward from the noise shield centerline to produce up to a 65% reduction of the root-mean-square (rms) pressure over previously employed wind tunnel test sections at equivalent Reynolds numbers.

*NASA, Langley Research Center, Hampton, Va.

228. *Reshotko, E.; and *Leventhal, L.: Preliminary Experimental Study of Disturbances in a Laminar Boundary-Layer Due to Distributed Surface Roughness. AIAA 14th Fluid and Plasma Dynamics Conference, Palo Alto, Calif., June 23-25, 1981, 12 pp.

AIAA-81-1224

Mean flow and disturbance measurements have been made on a flat plate model in the CWRU low speed wind tunnel using hot-wire anemometry. Tests were conducted on the smooth plate and with two sandpaper coverings, one with $Re_k = 15$ and a coarser sandpaper with $Re_k = 150$. The mean flow measurements indicated Blasius profiles for the smooth plate and with the finer sandpaper. With the coarser sandpaper, the profile was best approximated by a Blasius profile at the early stations but then progressed toward a turbulent profile. The finer sandpaper had only very minor effects on the disturbance profiles. For the coarser sandpaper, the departure of the mean profiles from Blasius could be identified with disturbance amplitudes about 10% of the mean values. A study of disturbance spectra for this case shows largest amplitudes and amplifications at frequencies well below the Blasius neutral curve.

*Case Western Reserve Univ., Cleveland, Ohio
Work supported by AFOSR.

229. *Harvey, W. D.; and *Bobbitt, P. J.: Some Anomalies Between Wind Tunnel and Flight Transition Results. Paper presented at AIAA 14th Fluid and Plasma Dynamics Conference, Palo Alto, Calif., June 23-25, 1981, 18 pp.

AIAA-81-1225

A81-38089#

A review of environmental disturbance influence and boundary layer transition measurements on a large collection of reference sharp cone tests in wind tunnels and of recent transonic-supersonic cone flight results have previously demonstrated the dominance of free-stream disturbance level on the transition process from the beginning to end. Variation of the ratio of transition Reynolds number at onset-to-end with Mach number has been shown to be consistently different between flight and wind tunnels. Previous correlations of the end of transition with disturbance level give good results for flight and large number of tunnels; however, anomalies occur for similar correlation based on transition onset. Present cone results with a tunnel sonic throat reduced the disturbance level by an order of magnitude with transition values comparable to flight.

*NASA, Langley Research Center, Hampton, Va.

230. *Malik, M. R.; and **Orszag, S. A.: Efficient Computation of the Stability of Three-Dimensional Compressible Boundary Layers. AIAA 14th Fluid and Plasma Dynamics Conference, Palo Alto, Calif., June 23-25, 1981, 14 pp.

AIAA-81-1277

A81-38113#

Methods for the computer analysis of the stability of three-dimensional compressible boundary layers are discussed and the user-oriented Compressible Stability Analysis (COSAL) computer code is described. The COSAL code uses a matrix finite-difference method for local eigenvalue solution when a good guess for the eigenvalue is available and is significantly more computationally efficient than the commonly used initial-

value approach. The local eigenvalue search procedure also results in eigenfunctions and, at little extra work, group velocities. A globally convergent eigenvalue procedure is also developed which may be used when no guess for the eigenvalue is available. The global problem is formulated in such a way that no unstable spurious modes appear so that the method is suitable for use in a black-box stability code. Sample stability calculations are presented for the boundary layer profiles of an LFC swept wing.

*Systems and Applied Sciences Corp., Hampton, Va.
**Mass. Institute of Technology, Cambridge, Mass.
Contracts NAS1-15604; NAS1-15894; and NAS1-16237

231. *El-Hady, N. M.; and *Verma, A. K.: Growth of Goertler Vortices in Compressible Boundary Layers Along Curved Surfaces. Paper presented at AIAA 14th Fluid and Plasma Dynamics Conference, Palo Alto, Calif., June 23-25, 1981, 15 pp.

AIAA-81-1278

The instability of the laminar compressible boundary layer flows along concave surfaces is investigated. The linearized disturbance equations for the three-dimensional, counter-rotating, longitudinal type vortices in two-dimensional boundary layers are presented in an orthogonal curvilinear system of coordinates. The basic approximation of the disturbance equations, that includes the effect of the growth of the boundary layer, is considered and solved numerically. The effect of compressibility on the critical stability limit, growth rates, and amplitude ratios of the vortices is evaluated for a range of Mach numbers from 0 to 5.

*Old Dominion University, Norfolk, Va.
Grant NSG-1645

232. *Reed, H. L.; and *Nayfeh, A. H.: Stability of Flow Over Plates with Porous Suction Strips. Paper presented at AIAA 14th Fluid and Plasma Dynamics Conference at Palo Alto, Calif., June 23-25, 1981, 15 pp.

AIAA-81-1280 A81-40049#

This paper addresses the stability of two-dimensional, incompressible boundary-layer flow over plates with suction through porous strips. The mean flow is calculated using linearized triple-deck, closed-form solutions. The stability results of the triple-deck theory are shown to be in good agreement with those of the interacting boundary layers. Then different configurations of number, spacing, and mass flow rate through such porous strips are analyzed and compared with non-similar uniform-suction stability results from the point of view of applicability to laminar flow control.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.
Grant NSG-1255

233. *Padhye, A. R.; and *Nayfeh, A. H.: Nonparallel Stability of Three-Dimensional Flows. AIAA 14th Fluid and Plasma Dynamics Conference, Palo Alto, Calif., June 23-25, 1981, 12 pp.

AIAA-81-1281 A81-39017#

The linear stability of three-dimensional incompressible, isothermal, nonparallel boundary-layer flows has been investigated. The method of multiple scales is used to derive the partial-differential equations that describe the spatial modulations of the amplitude, phase and wavenumber of a disturbance. Group velocities are used to determine the disturbance growth direction. The envelope method is used to calculate the logarithmic amplitude growth rate N. The theory is applied to the flows over a swept-back tapered wing with boundary-layer suction. Results of such analysis for the X-21 wing are discussed. It is found that the nonparallel effects for this wing are substantial.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

234. *Somers, Dan M.: Design and Experimental Results for a Natural-Laminar-Flow Airfoil for General Aviation Applications. NASA TP-1861, June 1981, 104 pp.

N81-24022#

A natural-laminar-flow airfoil for general aviation applications, the NLF(1)-0416, was designed and analyzed theoretically and verified experimentally in the Langley Low-Turbulence Pressure Tunnel. The basic objective of combining the high maximum lift of the NASA low-speed airfoils with the low cruise drag of the NACA 6-series airfoils was achieved. The safety requirement that the maximum lift coefficient not be significantly affected with transition fixed near the leading edge was also met. Comparisons of the theoretical and experimental results show excellent agreement. Comparisons with other airfoils, both laminar flow and turbulent flow, confirm the achievement of the basic objective.

*NASA, Langley Research Center, Hampton, Va.

235. *Somers, Dan M.: Design and Experimental Results for a Flapped Natural-Laminar-Flow Airfoil for General Aviation Applications. NASA TP-1865, June 1981, 122 pp.

This report is FEDD (For Early Domestic Dissemination). Available from NASA Industrial Applications Centers only to U.S. Requestors.

A flapped natural-laminar-flow airfoil for general aviation applications, the NLF(1)-0215F, has been designed and analyzed theoretically and verified experimentally in the Langley Low-Turbulence Pressure Tunnel. The basic objective of combining the high maximum lift of the NASA low-speed airfoils with the low cruise drag of

the NACA 6-series airfoils has been achieved. The safety requirement that the maximum lift coefficient not be significantly affected with transition fixed near the leading edge has also been met. Comparisons of the theoretical and experimental results show generally good agreement.

*NASA, Langley Research Center, Hampton, Va.

236. *Piatt, M.: An Experimental Investigation of a Large Delta P Settling Chamber for a Supersonic Pilot Quiet Tunnel. Final Rept. No. R-SAL-03/81-03, NASA CR-3436, June 1981, 81 pp.

N81-24112#

The mean streamwise flow distributions and turbulence levels across the chamber were measured with a hot wire anemometer downstream of a series of porous Rigimesh plates which were shown to be an effective means of reducing the chamber acoustic disturbance levels due to upstream pipe and valve systems. Tests made with various types of flow conditioners downstream of the porous plates showed that a series of screens was the most effective means of achieving the objective of a uniform mean flow distribution with reduced vorticity levels downstream of the porous components. Frequency spectra obtained across the series of screens shows that they reduce vorticity over a wide frequency range for several different initial upstream vorticity conditions. Improvements in the mechanical installation of the porous plates and damping screens and the use of porous plates with more uniform porosity should reduce the free-stream velocity fluctuations to the minimum acoustic levels of about 0.5 percent.

*Systems and Applied Sciences Corp., Hampton, Va.
Contract NAS1-16096

237. *McKinney, Marion O.; and *Scheiman, James: Evaluation of Turbulence Reduction Devices for the Langley 8-Foot Transonic Pressure Tunnel. NASA TM-81792, June 1981, 30 pp.

N81-24114#

Model tests were made of devices for reducing turbulence in the Langley 8-Foot Transonic Pressure Tunnel to permit laminar flow airfoil tests. The test model consisted of a cooler, turning vanes, and settling chamber (immediately upstream of the contraction) in which various combinations of screens and honeycomb were tested. Conventional hot wires were used to measure the axial and lateral turbulence reduction for the different turbulence reduction devices. The final configuration chosen consisted of a honeycomb followed by five screens. Results are presented herein to document this selection.

*NASA, Langley Research Center, Hampton, Va.

238. *Nayfeh, A. H.: Effect of Streamwise Vortices on Tollmien-Schlichting Waves. Journal of Fluid Mechanics, vol. 107, June 1981, pp. 441-453.

A81-39764#

The method of multiple scales is used to determine a first-order uniform expansion for the effect of counter-rotating steady streamwise vortices in growing boundary layers on oblique Tollmien-Schlichting waves. The results show that such vortices have a strong tendency to amplify oblique Tollmien-Schlichting waves having a spanwise wavelength that is twice the wavelength of the vortices. An analytical expression is derived for the growth rates of these waves. These exponential growth rates increase linearly with increasing amplitudes of the vortices. Numerical results are presented. They suggest that this mechanism may dominate the instability.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Grant NSG-1255
Also Navy supported.

239. *Pfenninger, W.: Program of Research in Laminar Flow Control in the JIAFS at NASA Langley Research Center. Status Report, 1 Jan. - 30 June 1981. NASA CR-164843, July 30, 1981, 15 pp.

N81-32121#

At high length Reynolds numbers, the performance of a low drag suction LFC airplane is essentially controlled by the induced drag and the turbulence friction drag of the nonlaminarized area. The question then arises as to how the airplane cruise lift to drag ratio $\left(\frac{L}{D}\right)_{cruise}$ increases with increasing extent of laminar flow $O_{lam.}/O_{total}$ (O = airplane wetted area). In particular, the question arises as to the airplane performance in the optimum case with all laminar flow over the airplane wetted area. Design approaches of all laminar flow LFC airplanes which optimize the airplane range $R = \eta_{OV}\left(\frac{L}{D}\right) H \ln(W_O/W_E)$ are considered.

*George Washington Univ., Wash., D.C.
Grant NsG-1585

240. *Mangiarotty, R. A.: Effect of Engine Noise on Aircraft Wing Laminar Boundary-Layer Stability. Journal of the Acoustical Society of America, vol. 70, no. 1, July 1981, pp. 98-109.

A81-41255

High-intensity acoustical disturbances can cause transition of controlled laminar flow. An

investigation was made to determine whether main propulsion engines installed on an aircraft wing would cause excessive transition of laminar to turbulent flow. A method was developed for analyzing the influence of noise on the stability of a controlled laminar boundary layer, based upon the Tollmien-Schlichting traveling wave solution of the Orr-Sommerfeld equation and some wind tunnel experimental data. It is concluded that wing-mounted, high-bypass-ratio engines with sufficient acoustic treatment for controlling turbomachinery noise would not cause excessive loss of wing laminar flow. Additional analytical and experimental work is needed, however, to improve the accuracy of engine nearfield noise prediction, and the need to improve the proposed model to account for the acoustic transfer function for predicting transition.

*The Boeing Commercial Airplane Co., Seattle, Wash.

241. *Scheiman, James; and *Brooks, J. D.: Comparison of Experimental and Theoretical Turbulence Reduction from Screens, Honeycomb, and Honeycomb-Screen Combinations. Journal of Aircraft, vol. 18, no. 8, Aug. 1981, pp. 638-643.

AIAA-80-0433R

A 1/2-scale model of a portion of the NASA Langley 8-Ft. Transonic Pressure Tunnel was used to conduct some turbulence reduction research. The experimental results are correlated with various theories. Screens alone reduce axial turbulence more than lateral turbulence, whereas honeycomb alone reduces lateral turbulence more than axial turbulence. Because of this difference, the physical mechanism for decreasing turbulence for screens and honeycomb must be completely different. Honeycomb with a downstream screen is an excellent combination for reducing turbulence.

