NASA Technical Memorandum 87639

Adaptive Wall Wind Tunnels

A Selected, Annotated Bibliography

Marie H. Tuttle and Raymond E. Mineck

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National Aeronautics
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Scientific and Technical
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CONTENTS

Current Adaptive Walled Test Sections

Organization	Tunnel	X-Section (h x w) m	Length m	Approx. Max. Mach No.	Approx. Max R_c millions	Walls	Adaptation Control	Remarks
2D Capability								
Genova Univ.	Low Defl. Cascade	.2x.05 Rectangular	1.58	>.9	1	2 Flexible 2 Solid	33 jacks/wall	BER
Genova Univ.	High Defl. Cascade	.2x.05 Rectangular	1.6	>.9	1	2 Flexible 2 Solid	13 jacks–top 26 jacks–bottom	BER
NASA Ames	Indraft 25x13	.13x.25 Rectangular	0.736	0.8	2	2 Slotted 2 Solid	10 PCCs/wall	BER
NASA Ames	2 ft	0.61 Square	1.53	>.85	2	2 Slotted 2 Solid	16 PCCs/wall	Production* AER
NASA Ames	25x11	.11x.25 Rectangular	0.61	>.8	2	2 Slotted 2 Solid	Nominally 10 PCCs/wall	AER
NASA Ames	HRC–2	.61x.41 Rectangular	2.79	>.8	27	2 Flexible 2 Solid	7 jacks/wall	AER
NASA Langley	0.3–m TCT	0.33 Square	1.417	>1.1	120	2 Flexible 2 Solid	18 jacks/wall	Production* AER
N P Univ. Xian, China	Low Speed	.256x.15 Rectangular	1.3	0.12	0.50	2 Flexible 2 Solid	19 jacks/wall	BER
ONERA/CERT	T.2	.37x.39 Rectangular	1.32	>1.0	30	2 Flexible 2 Solid	16 jacks/wall	AER
Southampton University	SSWT	.152x.305 Rectangular	0.697	0.1	0.29	2 Flexible 2 Solid	18 jacks/wall	BER
Southampton University	TSWT	0.15 Square	1.12	>1.0	2.5	2 Flexible 2 Solid	19 jacks/wall	AER
Tech. Univ. Berlin	I/II	0.15 Square	0.99	>1.0	2	2 Flexible 2 Solid	13 jacks/wall	AER
3D Capability								
AEDC	1 T	0.305 Square	0.953	0.95		4 Perforated	24 Segments/wall 8 Segmts/sidewall	AER
Arizona University		0.51 Square	0.89	0.2		2 Flexible Venetian Blinds 2 Solid	Not Specified	BER
DFVLR	Rubber Walled	0.8 Diameter	2.40	>.8		Rubber Tube	64 jacks total	BER
NASA Ames	Indraft 25x13	0.13x0.25 Rectangular	0.736	0.8		2 Slotted 2 Solid	10 PCCs/wall	BER
Southampton University	TSWT	0.15 Square	1.12	>1.0		2 Flexible 2 Solid	19 jacks/wall	BER
Tech. Univ. Berlin	I/II	0.15 Square	0.99	>1.0		2 Flexible 2 Solid	13 jacks/wall	BER
Tech. Univ. Berlin	III	.15x.18 Octagonal	0.83	>1.0		8 Flexible	78 jacks total	BER

AER – Advanced Exploratory Research
BER – Basic Exploratory Research

PCC – Plenum Chamber Compartment
* – Commissioning phase

SWD Wolf
July 1986

INTRODUCTION

This publication, containing 257 entries, supersedes an earlier bibliography on adaptive walls, NASA TM-84526, November 1982. It is the first of a series of bibliographies on the subject of wall interference in wind tunnels. The purpose of this selected bibliography is to list available publications that might be helpful to persons interested in reducing the interference due to the presence of the test section boundaries by adapting the flow at the walls.

Some interesting historical material has been included. The arrangement throughout is generally chronological by date of publication. However, papers presented at conferences or meetings are placed under dates of presentation. Therefore, the collection also serves as a "history" of the development of adaptive walls for wind tunnels. Corporate source, author, and subject indexes, by citation number, are included for the convenience of the users. The subject index is not intended to be complete, but may provide help in locating some information on specific topics.

An appendix includes citations of several books and some documents which do not deal directly with adaptive walls, but may provide helpful information to users of this bibliography. These citations are identified by the "A" added to their citation numbers, and are included in the indexes. Several documents were acquired too late to be included in the main part of the bibliography and are placed at the end of the appendix. In many cases, abstracts used are from the NASA announcement publications, "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, using parts pertinent to the subject of the bibliography.