*NASA, Langley Research Center, Hampton, Va.
(Note: See citation #265, NASA TP-1958, for a longer and more complete form of this article.)

242. *Ragab, S. A.; and *Nayfeh, A. H.: Görtler Instability. Physics of Fluids, vol. 24, no. 8, Aug. 1981, pp. 1405-1417.

A81-44527

Görtler instability for boundary-layer flows over generally curved walls is considered. The full linearized disturbance equations are obtained in an orthogonal curvilinear coordinate system. A perturbation procedure to account for second-order effects is used to determine the effects of the displacement thickness and the variation of the streamline curvature on the neutral stability of the Blasius flow. The pressure gradient in the mean flow is accounted for by solving the non-similar boundary-layer equations. Growth rates are obtained for the actual meanflow and compared with those for the Blasius flow and the Falkner-Skan flows. The results demonstrate the strong influence of the pressure gradient and the nonsimilarity of the basic flow on the stability characteristics.

*Virginia Polytechnic Institute and State University, Blacksburg, Va.
NsG-1255, Navy supported research.

243. *Scheiman, James: Considerations for the Installation of Honeycomb and Screens to Reduce Wind-Tunnel Turbulence. NASA TM-81868, Aug. 1981, 53 pp.

N81-29137#

Tests were conducted on a half-scale model representing a 0.914-m (3.0-ft.) square stream tube of the flow through the fourth corner and settling chamber of the Langley 8-Foot Transonic Pressure Tunnel. The model included the finned-tube cooler, 45° turning vanes, and the turbulence reduction screens and honeycomb, which were the subject of the tests. Hot-wire measurements of the turbulence reduction for various combinations of screens and honeycomb were made at various duct speeds. Of the four sizes of honeycomb cells tested, none were found to have a superior performance advantage. The effectiveness of screens and honeycomb in reducing turbulence is greatly affected by relatively minor physical damage; therefore, extreme care must be exercised in installing and maintaining honeycomb or screens if the turbulence reduction performance is to be maintained.

*NASA, Langley Research Center, Hampton, Va.

244. *Campbell, Richard L.: Computer Analysis of Flow Perturbations Generated by Placement of Choke Bumps in a Wind Tunnel. NASA TP-1892, Aug. 1981, 42 pp.

N81-30088#

An inviscid analytical study has been conducted to determine the upstream flow perturbations caused by placing choke bumps in a wind tunnel. A computer program based on the stream-tube curvature method was used to calculate the resulting flow fields for a nominal free-stream Mach number range of 0.6 to 0.9. The choke bump geometry was also varied to investigate the effect of bump shape on the disturbance produced. Results from the study indicate that a region of significant variation from the free-stream condition exists upstream of the throat of the tunnel. The extent of the disturbance region was, as a rule, dependent on Mach number and the geometry of the choke bump. In general, the upstream disturbance distance decreased for increasing nominal

free-stream Mach number and for decreasing length-to-height ratio of the bump. A polynomial-curve choke bump usually produced less of a disturbance than did a circular-arc bump, and going to an axisymmetric configuration (modeling choke bumps on all the tunnel walls) generally resulted in a lower disturbance than with the corresponding two-dimensional case.

*NASA, Langley Research Center, Hampton, Va.

245. *Montoya, L. C.; *Steers, L. L.; *Christopher, D.; and *Trujillo, B.: F-111 TACT Natural Laminar Flow Glove Flight Results. Presented at the 5th Annual Status Review of the NASA Aircraft Energy Efficiency (ACEE) Transport Program held at Dryden Flight Research Center, Edwards, Calif., Sept. 14-15, 1981. NASA CP-2208, Dec. 1981, pp. 11-20.

N82-71010

This report is FEDD (For Early Domestic Dissemination). Available from NASA Industrial Applications Centers only to U.S. Requestors.

The objective of the experiment was to evaluate the extent of natural laminar flow that could be achieved with consistency in a real flight environment at chord Reynolds numbers in the range of 30×10^6. The experiment consisted of 19 flights conducted on the F-111 TACT airplane having a NLF airfoil glove section. The section consisted of a supercritical airfoil providing favorable pressure gradients over extensive portions of the upper and lower surfaces of the wing. Boundary-layer measurements were obtained over a range of wing-leading-edge sweep angles at Mach numbers from 0.80 to 0.85. Data were obtained for natural transition and for a range of forced transition locations over the test airfoil.

*NASA, Dryden Flight Research Center, Edwards, Calif.

246. *Maddalon, Dal V., (Editor): Laminar Flow Control - 1981 Research and Technology Studies. NASA CP-2218, March 1982, 135 pp. Proceedings of a Conference held at Dryden Flight Research Center, Edwards, Calif., Sept. 17-18, 1981.

N82-20149

This Conference Publication contains papers presented at the Oral Status Review of the NASA Aircraft Energy Efficiency (ACEE) Laminar Flow Control (LFC) Program held at the Dryden Flight Research Center in Edwards, California on September 17-18, 1981. Laminar flow control technology has undergone tremendous progress in recent years as focused research efforts in structures, materials, aerodynamics, and systems have begun to pay off. This work, conducted under the NASA Aircraft Energy Efficiency Laminar Flow Control Program, was begun in 1976. The objective is to demonstrate practical, reliable, LFC technology for application to commercial transport aircraft. Earlier work has shown that an LFC system greatly reduces both aircraft fuel use and operating cost. Ongoing research studies described in these papers compliment the major strides being made by industry airframe manufacturers (under NASA sponsorship) in LFC structures and materials and in the demonstration of flight systems. Research and technology developments discussed herein include, for example, fundamental studies of improved analytical techniques in boundary-layer stability prediction and a greatly expanded experimental data base characterized by detailed transonic wind-tunnel measurements on supercritical airfoils.

*NASA, Langley Research Center, Hampton, Va.

247. Harvey, W. D.; and Pride, J. D., Jr.: The NASA Laminar Flow Control Airfoil Experiment. Presented at a Conference held at Dryden Flight Research Center, Sept. 17-18, 1981. Pages 1-42 in Laminar Flow Control, NASA CP-2218, March 1982.

N82-20150#

The design and construction of an advanced swept supercritical airfoil for commercial aircraft to be tested in a transonic wind tunnel is described. The swept LFC airfoil was designed for a given thickness ratio and lift coefficient, with emphasis placed on high critical Mach number with shock-free flow. It is compatible with satisfactory low speed and buffeting characteristics and minimizing the suction laminarization. Further emphasis was placed on achieving shock-free flow over a wide range of off-design conditions including trailing edge flap control. The requirements and design of the suction system and modifications to the Langley 8-Foot Transonic Pressure Tunnel is briefly described. Contouring of nonporous test section walls for free air simulation and flow quality improvements is included.

248. *Applin, Zachary T.: Status of NASA Advanced LFC Airfoil High-Lift Study. Presented at a Conference held at Dryden Flight Research Center, Edwards, Calif., Sept. 17-18, 1981. Pages 43-62 in Laminar Flow Control, NASA CP-2218, March 1982.

N82-20151#

The design of a high-lift system for the NASA advanced LFC airfoil designed by Pfenninger is described. The high-lift system consists of both leading- and trailing-edge flaps. A 3-meter semi-span, 1-meter chord wing model using the above airfoil and high-lift system is under construction and will be tested in the NASA Langley 4- by 7-Meter Tunnel. This model will have two separate full-span leading-edge flaps (0.10c and 0.12c) and one full-span trailing-edge flap (0.25c). The performance of this high-lift system was predicted by the NASA two-dimensional viscous multicomponent airfoil program. This program was also used to predict the characteris-

tics of the LFC airfoils developed by the Douglas Aircraft Company and Lockheed-Georgia Aircraft Company.

*NASA, Langley Research Center, Hampton, Va.

249. *Reynolds, G. A.; *Saric, W. S.; *Reed, H. L.; and *Nayfeh, A. H.: Stability of Boundary Layers With Porous Suction Strips: Experiment and Theory. Presented at a Conference held at Dryden Flight Research Center, Edwards, Calif., Sept. 17-18, 1981. Pages 63-74 in Laminar Flow Control, NASA CP-2218, March 1982.

N82-20152#

Low-turbulence tunnel experiments on the stability and transition of 2-D boundary layers on flat plates with and without suction are described. A number of general suction cases are discussed. Test results showed that the maximum stabilization occurred when the suction was moved toward the Branch I neutral point. An analytical study of the stability of two-dimensional, incompressible boundary-layer flows over plates with suction through porous strips was performed. The mean flow was calculated using linearized triple-deck, closed-form solutions. The stability results of the triple-deck theory are shown to be in good agreement with those of the interacting boundary layers. An analytical optimization scheme for the suction configuration was developed. Numerical calculations were performed corresponding to the experimental configurations. In each case, the theory correctly predicts the experimental results.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
ONR Contract N00014-75-C-0381
Grants NSG-1608 and NSG-1255

250. Davis, Richard E.: Probability of Laminar Flow Loss Because of Ice Crystal Encounters. Presented at a Conference held at Dryden Flight Research Center, Sept. 17-18, 1981. Pages 75-94 in Laminar Flow Control, NASA CP-2218, March 1982.

N82-20153#

A method for combining the cloud detector observation results from the Global Atmospheric Sampling Program (GASP) with Knollenberg probe observations of cloud particle concentration from other programs to derive estimates of the ambient concentration of particles larger than a given size was developed. The method was applied to estimate the probability of encountering particle concentrations which would degrade the performance of laminar flow-control (LFC) aircraft. It is concluded that LF loss should occur only about one percent of the time in clear air and that flight within clouds should always result in a significant loss of LF, with 90 percent LF loss occurring about one percent of the time. Preliminary estimates of cloud encounter probability are presented for four airline routes, and conclusions are presented as to the best altitudes for cloud avoidance in extratropical and tropical latitudes.

251. *Wilson, V. E.: SPF/DB Titanium Concepts for Structural Efficiency. Presented at a Conference held at Dryden Flight Research Center, Edwards, Calif., Sept. 17-18, 1981. Pages 95-110 in Laminar Flow Control, NASA CP-2218, March 1982.

N82-20154#

Illustrations for a presentation demonstrating superplastic forming-diffusion bonding titanium porous panels are presented. Fabrication phases, sandwich panels, load bearing qualities, microstructure, and panel surface after finishing are illustrated.

*Rockwell International Corp., Los Angeles, Calif.

252. *Williams, Neil R.: SPF/DB Titanium LFC Porous Panel Concept. Presented at a Conference held at Dryden Flight Research Center, Edwards, Calif., Sept. 17-18, 1981. Pages 111-138 in Laminar Flow Control, NASA CP-2218, March 1982.

N82-20155#

Illustrations for a presentation on superplastic forming/diffusion bonding titanium design concepts are presented. Sandwich skin panels with hat section, semicircular corrugation, sine wave, and truss cores are shown. The fabrication of wing panels is illustrated, and applications to the design of advanced variable sweep bombers summarized.

*McDonnell-Douglas Corp., Long Beach, Calif.

253. *Malik, M. R.; ** Wilkinson, S. P.; and ***Orszag, S. A.: Instability and Transition on a Rotating Disk. AIAA Journal, vol. 19, Sept. 1981, pp. 1131-1138.

A81-44443#

The stability of three-dimensional rotating disk flow is investigated, including the effects of Coriolis forces and streamline curvature. The numerical results show that the critical Reynolds number for establishment of stationary vortex flow is 287. These vortices spiral outward at an angle of about 11.2 deg, and transition to turbulence occurs when their total amplification is about e^{11}. New experimental results are also reported on the spatial growth rates of the stationary vortices. It is shown that the analysis gives growth rates that compare much better with the experimental results than do results obtained using the Orr-Sommerfeld equation. The experimental results tend to support the numerical prediction that the number of stationary vortices

varies directly with the Reynolds number. The calculations also indicate the existence of weakly unstable propagating (type II) modes at low Reynolds numbers (Critical Reynolds Number being approximately equal to 49).

*Systems and Applied Science Corp., Hampton, Va.
**NASA, Langley Research Center, Hampton, Va.
***Mass. Institute of Technology, Cambridge, Mass.
Contracts NAS1-15604 and NAS1-15894

254. *El-Hady, Nabil M.; and *Goglia, G. L.: Application of Stability Theory of Laminar Flow Control. Final Report, 1 Sept. 1980-1 August 1981. NASA CR-164709, Sept. 1981, 68 pp.

N81-30387#

Four publications resulted from work performed during the report period September 1, 1980 to August 1, 1981. Topics include: a computer program for calculating the linear incompressible or compressible stability characteristics of the laminar boundary layer on swept wings; the growth of Goertler vortices in compressible boundary layers along curved surfaces; the effect of boundary layer growth on the stability of compressible flows; and the effect of compressibility, suction, and cooling on the centrifugal instability of boundary layer flows along curved walls. For individual titles, see N81-30388 through N81-30389.

*Old Dominion Univ., Norfolk, Va.
Grant NsG-1645

255. *El-Hady, Nabil M.: HADY-1, A FORTRAN Program for the Compressible Stability Analysis of Three-Dimensional Boundary Layers. In "Application of Stability Theory of Laminar Flow Control," (N81-30387), Sept. 1981, 22 pp.

N81-30388#

A computer program, HADY-1, is described for calculating the linear incompressible or compressible stability characteristics of the laminar boundary layer on swept and tapered wings. The eigenvalue problem and its adjoint arising from the linearized disturbance equations with the appropriate boundary conditions are solved numerically using a combination of the Newton-Raphson iterative scheme and a variable step size integrator based on the Runge-Kutta-Fehlburg fifth-order formulas. The integrator is used in conjunction with a modified Gram-Schmidt orthonormalization procedure.

*Old Dominion Univ., Norfolk, Va.
Grant NSG-1645

256. *El-Hady, Nabil M.: The Effect of Boundary Layer Growth on the Stability of Compressible Flows. In: "Application of Stability Theory of Laminar Flow Control," (N81-30387#) Sept. 1981, 10 pp.

N81-30389#

The method of multiple scales is used to describe a formally correct method based on the nonparallel linear stability theory that examines the two and three dimensional stability of compressible boundary layer flows. The method is applied to the supersonic flat plate boundary layer at Mach number 4.5. The theoretical growth rates are in good agreement with the experimental results of Kendall. The method is also applied to the infinite span swept wing transonic boundary layer with suction to evaluate the effect of the nonparallel flow on the development of crossflow disturbances.

*Old Dominion Univ., Norfolk, Va.
Grant NSG-1645

257. *El-Hady, Nabil M.: HADY-1, A FORTRAN Program for the Compressible Stability Analysis of Three-Dimensional Boundary Layers, Final Rept. NASA CR-3467, Sept. 1981, 117 pp.

N82-12388#

A computer program HADY-1, for calculating the linear incompressible or compressible stability characteristics of the laminar boundary layer on swept and tapered wings is described. The eigenvalue problem and its adjoint arising from the linearized disturbance equations with the appropriate boundary conditions are solved numerically using a combination of the Newton-Raphson iterative scheme and a variable step size integrator based on the Runge-Kutta-Fehlburg fifth-order formulas. The integrator is used in conjunction with a modified Gram-Schmidt orthonormalization procedure. The computer program HADY-1 calculates the growth rates of crossflow or streamwise Tollmien-Schlichting instabilities. It also calculates the group velocities of these disturbances. It is restricted to parallel stability calculations, where the boundary layer (meanflow) is assumed to be parallel. The meanflow solution is an input to the program.

*Old Dominion Univ., Norfolk, Va.
Grant NSG-1645

258. *El-Hady, Nabil M.: On the Effect of Boundary Layer Growth on the Stability of Compressible Flows. NASA CR-3474, Oct. 1981, 45 pp.

N81-33426#

The method of multiple scales is used to describe a formally correct method based on the nonparallel linear stability theory, that examines the two- and three-dimensional stability of compressible boundary-layer flows. The method is applied to the supersonic flat plate boundary layer at Mach number 4.5. The theoretical growth rates are in good agreement with the experimental results of Kendall. The method is also applied to the infinite span swept wing transonic boundary

layer with suction to evaluate the effect of the nonparallel flow on the development of cross-flow disturbances.

*Old Dominion Univ., Norfolk, Va.
Grant NSG-1645

259. *Riley, N.: Non-Uniform Slot Injection into a Laminar Boundary Layer. Journal of Engineering Mathematics, vol. 15, Oct. 1981, pp. 299-314.

A82-11375

Slot injection into a laminar boundary layer in both supersonic and subsonic flow is treated. It is noted that the blowing rates are sufficiently large to provoke an interaction between the boundary layer and outer inviscid flow and that this interaction is accounted for by triple-deck theory. The nonuniformity of the blowing velocity models the channel flow from which the injection takes place.

*East Anglia, University, Norwich, England

260. *Bower, Robert E.: Progress in Aeronautical Research and Technology Applicable to Civil Air Transports. International Meeting on Transportation Research: "State of the Art - Perspectives and International Cooperation," held at Amalfi, Italy, Nov. 11-14, 1981, 51 pp.

A82-13974#

Recent progress in the aeronautical research and technology program being conducted by the United States National Aeronautics and Space Administration is discussed. Emphasis is on computational capability, new testing facilities, drag reduction, turbofan and turboprop propulsion, noise, composite materials, active controls, integrated avionics, cockpit displays, flight management, and operating problems. It is shown that this technology is significantly impacting the efficiency of the new civil air transports. The excitement of emerging research promises even greater benefits to future aircaft developments.

*NASA, Langley Research Center, Hampton, Va.

261. *Holmes, Bruce J.; *Coy, Paul F.; *Yip, Long P.; *Brown, Philip W.; and **Obara, Clifford J.: Natural Laminar Flow Data from Full Scale Flight and Wind Tunnel Experiments. Presented at AIAA 8th Annual General Aviation Technology Fest, Wichita, Kansas, Nov. 13-14, 1981, 21 pp.

Results are presented for laminar flow experiments and discussed in the context of related developments which may lead to the realization of practical application of NLF for high performance general aviation airplanes. Recent full-scale wind-tunnel and flight experiments have confirmed the existence of significant regions of NLF on several powered aircraft. These findings are significant in that the airfoils exhibited the maximum theoretical extents of laminar flow at Reynolds numbers equivalent to current high performance business airplane operating envelopes. None of the airfoil surfaces received any special preparation prior to flight testing. No premature transition due to surface imperfections was found on any of the airfoils tested. In addition, no evidence of crossflow instability was seen on any of the wings tested with leading-edge sweep angles as high as 27°.

The boundary-layer transition measurement methods used included sublimating chemicals and acoustic detection. A simplified technique for using sublimating chemicals without wing coverings (for protection against premature transition) was demonstrated using acenaphtene.

These recent boundary-layer experiment results clearly show that for general aviation flight Reynolds numbers, the necessary airfoil surface smoothness conditions for NLF can be provided by use of composite construction methods. Thus, the most significant remaining impediment to laminar flow applications is protection from ice and insect contamination.

*NASA, Langley Research Center, Hampton, Va.
**George Washington Univ., Langley Research Center, Hampton, Va.

262. *Smith, A. M. O.: The Boundary Layer and I. AIAA Journal, vol. 19, Nov. 1981, pp. 1377-1385.

A82-10979#

The author gives an account of his contributions to boundary layer theory since 1945, including such developments as the DESA-2 laminar-flow airfoil, the amplification ratio method, finite-difference boundary layer calculation, and the application of increasingly powerful computer codes to the solution of boundary layer aerodynamics problems. Attention is also given to the author's extension of laminar boundary analysis methods to turbulent flow structures. Other methods considered include the Goertler problem, the Falkner-Skan partial differential equation, the Galerkin and Picard methods, the Gram-Schmidt orthogonalization procedure, and Prandtl's mixing length relation.

*San Marino, Calif.

263. *Dagenhart, J. Ray: Amplified Crossflow Disturbances in the Laminar Boundary Layer on Swept Wings with Suction. NASA TP-1902, Nov. 1981, 88 pp.

N82-11391#

Solution charts of the Orr-Sommerfeld equation for stationary crossflow disturbances are presented for 10 typical velocity profiles on a swept laminar-flow-control (LFC) wing. The crit-

ical crossflow Reynolds number is shown to be a function of a boundary-layer shape factor. Amplification rates for crossflow disturbances are shown to be proportional to the maximum crossflow velocity. A computer stability program called MARIA, employing the amplification rate data for the 10 crossflow velocity profiles, is constructed. This code is shown to adequately approximate more involved computer stability codes using less than 2 percent as much computer time while retaining the essential physical disturbance growth model.

*NASA, Langley Research Center, Hampton, Va.

264. *Carmichael, B. H.: Low Reynolds Number Airfoil Survey, Vol. I, Final Rept. NASA CR-165803, vol. I, Nov. 1981, 106 pp.

N82-14059#

The differences in flow behavior on two dimensional airfoils in the critical chordlength Reynolds number compared with lower and higher Reynolds number are discussed. The large laminar separation bubble is discussed in view of its important influence on critical Reynolds number airfoil behavior. The shortcomings of application of theoretical boundary layer computations which are successful at higher Reynolds numbers to the critical regime are discussed. The large variation in experimental aerodynamic characteristic measurement due to small changes in ambient turbulence, vibration, and sound level is illustrated. The difficulties in obtaining accurate detailed measurements in free flight and dramatic performance improvements at critical Reynolds number, achieved with various types of boundary layer tripping devices are discussed.

*Low Energy Transport Systems, Capistrano Beach, Calif.
NASA L-4059B

265. *Scheiman, James: Comparison of Experimental and Theoretical Turbulence Reduction Characteristics for Screens, Honeycomb, and Honeycomb-Screen Combinations. NASA TP-1958, Dec. 1981, 58 pp.

N82-14055#

A half-scale model of a portion of the Langley 8-Foot Transonic Pressure Tunnel was used to conduct some turbulence reduction research using screens, honeycomb, and combinations thereof. The experimental results are compared with various theories. Screens alone reduce axial turbulence more than lateral turbulence; whereas, honeycomb alone reduces lateral turbulence more than axial turbulence. Because of this difference, the physical mechanism for decreasing turbulence for screens and honeycomb must be completely different. Honeycomb with a downstream screen is an excellent combination for reducing turbulence.

*NASA, Langley Research Center, Hampton, Va.

266. *Nastrom, Gregory D.; **Holdeman, James D.; and ***Davis, Richard E.: Cloud-Encounter and Particle-Concentration Variabilities from GASP Data. NASA TP-1886, Dec. 1981, 244 pp.

N82-15677#

Summary statistics, tabulations, and variability studies are presented for cloud-encounter and particle-concentration data taken as part of the National Aeronautics and Space Administration (NASA) Global Atmospheric Sampling Program (GASP). Cloud encounter was experienced in about 15 percent of the data samples; however, the percentage varies with season, latitude, and altitude (particularly distance from the tropopause). In agreement with classical storm models, the data show more clouds in the upper troposphere in anticyclones than in cyclones. The concentration of particles with a diameter greater than 3 μm also varies with time and location, depending primarily on the horizontal extent of cloudiness. Some examples of the application of the statistical data to the estimation of the frequency of cloud encounter and laminar-flow loss to be expected on long-range airline routes are also presented.

*Control Data Corp., Minneapolis, Minnesota
**NASA, Lewis Research Center, Cleveland, Ohio
***NASA, Langley Research Center, Hampton, Va.
(Note: This is a comprehensive development of: (1) AIAA-81-0308, Jan. 12-15, 1981 and (2) Journal of Aircraft version submitted July, 1981.)

267. *Reed, Helen L.: The Tollmein-Schlichting Instability of Laminar Viscous Flows. Ph.D. Thesis, Virginia Polytechnic Institute and State Univ., Dec. 1981, 210 pp. (Available from University Microfilms.)

The Tollmien-Schlichting instability is analyzed for a variety of laminar viscous flows. These include two-dimensional incompressible, axisymmetric incompressible, and three-dimensional compressible flows with suction. For the incompressible flows, a linear optimization scheme is developed to determine placement of and flow rate through suction strips. The important conclusion is that suction should be concentrated near the Branch I neutral stability point. The scheme is found to accurately predict the experimental results in the two-dimensional case. For the

compressible flows, a method for following one specific wave to ascertain the characteristics of the most unstable disturbance is presented.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
NASA Grant NSG-1255 and ONR N00014-75-C-0381
Consultants to Westinghouse Electric and Naval Underwater Sea Center.

268. Althaus, Dieter; and Wortmann, F. X.: Stuttgarter Profilkatalog I: messergebnisse aus dem Laminarwindkanal des Instituts fur Aerodynamik und Gasdynamik der Universitat Stuttgart - 1981. (Experimental results from the laminar wind tunnel.) New edition. Vieweg, Braunschweig, 1981, 320 pp. (Book).

QA929.A42 (1981) V81-22050 (1981)

Copies of this catalog must be ordered directly from the Universität Stuttgart. (NASA-LaRC library has an English edition of this publication.)

269. *Aircraft Energy Efficiency. Overview: NASA-Facts 96/9-80; NASA TM-80454, 1981, 7 pp.

N81-28083#

Six advanced technology development projects that could cut fuel consumption of future civil air transports by as much as 50 percent are highlighted. These include improved engine components; better engine design; thin short blades for turboprop aircraft; using composite primary structures for weight reduction; the use of supercritical wings, higher aspect ratio, and winglets for improved aerodynamics; active controls; and laminar flow control. The time span of each of the six efforts and NASA's expected expenditures are also discussed.

*NASA, Washington, D.C.

270. *Kong, F. Y.; and *Schetz, J. A.: Turbulent Boundary Layer Over Porous Surfaces with Different Surface Geometries. AIAA 20th Aerospace Sciences Meeting, Orlando, Florida, Jan. 11-14, 1982, 11 pp.