The first issue of an informal newsletter on adaptive walls was published in March 1986 by the Experimental Techniques Branch of NASA Langley Research Center. This newsletter is intended to assist in dissemination of information on adaptive walls and thus encourage research in this area to forge ahead in the quest for interference free wind tunnel data. Those interested may request this newsletter from

Dr. Stephen Wolf
Experimental Techniques Branch
Mail Stop 287
NASA Langley Research Center
Hampton, VA 23665-5225
USA

The information included about the authors is that existing when the papers were written and may not have remained the same. 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 filling requests for specific items. When requesting material from a library or other source, it is advisable to include the complete citation; the abstract may be omitted.

ISSN - is an acronym for International Standard Serial Number, an internationally accepted code for the identification of serial publications; it is precise, concise, unique, and unambiguous.

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XXX-XXXXX Example: X72-76040	Report literature having distribution limitation of some type	NASA Scientific and Technical Information Facility (STIF) P.O. Box 8757 B.W.I. Airport, MD 21240
AD Numbers	Report literature with or without distribution limitation	Defense Technical Information Center Cameron Station Alexandria, VA 22314
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A "#" after an acquisition number (AXX-XXXXX# or NXX-XXXXX#) indicates that the document is also available in microfiche form.

BIBLIOGRAPHY

1 *Bailey, A.; and *Wood, S.A.: **The Development of a High-Speed Induced Wind Tunnel of Rectangular Cross-Section.** British ARC R&M 1791, Feb. 1937, 15 pp. In: Technical Report of the Aeronautical Research Committee, 1937. Vol. 2, pp. 1304—1318.

5341 NPL/24
(Langley Research Center library no.)

Work at the N.P.L. during the early 1930's toward the design of high speed wind tunnels led to the construction of this induced flow tunnel for two-dimensional testing having a test section of 6 inches by 3 inches in cross section and capable of Mach 1 with no model present. Among the tests carried out were some with an airfoil of 4% blockage at zero and 10 degrees angle of attack for which side wall Mach number data is shown in the presence of supercritical flow over the airfoil. Attention is drawn to the severe thickness and wake blockage effects evident in the data. For example the wake blockage at zero lift caused the Mach number to rise from 0.77 ahead of the model to 0.85 downstream. The longitudinal profile of the test section was modified by the insertion of liners to compensate for the wake blockage with the result that the wake blockage effect was eliminated while the upper limit to test Mach number was raised. The authors advocate the future use of flexible walls.

*Engineering Department, National Physical Lab., Teddington, England

2 *Bailey, A.; and *Wood, S.A.: **Further Development of a High-Speed Wind Tunnel of Rectangular Cross-Section.** British ARC R&M 1853, Sept. 1938, 16 pp. In: Technical Report of the Aeronautical Research Committee, 1938, Vol. II, pp. 753—768.

5341 NPL/25
(Langley Research Center library no.)

Bailey and Wood appear to have been the originators of the concept of the Adaptive Wall test section. They fitted this pilot high-speed wind tunnel with a flexible walled test section specifically for the purpose of eliminating wall interference. The report describes the wind tunnel and gives preliminary test results. The test section was 2 inches wide and 6 inches deep, with the narrow walls made from spring steel and their shapes controlled by six micrometer screw jacks on each. The test data demonstrates the elimination of wake blockage in two-dimensional airfoil tests at zero lift and at 10 degrees angle of attack, at a free-stream Mach number of 0.89. They note that tests with lift are more severe than those without. Good Mach number distributions were obtained along the empty test section at free stream Mach numbers up to 0.95.

*Engineering Department, National Physical Lab., Teddington, England

3 *Bamber, M.J.: **The Stability Wind Tunnel of the NACA.** National Advisory Committee for Aeronautics, Dec. 19, 1941, 12 pp.

5341 NACA-5/1
(Langley Research Center library no.)

The tunnel, apart from the test section, followed conventional practice for closed-return, single-passage wind tunnels with a square-cross-section throat. It was planned and constructed primarily to measure stability derivatives, control forces, and airflow about models in steady curvilinear flight. There were two test sections each 24 feet long and readily interchangeable. One section was called the rotating-flow section, and the other, the curved flow section. The curved flow section was 6 feet square in cross section. It was provided with flexible steel sidewalls which were adjustable by jacks to any desired curvature from straight to 13.3 foot radius on the centerline. It also had interchangeable variable resistance guides in the upstream end. This tunnel was acquired by the Virginia Polytechnic Institute and State University in 1958 and is currently in operation there.