AIAA-82-0030 A82-17742#

The turbulent boundary layer over three porous walls with different surface geometries was studied in order to investigate the individual influences of porosity and small roughness, as well as their combined effects, on turbulent boundary layer behavior. The tests were conducted in a 2m × 2m tunnel on a large axisymmetric model at speeds corresponding to Re(L) = 5,000,000 - 6,000,000. The development of the turbulent boundary layer was compared for that of sintered metal, bonded screening, and perforated sheet and then to that for the flow over a solid smooth wall and a solid, sand-roughened wall. The comparisons reveal that the effect of porosity is to shift the logarithmic region of the wall law down by a certain amount from the solid wall results and to increase the skin friction values by about 30 - 40%. The downward shift of the logarithmic region of the wall law and the increase of the skin friction value by the combined effects of small roughness and porosity are found to be roughly the sum of their individual effects.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
NASA-supported research.

271. *Reynolds, G. A.: Experiments on the Stability of the Flat-Plate with Suction. Ph.D. Thesis, Virginia Polytechnic Institute and State Univ., Jan. 1982, 157 pp. (Available from University Microfilms.)

These experiments consider the effects of suction in stabilizing the laminar boundary layer with respect to Tollmien-Schlichting wave growth. Two-dimensional waves are introduced into the boundary layer using a vibrating ribbon and suction is applied at the surface of the model via two Dynapore porous panels. Suction is applied either in a spatially continuous fashion or through discrete spanwise strips. Detailed mean flow and disturbance amplitude measurements indicate that discrete suction can be as effective as continuous suction and that suction is more effective when placed forward on the model and not in the region of maximum disturbance growth rate.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Grant NSG-1608

272. *Biringen,. Sedat: Laminar Flow Transition: A Large-Eddy Simulation Approach. NASA CR-3518, Feb. 1982, NEAR-TR-251, 33 pp.

N82-19499#

A vectorized, semi-implicit code is developed for the solution of the time-dependent, three-dimensional equations of motion in plane Poiseuille flow by the large-eddy simulation technique. The code is tested by comparing results with those obtained from the solutions of the Orr-Sommerfeld equation. Comparisons indicate that finite-differences employed along the cross-stream direction act as an implicit filter. This removes

the necessity of explicit filtering along this direction (where a nonhomogeneous mesh is used) for the simulation of laminar flow transition into turbulence in which small scale turbulence will be accounted for by a subgrid scale turbulence model.

*Neilsen Engineering & Research, Inc., Mountain View, Calif.
Contract NAS1-16289

273. *Harvey, W. D.; and *Pride, J. D., Jr.: The NASA Langley Laminar Flow Control Airfoil Experiment. Presented at the AIAA 12th Aerodynamic Testing Conference, Williamsburg, Va., March 21-24, 1982, 25 pp.

AIAA-82-0567

A large chord swept supercritical laminar flow control airfoil has been designed, constructed, and soon will be tested as a part of NASA-Langley's ongoing research program to significantly reduce drag and increase aircraft efficiency. This experiment is aimed at validating prediction techniques and establishing a technology base for future transport designs. Unique features include a high design Mach number and shock-free flow, as well as the minimization of the laminarization suction through choice of airfoil geometry and pressure distribution. Success of the experiment requires transonic tunnel flow of excellent quality which simulates that in free air about an infinite yawed model. Modifications made to the NASA Langley/8-Ft. Transonic Pressure Tunnel to meet these requirements are discussed.

*NASA, Langley Research Center, Hampton, Va.

274. *Newman, Perry A.; *Anderson, E. Clay; and *Peterson, John B., Jr.: Numerical Design of the Contoured Wind-Tunnel Liner for the NASA Swept-Wing LFC Test. Presented at the AIAA 12th Aerodynamic Testing Conference, Williamsburg, Va., March 21-24, 1982, 12 pp.

AIAA-82-0568 A82-24656#

A contoured, nonporous, wind-tunnel liner has been designed in order to simulate a free-flight, infinite yawed-wing, transonic-flow condition about a large-chord supercritical-section, laminar-flow-control (LFC), swept-wing test panel. The numerical procedure developed for this aerodynamic liner design is based upon the simple idea of stream-lining and incorporates several existing transonic and boundary-layer analysis codes. A summary of the entire procedure is presented to indicate: What was done and why, the sequence of steps, and the overall data flow. The liner is being installed in the NASA Langley 8-Foot Transonic Pressure Tunnel (TPT). Test results indicating the aerodynamic performance of the liner are not yet available; thus, the liner design results given here are examples of the calculated requirements and the hardware implementation.

*NASA, Langley Research Center, Hampton, Va.

275. *Dagenhart, J. R.; and *Stack, J. P.: Boundary Layer Transition Detection Using Flush-Mounted Hot-Film Gages and Semiconducter Dynamic Pressure Transducers. Presented at the AIAA 12th Aerodynamic Testing Conference, Williamsburg, Va., March 21-24, 1982.

AIAA-82-0593

Flush-mounted hot-film gages and semiconducter dynamic pressure transducers (microphones) are compared as boundary layer transition detection devices. The films and microphones are flush-mounted on the side wall of a small, low-speed, open-circuit wind tunnel. The variation of the dynamic and root-mean-square voltage signals for the two detector types are compared over the range from laminar through transitional to fully turbulent flow. The hot-film signals change distinctly as the Reynolds number is increased. In contrast, the microphone signals change little in character over the Reynolds number range. These observations indicate that the hot-film gage is the superior transition detection device.

*NASA, Langley Research Center, Hampton, Va.

276. *Floryan, J. M.; and *Saric, W. S.: Stability of Görtler Vortices in Boundary Layers. AIAA 12th Fluid and Plasma Dynamics Conference, Williamsburg, Va., July 23-25, 1979, 18 pp. AIAA Journal, vol. 20, March 1982, pp. 316-324.

AIAA-79-1497R A82-23830#

A formal analysis of Görtler-type instability is presented. The boundary-layer and disturbance equations are formulated in a general, orthogonal, curvilinear system of coordinates constructed from the inviscid flow over a curved surface. Effects of curvature on the boundary-layer flow are analyzed. The basic approximation for the disturbance equations is presented and solved numerically. Previous analyses are discussed and compared with our analysis. It is shown that the general system of coordinates developed in this analysis and the correct order-of-magnitude analysis of the disturbance velocities with two velocity scales leads to a rational foundation for future work in Görtler vortices.

*Virginia Polytechnic and State Univ., Blacksburg, Va.
Grant NsG-1255

277. *Nastrom, G. D.; **Holdeman, J. D.; and ***Davis, R. E.: Cloud Encounter and Particle Number Density Variabilities from GASP Data. Journal of Aircraft, vol. 19, April, 1982, pp. 272-277.

AIAA-81-0308R

Summary statistics and variability studies are presented for cloud-encounter and particle number density data taken as part of the NASA Global Atmospheric Sampling Program (GASP) aboard

commercial Boeing 747 airliners. On average, cloud encounter is shown on about 15% of the 52,164 data samples available, but this value varies with season, latitude, synoptic weather situation, and distance from the tropopause. The number density of particles (diameter greater than 3μm) also varies with time and location, and depends on the horizontal extent of cloudiness.

*Control Data Corp., Minneapolis, Minn.
**NASA, Lewis Research Center, Cleveland, Ohio
***NASA, Langley Research Center, Hampton, Va.
(Note: See #217 in this bibliography for the AIAA paper, AIAA Aerospace Sciences Meeting, St. Louis, Mo., Jan. 12-15, 1981.)

278. *Campbell, Richard L.: Effect of Nacelles on Aerodynamic Characteristics of an Executive-Jet Model with Simulated, Partial-Chord, Laminar-Flow-Control Wing Glove. NASA TM-83271, April 1982, 103 pp.

N82-22217#

Tests were conducted in the Langley High-Speed 7- by 10-Foot Tunnel using a 1/10-scale model of an executive jet to examine the effects of the nacelles on the wing pressures and model longitudinal aerodynamic characteristics. For the present investigation, each wing panel was modified with a simulated, partial-chord, laminar-flow-control glove. Horizontal-tail effects were also briefly examined. The tests covered a range of Mach numbers from 0.40 to 0.82 and lift coefficients from 0.20 to 0.55. Oil-flow photographs of the wing at selected conditions are included.

*NASA, Langley Research Center, Hampton, Va.

279. Harvey, W. D.: NASA Supercritical Laminar Flow Control Airfoil Experiment. Energy Conservation in Air Transports Meeting, Toronto, Canada, May 4-6, 1982, 47 pp, 34 figures, 1 table, and 45 references.

A large chord swept supercritical laminar flow control airfoil has been designed, constructed, and soon will be tested as a part of NASA-Langley's ongoing research program to significantly reduce drag and increase aircraft efficiency. This experiment is aimed at validating prediction techniques and establishing a technology base for future transport designs. Unique features included a high design Mach number and shock-free flow as well as the minimization of the laminarization suction through choice of airfoil geometry and pressure distribution. Success of the experiment requires transonic tunnel flow of excellent quality which simulates that in free air about an infinite yawed model. Modifications made to the NASA Langley/8-Ft. Transonic Pressure Tunnel to meet these requirements are discussed.

*NASA, Langley Research Center, Hampton, Va.

280. *Holmes, Bruce J.; and **Obara, Clifford, J.: Observations and Implications of Natural Laminar Flow on Practical Airplane Surfaces. 13th Congress of the ICAS/AIAA Aircraft Systems and Technology Meeting, Aug. 22-27, 1982, Seattle, Wash.

ICAS-82-511

Recent flight experiment observations have recorded extensive regions of natural laminar flow (NLF) boundary layers in the favorable pressure gradient regions on several smooth, production-quality airframes. These observations have resulted in a new appreciation of the operational feasibility for obtaining NLF on certain modern practical airplane surfaces. The flight experiments were conducted on eight different airplanes, including propeller- and turbojet-powered configurations and airframes constructed of aluminum or composites. The experiments were conducted on surfaces which received (with two noted exceptions) no special preparation of contours or surface waviness for NLF considerations. Experimentally observed laminar flow transition Reynolds numbers ranged between 1 and 5 million on the propeller-driven airplanes and exceeded 11 million on the business jet tested.

The summarized results of these experiments include comparisons between measured and empirically predicted allowable surface waviness, comparison of flight-measured wing profile drag with tunnel data, comparisons of fixed and free transition airfoil and airplane aerodynamics, and comparisons between observed sweep effects on laminar flow and an empirical spanwise contamination criterion. Also discussed are the observations of laminar flow in the propeller slipstreams of two airplanes, and an example of insect debris contamination on an NLF wing. Several implications of these observations are also discussed, including the necessity for both fixed and free transition flight testing on airplanes with surfaces smooth enough for laminar flow.

*NASA, Langley Research Center, Hampton, Va.
**Kentron International, Hampton, Va.

281. *Petersen, Richard H.; and *Maddalon, Dal V.: NASA Research on Viscous Drag Reduction. 13th Congress of the International Council of the Aeronautical Sciences (ICAS)/AIAA Aircraft Systems and Technology Meeting, Seattle, Wash., Aug. 22-27, 1982, 11 pp.

ICAS-82-514 Also see NASA TM-84518

Current NASA research points toward exciting opportunities for large reductions in viscous drag. Research is underway on natural laminar flow, laminar flow control by suction, and turbulent drag reduction. Preliminary results suggest that a significant amount of natural laminar flow can be achieved on small, straight-wing airplanes. On larger, swept-wing aircraft, laminar flow con-

trol by distributed suction is expected to result in significant fuel savings. The area over which laminar flow control is applied depends on tradeoffs involving structural complexity, maintenance, and cost. Several methods of reducing turbulent skin friction by altering the turbulence structure itself have shown promise in exploratory testing. This paper reviews the status of these technologies and indicates the benefits of applying them to future aircraft.

*NASA, Langley Research Center, Hampton, Va.

282. *Braslow, Albert L.: Laminar Flow. McGraw-Hill Encyclopedia Yearbook of Science and Technology, 1982-1983, pp. 272-275, Sept. 1982.

The increase in cost of petroleum fuels in the past several years, greater than the general inflation of prices, has raised the percentage of aircraft operating expense due to fuel to the point where fuel efficiency is the key design goal for future derivative and new aircraft. NASA and the aircraft industry have identified technologies that can significantly reduce aircraft fuel consumption in coming years and are actively pursuing research and technology development programs. One of these technologies is the attainment of extensive regions of laminar air flow over aircraft surfaces. Although this offers the greatest potential for fuel conservation of any single new technology, it involves the greatest challenges in the areas of aircraft manufacture, maintenance, and operational procedures required to provide acceptable reliability at reasonable cost. This article discusses the phenomenon of transition from laminar to turbulent flow and what has been learned about its prevention.

*NASA, Langley Research Center, Hampton, Va. (retired)

283. Krishnaswamy, R.; and Nath, G.: A Parametric Differential Version with Finite-Difference Scheme Applicable to a Class of Problems in Boundary Layer Flow with Massive Blowing. Computers and Fluids, vol. 10, no. 1, 1982, pp. 1-6.

A numerical procedure, based on the parametric differentiation and implicit finite difference scheme, has been developed for a class of problems in the boundary-layer theory for saddle-point regions. Here, the results are presented for the case of a three-dimensional stagnation-point flow with massive blowing. The method compares very well with other methods for particular cases (zero or small mass blowing). Results emphasize that the present numerical procedure is well suited for the solution of saddle-point flows with massive blowing, which could not be solved by other methods.