*National Advisory Committee for Aeronautics (became NASA), Langley Field, VA 23665

4 *Beavan, J.A.; and *Hyde, G.A.M.: **Interim Report on the Rectangular High-Speed Tunnel Including Some Pitot Traverse Measurements of Drag of the Aerofoil EC 1250.** British ARC R&M no. 2067, Feb. 4, 1942, 19 pp.

5341 NPL/29
(Langley Research Center library no.)

After a short description of the tunnel and its development, the first part of this report describes observations bearing on the generally satisfactory behavior of the tunnel, including particularly the flexible walls by which its section can be altered at points along its length. At the same time a number of pitot traverse measurements of the profile drag of EC 1250 have been made, some in conjunction with photography of the shock waves. The observations and conclusions of this report have been considerably supplemented by much further work (R. & M. 2005, see entry no. 8 in this bibliography) since its original issue, but nothing included here requires serious modification.

*Aerodynamics Division, National Physical Lab., Teddington, England

5 *Preston, J.H.; and *Sweeting, N.E.: **The Experimental Determination of the Interference on a Large Chord Symmetrical Joukowski Aerofoil Spanning a Closed Tunnel.** British ARC R&M 1997, Dec. 22, 1942, 18 pp.

1115.5 Joukowski/19
(Langley Research Center library no.)

The interference on a 20 in. chord simple Joukowski aerofoil approximately 12 percent thick was measured in the 4 ft. No. 2 tunnel at the National Physical Laboratory. Tunnel constraint was removed by shaping the walls over a limited distance fore and aft of the model to the calculated streamlines of the unbounded flow about the wing. When the model chord is less than half the tunnel height, and the incidence is less than 9 deg., the wing can be replaced by its equivalent doublet at the position of maximum thickness, together with a vortex with the same circulation at the centre of pressure, for the purpose of calculating the streamlines. The measured interference on the forces and moments, expressed as a percentage, agrees closely with that predicted by potential flow theory for a flat plate.

*Aerodynamics Division, National Physical Lab., Teddington, England

6 *Wood, R. McK.: **Streamline Walls in High Speed Tunnels.** ARC Aerodynamics Sub-Committee no. 7332 (T.P.11), Jan. 6, 1944, 6 pp.

5341 NPL/41
(Langley Research Center library no.)

The device of "streamline walls" permits tests in a more limited depth of stream, the reduction of depth that can be used being of course conditioned by the accuracy with which the walls can be set to the form of a true streamline. This paper investigates principles upon which the correct wall form may be determined. Making the simplest possible assumptions, we represent the parting of the stream by the model by a single doublet, the wake behind the model by a single source, and lift by a point vortex. The discussion is confined to the two-dimensional flow for which the device has been used.

*Aerodynamics Division, National Physical Lab., Teddington, England

7 *Preston, J.H.: **The Interference on a Wing Spanning a Closed Tunnel Arising From the Boundary Layers on the Side Walls, With Special Reference to the Design of Two-Dimensional Tunnels.** British ARC R&M 1924, Mar. 1944, 10 pp.

1115.5 532
(Langley Research Center library no.)

This investigation forms part of a study of the factors which should fix the dimensions of a proposed two-dimensional tunnel. It is desirable that the sectional characteristics of large chord wings with flaps should be measured with considerable accuracy. At the same time it is necessary to restrict tunnel dimensions from considerations of economy of power, and of time and cost of model manufacture. The height of the tunnel can be fixed from considerations of roof and floor interference. The width of the tunnel will evidently be governed by the effects of the boundary layers on the side walls. These give rise to two effects. Firstly they cause a loss of lift at sections of the wing lying within them, giving rise to trailing vortices, which in turn affect the spanwise distribution of lift over the whole wing. An approximate and elementary theory is developed which is in qualitative agreement with experiment. The interference is appreciable for wings of chord greater than half the tunnel width. It is suggested that it could be effectively removed by increasing the chord of the end-pieces, where they enter the boundary layers, in such a manner that the product of the chord and the velocity in the boundary layer at a given distance from the wall remains constant. The second effect arises when there is a large extent of laminar flow present on a wing. Inward spread of turbulence takes place from the walls, and on large chord wings the extent of this spread at the trailing edge is serious. This, in conjunction with considerations of the span of the center portion of the wing required for accurate force measurement, fixes the width of the tunnel.

*Aerodynamics Division, National Physical Lab., Teddington, England

8 *Lock, C.N.H.; and *Beavan, J.A.: **Tunnel Interference at Compressibility Speeds Using the Flexible Walls of the Rectangular High-Speed Tunnel.** British ARC R&M 2005, Sept. 1944, 37 pp.

5341 NPL/37
(Langley Research Center library no.)

Results of various measurements made in the National Physical Laboratory Rectangular High-Speed Tunnel using the flexible walls are compared with theory in order to throw further light on the problem of tunnel interference at very high speeds. The dependence of the wall pressures and overall aerofoil forces on the wall shape has been investigated for two-dimensional tests of various aerofoils, though most of the work relates only to the low drag section EC 1250. It is concluded that the standard methods of "streamlining" the walls to simulate free air conditions are satisfactory up to speeds at which the shockwave from the aerofoil first reaches one wall, which in ordinary cases occurs above about $M = 0.85$ for a low-drag 12 percent t/c section, or 0.81 for a conventional 18 percent t/c. The 5-in. chord ($c/2h = 0.28$) is about as large as should normally be used, and in this case lift can be estimated from the streamline wall pressures, a correction being made for insufficient length of tunnel. If straight walls are used, the theoretical corrections to free air seem applicable up to top speed, and in this case the lift can be obtained from the wall pressures without addition beyond the end of the tunnel.

*Aerodynamics Division, National Physical Lab., Teddington, England

9 *Preston, J.H.; *Sweeting, N.E.; and *Cox, D.K.: **The Experimental Determination of the Two-Dimensional Interference on a Large Chord Piercy 12/40 Aerofoil in a Closed Tunnel Fitted With a Flexible Roof and Floor.** British ARC R&M 2007, Sept. 1944, 14 pp.

1115.5 Piercy 1240/1
(Langley Research Center library no.)

Experiments were designed to test the construction of flexible walls on a fairly large scale in connection with a proposed two-dimensional tunnel. The walls were constructed from high grade plywood approximately ¼ in. thick, 4 ft. wide and 13 ft. long. It was necessary to stiffen them laterally by wooden battens 4 ft. × 1¼ in. × 1 in. between the jack positions. The jacks were of steel attached by ball-ended fittings to the plywood in pairs 32 in. apart. Nuts with spherical ball joints were attached to the existing tunnel roof and floor. By turning the jacks in these nuts the walls could be shaped as desired, and the jacks locked in position. Special sliding gauges enabled the walls to be set to 1/100 in. Self-adjusting flexible fairings were used to fair the flexible walls into the original tunnel walls rather abruptly. Initially, the walls were set as near horizontal as possible by means of levels, so as to provide a datum and to check the walls for waviness. This existed, but it was considered small and it would have been difficult to remove. The static pressure gradient down the centre of the tunnel was determined next and the walls were then adjusted to cancel this by a process of trial and error. With regard to the flexible walls the method of construction is satisfactory and there would be no difficulty in designing walls for a larger tunnel. The flexible walls might well be made in metal as the various attachments would then be more easily made. Each pair of jacks will be mechanically geared together and it is suggested that pre-selector devices for setting to a given shape with electric motors for driving the jacks should be considered. This would save considerable time and labor if it is necessary to perform a large number of tests on a wing under infinite stream conditions. Care in the letting-in of pressure tubes, avoidance of waviness, and removal of burrs from holes are all necessary if irregularities in the pressure curves are to be avoided, especially when critical comparisons with theory are attempted. The conclusion is reached that pressure tubes lying along the surface are unsatisfactory and that the ideal method is to use a separate tube to each hole.

*Aerodynamics Division, National Physical Lab., Teddington, England

10 *Bird, J.D.; *Jaquet, B.M.; and *Cowan, J.W.: **Effect of Fuselage and Tail Surfaces on Low-Speed Yawing Characteristics of a Swept-Wing Model as Determined in Curved-Flow Test Section of Langley Stability Tunnel.** NACA TN 2483, Oct. 1951, 19 pp. (Formerly RM-L8G13, July 13, 1948).

Results are presented of one of a series of tests made to investigate the factors affecting the rotary derivatives of various swept-wing configurations. This investigation was begun because conventional straight-flow tests of swept wings had given results that were very different, particularly at moderate and high lift coefficients, from those generally obtained from tests of unswept wings and that were of a nature not readily adaptable to thorough mathematical analysis. The tests were conducted in the 6- by 6-ft curved-flow test section of the Langley stability tunnel which was designed for simulation of steady yawing or pitching flight of rigidly mounted models. The test section of this tunnel was equipped with flexible side walls for curving the air stream and specially constructed drag screens for producing the desired velocity gradient in the jet. The principle of operation of this test section was conceived by M.J. Bamber while he was a member of the staff of the Langley Laboratory.