284. *Preliminary Design Dept., Boeing Commercial Airplane Co. (BCAC): Hybrid Laminar Flow Control Study, Final Technical Rept. Boeing Rept. no. D6-49359; also NASA CR-165930, 1982, 201 pp.

The hybrid laminar flow control (HLFC) concept was examined in which leading-edge suction is used in conjunction with wing pressure distribution tailoring to postpone boundary layer transition and reduce friction drag. A parametric study was conducted to determine airfoil design characteristics required for laminar flow control (LFC). The aerodynamic design of an HLFC wing for a 178-passenger commercial turbofan transport was developed, and a drag estimate was made. Systems changes required to install HLFC were defined, and weights and fuel economy were estimated. The potential for 9% fuel reduction for a 3926-km (2120-nmi) mission was identified.

*Boeing Commercial Airplane Co., Seattle, Wash. Contract NAS1-15325

285. *Ecklund, R. C.; and *Williams, N. R.: Laminar Flow Control SPF/DB Feasibility Demonstration, Final Report. NASA CR-165818, 1982, 50 pp.

N82-21532#

The feasibility of applying superplastic forming/diffusion bonding (SPF/DB) technology to laminar flow control (LFC) system concepts was demonstrated. Procedures were developed to produce smooth, flat titanium panels, using thin 0.016 inch sheets, meeting LFC surface smoothness requirements. Two large panels 28 x 28 inches were fabricated as final demonstration articles. The first was flat on the top and bottom sides demonstrating the capability of the tooling and the forming and diffusion bonding procedures to produce flat, defect free surfaces. The second panel was configurated for LFC porous panel treatment by forming channels with dimpled projections on the top side. The projections were machined away leaving holes extending into the panel. A perforated titanium sheet was adhesively bonded over this surface to complete the LFC demonstration panel. The final surface was considered flat enough to meet LFC requirements for a jet transport aircraft in cruising flight.

*Douglas Aircraft Co., Long Beach, Calif.

286. *McQuilkin, Fred T.: Feasibility of SPF/DB Titanium Sandwich for LFC Wings. NASA CR-165929, 1982.

The feasibility of fabricating SFP/DB titanium structures of sufficient smoothness to be used for laminar flow wing surfaces has been demonstrated. Two methods of fabricating panels which meet the surface smoothness criteria have been demonstrated. The first consists of superplastically forming/diffusion bonding a panel using steel dies, and then machining the surface to the required flatness and finish after forming. This approach, however, has been estimated to be more costly than the second approach, in which the panel is formed against ceramic platens which produce the desired surface smoothness without subsequent finishing. Acceptable surface

quality as well as feasibility of the laminar flow control (LFC) surface design, in which separate strips incorporating the boundary layer bleed provisions are bonded into slots on the surface, has also been demonstrated. Recommendations for future work are presented, including continued study on additional smoothness concerns, scale-up to larger wing panels, fabrication of separate LFC strips, and the application of the technology to military aircraft.

*Rockwell International, North American Aircraft Operations, Los Angeles, Calif.
Contract NAS1-16236

The following citations are included for the sake of completeness. Abstracts for some were not available and some were identified too late to be included in chronological order.

287. *Saric, W. S.; and *Reynolds, G. A.: Experiments on the Stability and Transition of Two-Dimensional and Three-Dimensional Boundary Layers With Suction. Final Rept., NASA CR-157256, July 1979, 71 pp.

N79-27464#

The preliminary experimental development work directed towards the understanding of transition in boundary layers with suction is presented. The basic stability experiment was established and the facility was certified.

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.
Grant NSG-1358

288. *Bobbitt, P. J.: Modern Fluid Dynamics of Subsonic and Transonic Flight. AIAA International Meeting and Technical Display on Global Technology 2000, Baltimore, Md., May 6-8, 1980, 39 pp., 65 refs.

AIAA-80-0861 A80-33274#

The paper discusses a number of factors, termed research drivers, which are expected to provide much of the stimulus for research in the subsonic and transonic flight regimes in the coming decade. The research drivers discussed comprise the need for energy efficiency, new and improved facilities, better instrumentation, more capable and efficient computers, theoretical methodology refinements, increased use of optimization techniques, and military requirements. Illustrations of advances in aircraft aerodynamics at subsonic and transonic speeds are presented, along with a discussion of future research opportunities and trends. Particular attention is given to airfoil and basic fluids research designed to reduce skin-friction drag. (Laminar flow is discussed beginning on page 15.)

*NASA, Langley Research Center, Hampton, Va.

289. *Tan-Atichat, J.; *Nagib, H. M.; and **Loehrke, R. I.: Interaction of Free-Stream Turbulence with Screens and Grids - A Balance Between Turbulence Scales. Journal of Fluid Mechanics, vol. 114, Jan. 1982, pp. 501-528.

A82-26131

Effects of screens and perforated plates (grids) on free-stream turbulence are studied in several test flow conditions. The level, structure and decay of the turbulence generated by such "manipulators" depend in part on their shear-layer instabilities, and can therefore be modified by inserting additional devices immediately downstream. The performance of screens and some perforated plates is found to depend on the characteristics of the incoming flow such as velocity, turbulence level and spectra. Combinations of perforated plates and screens are found to be very effective flow manipulators. By optimizing the intermanipulator separation and carefully matching the scales between the manipulator pair, the turbulence decay rate downstream of a grid can be quadrupled.

*Illinois Institute of Technology, Chicago, Ill.
**Colorado State Univ., Fort Collins, Colo.

290. *Chen, J. L. S.; and *Jeng, M. C.: Fluid Injection to a Laminar Boundary Layer with Variable Wall Mass and Heat Flux. AIAA/ASME 3rd Joint Thermophysics, Fluids, Plasma and Heat Transfer Conference, St. Louis, Mo., June 7-11, 1982.

ASME-82-HT61

*University of Pittsburgh, Pittsburgh, Pa.

291. *Nayfeh, A. H.; and *Reed, H. L.: Stability of Flow Over Axisymmetric Bodies with Porous Suction Strips. AIAA/ASME 3rd Joint Thermophysics Fluids, Plasma and Heat Transfer Conference, St. Louis, Mo., June 7-11, 1982.

AIAA-82-1025

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

292. *Reynolds, G. A.; and **Saric, W. S.: Experiments on the Stability of the Flat-Plate Boundary Layer with Suction. AIAA/ASME 3rd Joint Thermophysics, Fluids, Plasma and Heat Transfer Conference, St. Louis, Mo., June 7-11, 1982.

AIAA-82-1026

*National Bureau of Standards, Washington, D.C.
**Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

293. *El-Hady, N. M.; and *Verma, A. K.: Instability of Compressible Boundary Layers Along Curved Walls with Suction or Cooling. AIAA/ASME 3rd Joint Thermophysics, Fluids, Plasma and Heat Transfer Conference, St. Louis, Mo., June 7-11, 1982.

AIAA-82-1010

*Old Dominion Univ., Norfolk, Va.

294. *Hankey, W. L.; and *Shang, J. S.: Natural Transition - A Self Excited Oscillation. AIAA/ASME 3rd Joint Thermophysics, Fluids, Plasma and Heat Transfer Conference, St. Louis, Mo., June 7-11, 1982.

AIAA-82-1011

*Air Force Wright Aeronautical Labs., Wright-Patterson AFB, Ohio

295. *Morris, P. J.; and *Byon, W.: The Stability of the Axisymmetric Boundary Layer on a Circular Cylinder. AIAA/ASME 3rd Joint Thermophysics, Fluids, Plasma and Heat Transfer Conference, St. Louis, Mo., June 7-11, 1982.

AIAA-82-1012

*Penn. State Univ., University Park, Pa.

296. *Reed, H. L.; and *Nayfeh, A. H.: Stability of Compressible Three-Dimensional Boundary-Layer Flows. AIAA/ASME 3rd Joint Thermophysics, Fluids, Plasma and Heat Transfer Conference, St. Louis, Mo., June 7-11, 1982.

AIAA-82-1009

*Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

297. *Bennett, J. A.: External Aerodynamic Design for a Laminar Flow Control Glove on a Lockheed Jet Star Wing. 13th Congress of the International Council of the Aeronautical Sciences (ICAS)/AIAA Aircraft Systems and Technology Meeting, Seattle, Wash., Aug. 22-27, 1982.

ICAS-82-513

*Lockheed-Georgia Co., Marietta, Georgia

298. *Thelander, J. A.; *Allen, J. B.; and * Welge, H. R.: Aerodynamic Development of Laminar Flow Control on Swept Wings Using Distributed Suction Through Porous Surfaces. 13th Congress of the International Council of the Aeronautical Sciences (ICAS)/AIAA Aircraft Systems and Technology Meeting, Seattle, Wash., Aug. 22-27, 1982.

ICAS-82-512

Development of a laminar flow control system utilizing distributed suction through porous strips is reviewed. Recent improvements in electron beam perforation technology have greatly enhanced the potential for practical LFC application. Design of airfoil shapes compatible with LFC on swept wings is outlined. Boundary layer stability analysis results and determination of suction distributions are reviewed. Considerations for an operational system for protection from ice and insect contamination are noted. Results of a swept wing model test and plans for a LFC leading edge glove flight test program are reviewed.

*Douglas Aircraft Co., Long Beach, Calif.

299. *Pearce, W. E.: Progress at Douglas on Laminar Flow Control Applied to Commercial Transport Aircraft. 13th Congress of the International Council of the Aeronautical Sciences (ICAS)/AIAA Aircraft Systems and Technology Meeting, Seattle, Wash., Aug. 22-27, 1982.

ICAS-82-153

*Douglas Aircraft Co., Long Beach, Calif.

APPENDIX

The 49 entries in this appendix have publication dates prior to 1976 but they were not included in NASA RP-1035 (citation 141). Many of them were not freely available when that report was published. They are included here because of their relevance.

These documents have been included in the author index as A-1, A-2, etc., and are also arranged in chronological order.

A-1. *Johnson, D.: Brief Measurements of Insect Contamination on Aircraft Wings. Tech. Note Aero. 2164, May 1952, 11 pp. (Available to U.S. Gov't. Agencies Only.)

N-53305 from STIF

*Royal Aircraft Establishment, Farnborough, England.

A-2. *Coleman, W. S.: Wind Tunnel Experiments on the Prevention of Insect Contamination by Means of Soluble Films and by Liquids Discharged Over the Surface. BLCC Note 39 (Note W.T. 131), British Minist. Supply, July 1952. (Available to U.S. Gov't. Agencies and Their Contractors Only.)

CN-142,061
X80-71190#

*Ministry of Supply, London, England

A-3. *Rogers, Kenneth H.: Investigation of the Pressure Distribution in Suction Ducts. Rept. No. BLC-22, Northrop Aircraft, Inc., Nov. 1953, 45 pp.

AD 25 566 N79-75676

Results of tests to determine the pressure distribution in suction ducts for aircraft with boundary layer control are presented. This report includes the material presented in Northrop Aircraft, Inc. Report No. BLC-13, "Preliminary Investigation of the Pressure Drop in Suction Ducts," plus the results of additional tests made subsequent to the release of the preliminary report. Results show that the pressure drop along the duct is small if turning-vanes are provided to turn the inlet flow into the direction of the duct. This is due to the reduced losses in the duct and to the mixing of the duct flow with the flow from the turning-vanes (diffuser effect). Without turning-vanes, the pressure drop along the duct is increased considerably. Within reasonable limits, variations in duct taper, variations in the ratio of inlet velocity to duct velocity, and variations in Reynolds number of the duct flow have only minor effects upon the pressure distribution along the duct.

*Northrop Aircraft, Inc., Hawthorne, Calif.

A-4. *Schuh, H.; and *Winter, K. G.: The R.A.E. 4-ft × 3-ft Experimental Low-Turbulence Wind Tunnel. Part II. Measurements of Turbulence Intensity and Noise in the Working-Section. R. & M. 2905, British, A.R.C., 1957, 20 pp.

N78-78591

With all the screens fitted in the tunnel, the intensities of lateral components are of the same order as the longitudinal component and range from about 0.01% to 0.03% of the mean speed. Frequency analyses have shown the longitudinal components to consist of fan frequencies and a low-frequency contribution at about 5 to 10 c.p.s. The lateral components consist almost entirely of a similar low-frequency contribution. With all the screens in the tunnel the low level of turbulence is confined to a restricted area near the centre of the tunnel with flashes of high-intensity turbulence spreading a considerable distance from the walls. Noise measurements with the hot-wire microphone in the middle of the working-section showed that above a tunnel speed of 150 ft/sec the longitudinal component consisted mainly of noise. Some measurements were also made with the hot-wire microphone in the turbulent boundary layer on the walls.

*Aeronautical Research Council, London, England

A-5. *Goldsmith, J.: Experiments With Laminar Flow Near the Juncture of a Fuselage and a Wing Trailing Edge. Northrop Corp., Norair Div., Rept. No. NOR-59-306, BLC-120, June 1959, 114 pp.

N79-77133

The problem of maintaining laminar flow in the region of the juncture of two airplane components is being considered at Norair, and the possibility for laminar flow in the region of a wing leading edge and fuselage juncture has been demonstrated. These juncture experiments were extended to include the wing trailing edge and fuselage intersection, and it is with the latter subject that this report deals.

The experiments demonstrated that it is possible to achieve laminar flow in and downstream of the juncture of a wing and flat plate. The experiments also demonstrate that laminar flow is facilitated by installing two small vortex generators on the wing trailing edge near the intersection of the wing and plate. The vortices generated in this manner seem to "sweep" the wing wake away from the plate; consequently larger wake disturbances than formerly believed can be tolerated without causing transition on the fuselage (or plate) downstream of a wing.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-6. *Carmichael, B. H.; and *Pfenninger, W.: Surface Imperfection Experiments on a Swept Laminar Suction Wing. Northrop Corp., Norair Rept. No. NOR-59-454, BLC-124, August 1959, 34 pp.

N79-77135

The 30° swept laminar suction wing was modified by extending suction forward to 0.5 percent chord. This configuration was tested with and without surface waviness at both the 5- by 7-Foot University of Michigan and the 7- by 10-Foot Norair Low Turbulence Wind Tunnels. The total drag coefficients for the clean model were practically identical over the Reynolds number range tested.

Allowable values of surface waviness ($1/400 < h/\lambda < 1/70$) appear to be very similar to

those previously found on unswept low drag suction wings in the nonsuction region. Allowable wave height was found to be proportional to (wave length)$^{1/2}$ and (Reynolds number)$^{-3/4}$. The single wave results were well described by

$\frac{h^2}{\lambda \cdot c}(R_c)^{3/2} \simeq 59{,}000$. The allowable wave height of four waves in series was less than half that for a single wave. Critical waviness appeared identical at 27 and 75 percent chord locations for either single or multiple waves. Possible outflow of air from the slots due to excessively low static pressures over a wave may often limit the permissible surface waviness. Total drag coefficients and suction distributions with waves installed and just subcritical conditions were identical with clean model data.

The effect of slot spacing on the suction requirements of the clean model was investigated by plugging two-thirds of the slots. This increased the spacing in the rear half of the model from 0.55 percent chord to 2.2 percent chord. No increase in suction quantity for full laminar flow was noted over the range investigated ($7 \times 10^6 < R_c < 11 \times 10^6$).

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-7. *Carmichael, B. H.: Surface Waviness Criteria for Swept and Unswept Laminar Suction Wings. Northrop Norair Rept. No. NOR-59-438, BLC-123, August 1959, 19 pp.

N79-77134

This report summarizes the available experimental data concerning the critical size of surface waviness on swept and unswept laminar suction wings. A critical wave is defined as the minimum size which prevents the attainment of laminar flow to the trailing edge under moderate suction. Data are shown which establish the effect of the two principal variables, Reynolds number and relative wave length. A design chart is provided to enable computation of the critical wave ratio over a wide range of the variables. A small amount of information is presented to show the reduction in critical wave ratio due to a group of consecutive waves. A short discussion of all pertinent variables is included in the text.

These design charts apply to sinusoidal waves on swept or unswept wings in regions having a close approach to distributed suction (e.g., multi-slot construction). They also apply to unswept wings where the wave is in a nonsuction region but where strong flow acceleration exists.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-8. *Bacon, J. W., Jr.; *Tucker, Virginia L.; and *Pfenninger, W.: Experiments on a 30° Swept 12 Percent Thick Symmetrical Laminar Suction Wing in the 5- by 7-Foot University of Michigan Tunnel. Northrop Norair Rept. No. NOR-59-328, BLC-119, August 1959, 62 pp.

N79-77132

The first series of experiments on this wing proved that full chord laminar flow can be maintained on a swept wing with adequate suction throughout the strong cross flow region in the aft portion of the wing at chord Reynolds numbers of at least 12×10^6. In addition, the leading edge cross flow instability was not critical at 0° and +1°, but was critical at a chord Reynolds number above 7×10^6 for -1° angle of attack.

In the present series of tests, the swept wing laminar suction model has been modified by the installation of slots forward to achieve laminar flow at higher Reynolds numbers where the less severe leading edge cross flow becomes critical at 0° angle of attack. Full chord laminar flow and low friction drags were observed up to the tunnel-limited wing chord Reynolds number. The measured drags at 0° are slightly lower than those from the first series of tests and there were no indications that the forward slots caused any disturbances with or without suction applied. The satisfactory performance of the forward slots suggests that laminar flow is possible on swept wings to much higher wing chord Reynolds numbers.

*Northrop Aircraft, Inc., Hawthorne, Calif.

A-9. *Stall, C. G.: Present Status of Production Aircraft Surface Waviness at Norair. Northrop Corp., Norair Rept. No. NOR-59-444, BLC-126, September 1959, 19 pp.

N79-77136

Waviness measurements were made on all models of airframes currently in production at Norair to determine whether products of standard fabrication procedures were within the range of waviness requirements for a BLC surface. A typical required waviness range for a medium size high subsonic logistic airplane is 1/750 to 1/1500 (one part in 750 to one part in 1500). The majority of specimens measured were grouped into three categories or types with their respective waviness ranges.

Type	Waviness Range
1. Thick skins	1/750 to 1/1500
2. Thin skins over honeycomb core	1/900 to 1/3000
3. Skins over spars and skin joints	1/150 to 1/1000

The survey showed that Category 3 (skins over spars and skin joints) failed to meet BLC waviness requirements range.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-10. *Pfenninger, W.: Preliminary Design Studies of Large Low Drag BLC Long Endurance Airplanes. Northrop Corp., Norair Rept. No. NOR-59-613, BLC-127, December 1959, 64 pp.

N79-77137

General design, propulsion, and general aerodynamic consideration and preliminary design calculations are made. An example of a low drag long endurance airplane is worked-out based on results of the study.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-11. *Worth, R. N.: Effect of Weathering on Typical Bonded Boundary Layer Control Structure. Northrop Corp., Norair Rept. No. NOR-59-608, BLC-128, January 1960, 39 pp.

N79-77174

The objects were to determine the effects of various climatic conditions on typical boundary layer control skin configurations with respect to the operational characteristics and maintenance requirements of the suction system, and to evaluate the strength characteristics of the adhesives, used to bond the test panels, after exposure to the various climatic conditions of the test program.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-12. *Pfenninger, W.; and *Bacon, J. W., Jr.: About the Development of Swept Laminar Suction Wings With Full Chord Laminar Flow. Northrop Corp., Norair Rept. No. NOR-60-299, BLC-130, September 1960, Revised January 1961, 59 pp. (Presented at the Tenth International Congress of Applied Mechanics at Stresa, Italy, August-September 1960.)

N79-77138

On a swept laminar suction wing spanwise pressure gradients deflect the boundary layer air, which has lost part of its energy, toward the regions of low static pressure. As a result, the flow path of the boundary layer particles on a swept laminar suction wing differs from the potential flow streamline, and a boundary layer cross flow develops in the direction normal to the potential flow streamline. The boundary layer cross flow profiles in this direction show inflection points and are thus dynamically highly unstable against external disturbances at high wing chord Reynolds numbers. The question concerning the feasibility of full chord laminar flow on swept wings under cross flow conditions at high Reynolds numbers by means of boundary layer suction is the object of this study.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-13. *Groth, E. E.: Low Drag Boundary Layer Suction Experiments at Supersonic Speeds on an Ogive Cylinder with 29 Closely Spaced Slots. Northrop Corp., Norair Rept. No. NOR-61-162, BLC-131, August 1961, 69 pp.

N79-77139

Low drag boundary layer suction experiments on an ogive cylinder were conducted at the Arnold Engineering Development Center Supersonic Tunnel E-1 at Tullahoma, Tennessee, at Mach numbers 2.5, 3.0, and 3.5. The model had the same external dimensions as the one tested in 1958, but was equipped with an improved suction system. A larger number of closely spaced slots approached continuous suction to a better degree, and larger suction tubes permitted higher suction coefficients. Full laminar flow and low drag coefficients were measured up to Reynolds numbers $R_L \sim 15 \times 10^6$ at $M = 2.5$, $R_L \sim 12 \times 10^6$ at $M = 3.0$ and $R_L \sim 7 \times 10^6$ at $M = 3.5$.

The boundary layer development along the body was computed for several experimental suction and surface pressure distributions and the results were compared with the test data.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-14. *Worth, R. N.: Effect of Environmental Exposure on Boundary Layer Control Surfaces and Operations. Northrop Corp., Norair Div. Rept. No. NOR-61-211, BLC-133, September 1961, 31 pp.

N79-77154

The object was to determine the effects of exposure to various climatic environments on typical boundary layer control skin configurations with respect to the operational characteristics and maintenance requirements of the suction system.

Steam cleaning of the surfaces every seven to ten days during operations in normal climatic conditions should prevent degradation of the suction system beyond a maximum of 5 percent due to contamination of the slots and holes.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-15. *Groth, Eric, E.: Low Drag Boundary Layer Suction Experiments on a Flat Plate at Mach Numbers 3.0 and 3.5. Northrop Rept. No. NOR-61-251, BLC-135, October 1961 (with February 1963 Addendum), 67 pp.

N79-77141

Low drag boundary layer suction experiments on a 41-inch long flat plate were conducted at the 40- by 40-Inch Continuous Supersonic Tunnel A of the Arnold Engineering Development Center at Tullahoma, Tennessee. The model was equipped with 76 closely spaced, fine slots arranged in eight suction chambers. Full length laminar flow was obtained at $M = 3.0$ and 3.5 up to the highest possible tunnel pressures, resulting in length Reynolds numbers of 25.7×10^6 and 21.4×10^6, respectively. The measured drag coefficients (sum of wake and suction drag) were of the order of 28

to 43 percent of the turbulence friction drag at the same Reynolds and Mach numbers.

The results of a calculation of the laminar boundary layer development along the plate at typical suction distributions are compared with the test data.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-16. *Walz, A.: Approximation Theory for Boundary Layer Suction Through Individual Slits. NASA TM-75384, May 1979, 51 pp.

Translation of "Naeherungstheorie fuer Grenzschichtabsaugung durch Einzelschlitze," Rept. No. DVL-184, June 1962.

N62-16345 (German form)
N79-23910 (English translation)

The basic concepts of influencing boundary layers are summarized, especially the prevention of flow detachment and the reduction of frictional resistance. A mathematical analysis of suction through a slit is presented, two parameters, for thickness and for shape of the boundary layer, being introduced to specify the flow's velocity profile behind the slit. An approximation of the shape parameter produces a useful formula, which can be used to determine the most favorable position of the slit. An aerodynamic example is given.

*Deutsche Versuchsanstalt fuer Luft- und Raumfahrt, Institut fuer Angewandte Mathematik und Mechanik, Freiburg, West Germany
Contract NASw-3199.

A-17. *Rogers, O. R.; *Curran, E. T.; *Wrobel, N. A.: Aero-Acoustic Aspects of Laminar Flow Control. ASD-TDR-62-718, Vol. I. In: 1962 Compendium of Symposium Papers, Vol. I, Sept. 1962, (X68-81601), pp. 11-40. (Available to U.S. Gov't. Agencies and Their Contractors Only.)

X68-81603

*Aeronautical Systems Division, Air Force Systems Command, Brooks AFB, Texas.

A-18. *Pate, S. R.; and *Deitering, J. S.: Investigation of Drag Reduction by Boundary-Layer Suction on a 36-Deg Swept Wing at $M_\infty = 2.5$ to 4. AEDC-TDR-63-23, U.S. Air Force, Feb. 1963, 33 pp. (Available to U.S. Gov't Agencies and Their Contractors Only.)

X63-11101

*ARO, Inc., Arnold Air Force Station, Tenn.
Contract AF40/600/-1000

A-19. Summary of Studies Leading to the Development of a Laminar Flow Torpedo. Final Rept. No. NOR-64-114, (BLC-157), Northrop Corp., June 1964, 207 pp.
(Available to U.S. Gov't. Agencies and Their Contractors Only.)

AD 351 916 X67-88932

(Contract NOw 61-0413-c)

Northrop Corp., Hawthorne, Calif.

A-20. *Gross, L. W.; and *Pfenninger, W.: Experimental and Theoretical Investigation of a Reichardt Body of Revolution with Low Drag Suction in the NASA-Ames 12 ft. Pressure Wind Tunnel. NASA CR-158413. Northrop Corp. Rept. No. NOR-63-46, BLC-148, July 1963, 134 pp.

N78-77795

Full length laminar flow with very low friction and equivalent total drags was maintained on an 8 to 1 fineness ratio Reichardt body of revolution of 12-foot length by means of boundary layer suction through 113 fine slots up to a length Reynolds number $R_L = 57.76 \times 10^6$. The lowest coefficient of equivalent total drag (based on body wetted area and including the equivalent suction drag) at an angle of attack $\alpha = 0°$ was $C_{D_t} = 2.63 \times 10^{-4}$ at $R_L = 57.76 \times 10^6$ with a corresponding total suction flow coefficient (based on wetted area) $C_{Q_t} = 1.77 \times 10^{-4}$. This value of equivalent total drag is 12 percent of the friction coefficient of a turbulent flat plate at this length Reynolds number.

*Northrop Corp., Norair Div., Hawthorne, Calif.
Sponsored by NASA.

A-21. *Pfenninger, W.: About Some Flow Problems in the Leading Edge Region of Swept Laminar Flow Wings. Northrop Corp. Rept. No. BLC-160, July 1964, 30 pp.

N79-77143

During the first phase of the X-21 flight tests, full chord laminar flow was observed only in the outer part of the 30° swept wings of the X-21 airplane. Total pressure probes located at the wing trailing edge close to the outer edge of the boundary layer, if it were laminar, showed a rather large loss in total pressure in the inboard areas of the wing, indicating the presence of a thick turbulent layer at the trailing edge and hence of extensive turbulent flow in the inboard wing regions. (This report discusses problems concerned with turbulence on laminar flow swept wings.)

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-22. *Lang, T. G.; and *Patrick, H. V. L.: Wind-Tunnel Tests on a Porous Body With Suction. U.S.

Navy NAVWEPS Rept. 8528, NOTS TP 3529, 1964, 42 pp. (Available to U.S. Gov't. Agencies and Their Contractors Only.)

AD-358 692 X68-85165

*Naval Ordnance Test Station, China Lake, Calif.

A-23. *Kobashi, Y.; and *Onji, A.: An Experimental Investigation of Stability Characteristics of Unsteady Laminar Boundary Layer. Rept. No. NAL-TR-65, 1964, 16 pp. (In Japanese.)

N65-22096#

In order to determine a stability criterion of small disturbances in a boundary layer with a time-dependent outside flow, experimental studies have been carried out in a wind tunnel of a 20 cm × 15 cm cross section, in which the flow speed was forced to oscillate sinusoidally around its mean value.

The results are summarized as follows:

The boundary layer velocity profiles and their stability characteristics vary with the phase of the outside flow, and are related to unsteadiness parameters $\Delta U/U_m$ and ω_s/U_m. As far as these parameters are small, the stability of the disturbances is related to the instantaneous boundary layer profiles.

*National Aerospace Laboratory, Tokyo, Japan

A-24. *Goldsmith, John: A Suggested Procedure for Determining the Wake Drag of Highly Swept Wings by Means of Simple Wake Measurements. Northrop Rept. No. NOR-65-285, BLC-165, October 1965, 36 pp.

N79-77145

In laminar flow control experiments, measurements are normally made of the boundary layer in order to evaluate the wake drag. This wake drag is then added to the equivalent suction drag in order to determine the effective skin friction drag. The boundary layer profile is measured by means of a total head rake and for two-dimensional unswept airfoils the wake drag may be determined from the momentum thickness of this profile by conventional means. When, however, the trailing edge is swept the momentum thickness (determined from the streamwise boundary layer profile) cannot be used by itself to determine the wake drag accurately. A change of procedure is required since the mass flow rate on which the momentum deficit should be based must be modified by the boundary layer cross flow whenever such cross flow is present. Cross flow components will normally occur whenever pressure gradients are present on a swept wing and larger sweep angles generally result in greater cross flow and larger correction factors for the wake drag. Methods for determining the wake drag for constant chord wings have been described for small and large sweep angles, respectively. With certain modifications, the method for large sweep angles (in excess of the Mach angle) has been made more general so that it may also be used to determine the local drag coefficient of a tapered wing, and the local coefficients may then be integrated along the spanwise coordinate in order to determine the overall drag coefficient. The development and method of using this more general wake correction is given in this report.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-25. *Carmichael, R. F.; and *Finwall, P.: Analysis of the Results of the Laboratory Duct Model Test for the X-21A Laminar Flow Aircraft. Rept. No. NOR-65-303, Northrop Corp., Nov. 1965, 80 pp.

N79-75674

A method has been developed that predicts the slot perturbation velocity, Δw, existing at the intersection of the wing surface and suction slot, given the spanwise duct sound pressure P_D, and the pertinent geometric and flow parameters. The method has been empirically derived and qualitatively substantiated by theoretical methods. The result is presented in terms of the mean, or best estimate; the probable error, or the 50% probability limits; and the upper 95% confidence limit assuming normal distribution about the mean of all test data.

The test results also disclosed the existence of a disturbance in the suction slot that appears to be a function of the slot flow. The existence of this disturbance in a high streamwise flow such as would occur in flight has not been confirmed.

*Northrop Corp., Norair Div., Hawthorne, Calif.

A-26. *Bacon, John W., Jr.; and *Pfenninger, W.: Transition Experiments at the Front Attachment Line of a 45° Swept Wing with a Blunt Leading Edge. AFFDL-TR-67-33, June 1967, 43 pp. Final Rept. Feb.-Dec. 1966. (Available to U.S. Gov't. Agencies and Their Contractors Only.)

AD-818 962 X67-23005

*Northrop Corp., Norair Division, Hawthorne, Calif.
Contract AF33(657)-11618

A-27. Final Report on LFC Aircraft Design Data Laminar Flow Control Demonstration Program. Northrop Corp., NOR-67-136, June 1967, 415 pp. (Available to U.S. Gov't. Agencies and Their Contractors Only.)

AD 819 317 X67-22964

This is a revision of Report NOR 61-141, "Laminar Flow Control Demonstration Program, Final Report - LFC Design Data," Contract AF 33(600)-42052, April 1964.

Northrop Corp., Hawthorne, Calif.
(Contract AF 33(657)-13930)

A-28. *Beasley, J. A.: Some Notes on the Design of Swept Wings for Laminar Flow Aircraft. Tech. Rept. 67169, British R.A.E., July 1967, 34 pp. (Available to U.S. Gov't. Agencies and Their Contractors Only.)

AD 822 711 X68-11331

*Royal Aircraft Establishment, Farnborough, England

A-29. *McCauley, William D., ed.: Boundary Layer Transition Study Group Meeting, July 11-12, 1967. Volume II - Session on Boundary Layer Stability. BSD-TR-67-213, Volume II, U.S. Air Force, Aug. 1967, 225 pp. (Available to U.S. Gov't. Agencies and Their Contractors Only.)

AD 820 364 X67-23560

The following papers are contained in this volume:

Mack, Leslie M.: Numerical Solutions of Compressible Boundary Layer Stability, pp. 9-1 - 9-22.

Kendall, James M., Jr.: Supersonic Boundary Layer Stability Experiments, pp. 10-1 - 10-8.

Brown, W. Byron: Improvements in Compressible Solutions of Stability Theory, pp. 11-1 - 11-16.

Donaldson, Coleman duP.; and Sullivan, Roger D.: A Computer Study of an Analytical Model of Boundary Layer Transition, pp. 12-1 - 12-36.

Reshotko, Eli: Stability Theory as a Guide to the Evaluation of Transition Data, pp. 13-1 - 13-22.

Nagel, A. L.: Compressible Boundary Layer Stability by Time-Integration of the Navier-Stokes Equations, and an Extension of Emmons' Transition Theory to Hypersonic Flow, pp. 14-1 - 14-62.

Van Driest, E. R.; and Blumer, C. B.: Boundary Layer Transition on Cones and Spheres at Supersonic Speeds - Effects of Roughness and Cooling, pp. 15-1 - 15-30.

*Aerospace Corp., San Bernardino, Calif.

A-30. *Vasudeva, B. R.: Boundary-Layer Instability Experiment with Localized Disturbance. Journal of Fluid Mechanics, vol. 29, pt. 4, pp. 745-763, 1967.

Laminar boundary layer on a flat plate with zero pressure gradient was excited by a solitary three-dimensional disturbance. The growth of the disturbance was studied using a 10-channel linearized d.c.-coupled hot-wire system. The development of the disturbance flow field was studied and compared with theory by Criminale & Kovasznay (1962). The experimental results indicate a departure from the theory on account of the simplifying assumptions made in the theory. Certain new results were also obtained.

*Dept. of Mechanics, The Johns Hopkins Univ., Baltimore, Md.

A-31. *Kurn, A. G.: A Suction Control System for the Boundary Layer Developed Along a Cylinder. Tech. Memo. Aero. 1090, British R.A.E., Aug. 1968, 28 pp. (Available to U.S. Gov't. Agencies Only.)

X69-15349

*Royal Aircraft Establishment, Farnborough, England

A-32. *Morkovin, M. V.: Mechanics of Boundary Layer Transition, Part 2: Instability and Transition to Turbulence. VKI-Lecture-Series-3-Part 2, 176 pp. DCAF-F002628. Von Karman Inst. for Fluid Dynamics, Rhode-St.-Genese, Belgium.

N79-31530#

Instability and transition from laminar to turbulent shear layers is discussed. Topics include advances in understanding the transition and contradictions in transition research. Transition correlations for hypersonic wakes, three dimensional boundary layers, laminar suction wings, heat transfer and boundary layer transition, and Reynolds number effects are covered.

*Martin Co., Baltimore, Md.

A-33. *Bacon, John W., Jr.; *Goldsmith, John; and *Gross, Lloyd W.: Effect of Slot Configuration and Disturbances From Slot or Environment on Laminar Flow Vehicles. NCL-68-46R, Northrop Corp. Lab., July 31, 1968, 143 pp. (Available to U.S. Gov't. Agencies and Their Contractors Only.)

AD-851246 X69-16041

*Northrop Corp., Hawthorne, Calif.
Contract N00017-67-C-1112

A-34. *Eppler, R.: Laminar Airfoils for Reynolds Numbers Greater Than 4×10^6. Boeing Co., Seattle, Wash., Office of International Operations. Translation into English from German Report AVA-67-A-62, B-819-35; April 1969, 32 pp.

A70-10930 (Original German)
N69-28178# (Translation)

Laminar airfoils, which means airfoils with the highest possible drag gain by laminar boundary layers without suction, have been examined thoroughly in the region of smaller Re numbers. It is time to report on the gains possible in the region above $Re = 4 \times 10^6$. The NACA airfoils which are now over 20 years old, are considered as a point of departure. We proceed at first purely theoretically, in a way which has already been successful for smaller Re numbers. It could be seen that keeping a boundary layer laminar is not so difficult in the region of smaller Re numbers if one builds precision wings. The most difficult problem lies here in avoiding laminar separations and so-called local separation bubbles. In the Re number region under discussion this problem does practically not play any role at all and any measurements with $Re = 4 \times 10^6$, where such "bubbles" would have had any effect, are not known to the author had there not been very sudden and very steep pressure increases. These however, are not appropriate for reasons of flight characteristics. The boundary layer transition is here of the utmost importance. A reliable transition criterion is therefore of considerable importance for a theoretical treatment.

Note: The original German report is listed as #491 in NASA RP-1035.

*Stuttgart Univ., West Germany

A-35. *Struminskii, V. V.; *Filmono, M. L.; and *Glushko, G. S.: Turbulent Flows (Selected Articles) - Stability of Laminar Flows and Boundary Layer Transition. (Translation into English by Foreign Technology Div. AFSC, Wright-Patterson AFB). Moscow, 1970.

AD-754323 N74-10344#

A series of articles discuss turbulent flows. The overall problem, the stability of laminar flow, and transition to turbulent flow are discussed. Diagram equations for the degeneration of turbulence, and calculations of pressure and velocity fluctuations in the boundary layer are followed by articles on the kinematic characteristics of a turbulent flow during steady motion, pressure fluctuations on the boundary of a turbulent flow, turbulent flows in jets and ducts, and the turbulent mixing of free jets.

*Akademiia Nauk SSSR, Institut Teoreticheskoi i Prikladnoi Mekhaniki, Novosibirsk, USSR

A-36. *Craik, Alex D. D.: Non-Linear Resonant Instability in Boundary Layers. Journal of Fluid Mechanics, vol. 50, part 2, 1971, pp. 393-413.

A72-13160

Investigation of resonant triads of Tollmien-Schlichting waves in an unstable boundary layer. The triads considered are those comprising a two-dimensional wave and two oblique waves propagating at equal and opposite angles to the flow direction and such that all three waves have the same phase velocity in the downstream direction. For such a resonant triad remarkably powerful wave interactions take place, which may cause a continuous and rapid transfer of energy from the primary shear flow to the disturbance. It appears that the oblique waves can grow particularly rapidly and it is suggested that such preferential growth may be responsible for the rapid development of three-dimensionality in unstable boundary layers. The non-linear energy transfer primarily takes place in the vicinity of the critical layer where the downstream propagation velocity of the waves equals the velocity of the primary flow.

*Dept. of Applied Mathematics, St. Andrews Univ., St. Andrews, Scotland

A-37. *East, L. F.: Spatial Variations of the Boundary Layer in a Large Low-Speed Wind Tunnel. Aeronautical Journal, vol. 76, Jan. 1972, pp. 43, 44.

A72-19061

Experimental study of boundary layer variations caused by fitting screen insets in wind tunnels. The results obtained indicate that fitting screens can remove spatial variations of the boundary layer flow in the working section of the tunnel and that the dependence of the flow upon the screens in the settling chamber is as great in large as it is in small tunnels.

*Royal Aircraft Establishment, Farnborough, England

A-38. *Struminskii, V. V.: Laminar Flow Stability Problems and the Transition to Turbulent Flow. Fluid Mechanics - Soviet Research, vol. 1, No. 2, Mar.-April 1972, pp. 121-134. (A Survey Paper.)

A72-37468 (English)
A71-15602 (Russian)

An analysis is given of the results of theoretical studies using the linear theory of hydrodynamic stability. The need for careful experimental verification of the deductions from linear theory in the development of a non-linear theory is shown. A critical analysis is made of the existing attempts to construct a non-linear theory

of hydrodynamic stability. The author's nonlinear theory unambiguously defines the nature of the development of perturbations in a laminar flow. Based on this theory, a qualitative picture is given of the transition from laminar to turbulent flow.

*Akademiia Nauk SSSR, Institut Teoreticheskoi i Prikladnoi Mekhanik, Novosibirsk, USSR

A-39. *Burnel, S.; and *Gougat, P.: Study of the Development of Natural Instabilities in a Laminar Boundary Layer in Incompressible Flow. NASA TM-76560, June 1981, 7 pp. Translation into English by Scientific Translation Service, Santa Barbara, Calif. from Comptes Rendus, Serie A - Science & Math., vol. 2, no. 16, April 17, 1972, pp. 1251-1254.

N81-27432# (English)
A72-29784 (French)

Natural instabilities which are created in a laminar boundary layer consist of intermittent wave trains. The spectral analysis of these fluctuations makes it possible to localize them in terms of frequency and to isolate their spectrum of amplitude modulation. The variation in terms of abscissa value and ordinate value of these instabilities is compared with the results derived from the solution of the Orr-Sommerfeld equation.

NASW-3198 (Translation)

*CNRS, Laboratoire d'Aerothermique, Meudon, Hauts-de-Seine, France

A-40. *Dods, Jules B., Jr.; and *Hanly, Richard D.: Evaluation of Transonic and Supersonic Wind-Tunnel Background Noise and Effects of Surface Pressure Fluctuation Measurements. Presented at the AIAA 7th Aerodynamic Testing Conference, Palo Alto, Calif., Sept. 13-15, 1972, 8 pp.

AIAA-72-1004 A72-41588#

An investigation of wind-tunnel background noise in the Ames Research Center 12-foot pressure wind tunnel, the 11- by 11-foot and the 14-foot transonic wind tunnels, and the 9- by 7-foot supersonic wind tunnel has been made. The data, which represent a frequency range from 10 Hz to 20 kHz, have been analyzed in the form of (1) broadband sound pressure levels and root-mean-square fluctuations of pressure coefficient, (2) power spectra in both dimensional and non-dimensional form, and (3) cross spectra and phase angle, yielding narrow band convection velocities. The surveys indicated a maximum broadband sound pressure level of 155 dB at maximum tunnel stagnation pressure in the 11- by 11-foot transonic tunnel. For equivalent stagnation pressures, the sound pressure levels were approximately the same in both the 11- by 11-foot and 14-foot transonic wind tunnels. The maximum sound pressure level in the 12-foot tunnel was 146 dB at a Mach number of 0.6 for near atmospheric stagnation pressure. Sound pressure levels were about 13 to 15 dB lower for equivalent stagnation pressures in the 9- by 7-foot supersonic wind tunnel than in the transonic facilities. The slots and the plenum chamber surrounding a transonic test section have been identified as the source of the most prominent peaks which occur in the power spectral density measurements in transonic wind tunnels. Comparison of results of a model in the wind tunnel and in free flight provides an appraisal of the effects of tunnel background noise.

*NASA, Ames Research Center, Moffett Field, Calif.

A-41. *Dougherty, N. S., Jr; and **Steinle, F. W.; Jr.: Transition Reynolds Number Comparisons in Several Major Transonic Tunnels. AIAA 8th Aerodynamic Testing Conference, Bethesda, Md., July 8-10, 1974.

AIAA-74-627 A74-36048#

Boundary-layer transition and test section environmental noise data were acquired in six major transonic wind tunnels as a part of a broader correlation of the effect of free-stream disturbances on transition Reynolds number. The data were taken at comparative test conditions on a sharp, smooth 10-deg included-angle cone. It was found that aerodynamic noise sources within the test section were the dominant sources of unsteadiness and that transition Reynolds number provided a good indicator for the resulting degradation in flow quality. Amplitudes, frequency composition, directivity, and origin of these disturbances are described.

*ARO, Inc., Arnold Air Force Station, Tenn.
**NASA, Ames Research Center, Moffett Field, Calif.

A-42. *Varner, M. O.: Noise Generation in Transonic Tunnels. AIAA 8th Aerodynamic Testing Conference, Bethesda, Md., July 8-10, 1974, 13 pp.

AIAA-74-633 A74-35397#

In an attempt to better understand the noise environment in transonic tunnels, noise generation mechanisms were isolated and studied. The noise environment in the test section is separated into three distinct parts: the noise due to jet flow through the porous walls, a wall hole-tunnel resonance phenomenon, and the turbulent boundary layer on the test section walls and in the diffuser. Each part is analyzed separately for the effects of aerodynamic and geometric flow constraints on the frequency and power characteristics. The contribution of each of the models to the fluctuating pressure level is also examined.

*ARO, Inc., Arnold Air Force Station, Tenn.

A-43. *Pfenninger, W.; and *Syberg, J.: Reduction of Acoustic Disturbances in the Test Section of Supersonic Wind Tunnels by Laminarizing Their Nozzle and Test Section Wall Boundary Layers by Means of Suction. NASA CR-2436, Nov. 1974, 305 pp.

N75-12977#

The feasibility of quiet, suction laminarized, high Reynolds number (Re) supersonic wind tunnel nozzles was studied. According to nozzle wall boundary layer development and stability studies, relatively weak area suction can prevent amplified nozzle wall TS (Tollmien-Schlichting) boundary layer oscillations. Stronger suction is needed in and shortly upstream of the supersonic concave curvature nozzle area to avoid transition due to amplified TG (Taylor-Goertler) vortices. To control TG instability, moderately rapid and slow expansion nozzles require smaller total suction rates than rapid expansion nozzles, at the cost of larger nozzle length Re and increased TS disturbances. The total suction mass flow ratios for the laminarization of high Re supersonic air nozzles increase from $\dot{m}_s/m_o = 0.005$ at $M^* = 3$ (test section) to 0.0105 at $M^* = 9$. Nozzle wall cooling decreases TS oscillation; TG instability in the concave curvature region, though, may be worse. Due to smaller nozzle length Re and Goertler parameters, $M^* = 9$ helium nozzles require half as much suction for their laminarization as $M^* = 9$ air nozzles of the same U^*D^*/ν^* (test section). Boundary layer crossflow instability on the side walls of two-dimensional high Re supersonic nozzles due to streamline curvature requires strong local suction to avoid transition. Nozzle wall surface roughness is critical in the throat area, especially at high M^*, but not in the downstream nozzle region. Allowable surface roughness in the throat area of a $M^* = 9$ helium nozzle is five times larger than for a comparable $M^* = 9$ air nozzle. Test section mean flow irregularities can be minimized with suction through longitudinal or highly swept slots (swept behind local Mach cone) as well as finely perforated surfaces (hole spacing < subsonic nozzle wall boundary layer thickness). Longitudinal slot suction is optimized when the suction-induced crossflow velocity increases linearly with surface distance from the slot "attachment line" toward the slot (through suitable slot geometry). Suction in supersonic blowdown tunnels may be operated by one or several individual vacuum spheres.

*Boeing Commercial Airplane Co., Seattle, Wash., Contract NASw-2359

A-44. *McCanless, G. F., Jr.; and *Boone, J. R.: Noise Reduction in Transonic Wind Tunnels. Acoustical Society of America, Journal, vol. 56, Nov. 1974, pp. 1501-1510.

A75-14385

The phenomena of background noise generation in transonic wind tunnels are analyzed. In unsteady aerodynamic tests, background disturbances create problems because the instrumentation senses them in addition to the fluctuations generated by the aerodynamic flow over wind-tunnel models. Calibrations of 25 facilities show that the amplitudes of the background fluctuations are excessive. In porous-wall facilities, one noise source consists of porous-wall edgetones that are generated by the passage of air over the holes. A flow model is developed that yields the frequencies of these oscillations. Test section boundary layers and hole configurations govern the occurrence of these fluctuations. In slotted-wall facilities, a noise source is the slotted-wall shearing caused by the air flowing along the openings. In both types of wind tunnels, other flow mechanisms also cause disturbances, and these phenomena are described. Noise-reduction methods are outlined which will provide valid unsteady aerodynamic results.

*Chrysler Corp., Huntsville, Ala.
Contracts NAS8-27503 and NAS8-30517

A-45. *Roos, F. W.: Surface Pressure and Wake Flow Fluctuations in a Supercritical Airfoil Flowfield. AIAA 13th Aerospace Sciences Meeting, Pasadena, Calif., Jan. 20-22, 1975, 10 pp.

AIAA-75-66 A75-18288#

Nonsteady features of a Whitcomb-type supercritical airfoil flowfield were studied in a series of transonic wind tunnel experiments. Data consisted of mean and fluctuating pressures on the airfoil and in the free stream, velocity fluctuations in the wake region, and airfoil vibrations. Fluctuation data were analyzed statistically for intensity, frequency content, and spatial coherence; variations in these parameters were correlated with changes in the mean airfoil flowfield. Surface pressure fluctuation intensity was influenced primarily by the location and motion of the upper-surface shock, the existence of separation, and (downstream of the shock) the development and upstream propagation of "shocklets." Power spectra of pressure fluctuations showed characteristics differences up and downstream of the shock. Chordwise and spanwise coherences were considerably reduced in the presence of separation. Downwash fluctuations at the edge of the wake were noticeably affected only by the development of trailing-edge flow separation.

*McDonnell Douglas Research Labs., St. Louis, Mo.
Research supported by McDonnell-Douglas and NASA

A-46. *Saric, William S.; and *Nayfeh, Ali H.: Non-Parallel Stability of Boundary-Layer Flows. VPI-E-75-5, Feb. 1975, 27 pp.

AD-A006918 N75-22654#

The spatial stability of two-dimensional incompressible boundary-layer flows is analyzed by using the method of multiple scales. The analysis takes into account the streamwise variations of the mean flow, the disturbance amplitude, and the

wavenumber. The theory is applied to the Blasius and the Falkner-Skan flows. For the Blasius flow, the non-parallel analytical results are in good agreement with the experimental data. The results show that the non-parallel effects increase as the pressure gradient decreases.

*Virginia Polytechnic Inst. and State Univ., Blacksburg, Va.
Contract N00014-72-A-0136-0002
Prepared in cooperation with Sandia Labs, Albuquerque, N. Mex.

A-47. *Nagel, A. L.; *Alford, W. J., Jr.; and **Dugan, J. F., Jr.: Future Long-Range Transports - Prospects for Improved Fuel Efficiency. NASA TM-X-72659, Feb. 1975, 18 pp.

N75-17339#

A status report is provided on current thinking concerning potential improvements in fuel efficiency and possible alternate fuels. Topics reviewed are: historical trends in airplane efficiency; technological opportunities including supercritical aerodynamics, vortex diffusers, composite materials, propulsion systems, active controls, and terminal-area operations; unconventional design concepts, and hydrogen-fueled airplane.

*NASA, Langley Research Center, Hampton, Va.
**NASA, Lewis Research Center, Cleveland, Ohio

A-48. *Varner, M. O.: Noise Generation in Transonic Wind Tunnels. Final Report, June 1973-June 1974. AEDC-TR-74-126, April, 1975, 40 pp.

AD-A007688

N75-23614#

In an attempt to determine the parameters characterizing the noise environment in transonic tunnels, noise-generating mechanisms for porous-wall tunnels with 60-deg inclined holes were isolated and studied. The noise environment in the test section is separated into three distinct parts: the noise due to jet flow through the porous walls, a wall hole-tunnel resonance phenomenon, and the turbulent boundary layer on the test section walls and in the diffuser. Each part is analyzed separately for the effects of aerodynamic and geometric flow constraints on the frequency and power characteristics. The contribution of each of the acoustic models to the test section free-stream fluctuating pressure level is also examined.

*ARO, Inc., Arnold Air Force Station, Tenn.

A-49. *Kulfan, R. M.; and *Howard, W. M.: Application of Advanced Aerodynamic Concepts to Large Subsonic Transport Airplanes. Final Tech. Rept., October 1974-September 1975; D6-75748; AFFDL-TR-75-112; Nov. 17, 1975, 117 pp.

AD-A019956

N76-25159#

A preliminary design study has been made to identify the performance advantages obtained when advanced aerodynamic technology aircraft are used to perform subsonic military air missions requiring long range (10,000 nmi) or high endurance (24 hr) with heavy payloads (250,000 lb and 400,000 lb, respectively). The study consisted of two phases; the first included evaluating the performance benefits by individually applying various advanced aerodynamic concepts and recommending areas where additional research and development work are necessary. The second phase included configuring integrated advanced technology aircraft that incorporated the most promising compatible aerodynamic concepts. Comparisons were made with conventional aerodynamic technology configurations designed for similar missions.

*Boeing Commercial Airplane Co., Seattle, Wash.
Contract F33615-75-C-3013

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