*Langley Aeronautical Lab., NACA (became NASA), Langley Field, VA 23665

11 *Piercy, N.A.V.: **Aerodynamics.** English University Press, 2nd edition, Revised Impression, 1950, pp. 105—114 (in first edition, 1937, see p. 265).

TL 570.P48

This text (and its earlier editions) contains a description of the principles of the flexible walled test sections as applied by the British National Physical Laboratory from about 1938 onwards in two-dimensional Adaptive Wall testing. A subsonic test section is described for an induced flow wind tunnel. The test section, 8 inches by 17.5 inches, had its two narrow walls made from flexible steel which could be adjusted separately by micrometers to streamline forms. The tunnel could operate up to approximately Mach 1. The methods are described by which solid and wake blockage effects were eliminated. It is noted that a greater air speed became possible after the walls were streamlined. Examples of drag data are included for airfoils tested with unstreamlined and with streamlined test section walls at Mach numbers up to 0.81.

*Department of Aeronautics, Queen Mary College, London, England

12 *Pankhurst, R.C.; and *Holder, D.W.: **Wind Tunnel Technique,** Chapter 8, **Tunnel Interference Effects.** Pitmans (London), 1965, pp. 384—386.

TL567.W5P3

One of the N.P.L. induced flow adaptive wall wind tunnels is described, having two flexible walls, with an outline of the procedures for setting "aerodynamically straight" walls with the test section empty and for streamlining the walls in two-dimensional airfoil testing. It is noted that at low speeds a larger than usual model may be used with the advantage of an increase in Reynolds number. The claim is made that the procedures developed for streamlining the walls are reasonably accurate even when extensive local supersonic regions are present, but fails when the Mach number at the walls approaches 1.

*Aerodynamics Division, National Physical Lab., Teddington, England

13 *Kroeger, R.A.; and **Martin, W.A.: **The Streamline Matching Technique for V/STOL Wind Tunnel Wall Corrections.** Presented at the AIAA 5th Aerospace Sciences Meeting, Jan. 23—26, 1967, New York, N.Y. 9 pp.

AIAA Paper 67-183 A67-19439#

The validity of current V/STOL aircraft model test data is questionable in many instances. This is due to the complexity of the aerodynamic interaction between the model and the wind tunnel walls. Only specialized cases lend themselves to adequate data interpretation. This study presents an approach to the problem of wind tunnel data correction by providing matched stream surfaces in the near flow field. The flow conditions at the walls are first analytically calculated and then wall modifications made where necessary to provide adequate aerodynamic relief, such that relatively interference-free test data may be obtained. This paper presents the analytical method, the important parameters of the method, and discusses the status of an experimental evaluation.

*ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389
**Northrop Corp., Northrop Norair, Hawthorne, CA
Contract AF40 (600)-1200
Contract 66-42-TS/OMD and 67-39-TS/OMD

14 *Klunker, E.B.: **Contribution to Methods for Calculating the Flow About Thin Lifting Wings at Transonic Speeds—Analytic Expressions for the Far Field.** NASA TN D-6530, Nov. 1971, 16 pp.

N72-11289#

The problem of determining the small-disturbance flow about two-dimensional airfoils at transonic speeds has been successfully treated by the process of matching a numerical solution of the near field to analytical expressions for the far field. The three-dimensional problem, it would appear, can be treated in a similar way with the aid of algorithms adapted to high-speed and high-capacity computers. The far-field potential for both lifting and nonlifting three-dimensional wings at transonic speeds is developed herein for a subsonic free stream. This potential could be used for a three-dimensional-wing computation similar to the computation made for the two-dimensional wing.

*NASA Langley Research Center, Hampton, VA 23665

15 *Lo, C.-F.: **Wind-Tunnel Wall Interference Reduction by Streamwise Porosity Distribution.** AIAA Journal, vol. 10, no. 4, Apr. 1972, pp. 547-550. Also see a comment from M. Mokry and a reply by the author in AIAA Journal, vol. 10, no. 12, Dec. 1972, p. 1727.

A72-26001#

An analytic method has been developed to solve the interference problem of a tunnel with porosity distribution in the streamwise direction. The method can be applied to tunnel configurations other than the two-dimensional tunnel presented here. A distributed porosity in the streamwise direction has been found which gives essentially zero gradient of the lift interference and also improves the blockage interference. For a two-dimensional tunnel with uniform porosity, the zero lift interference occurs at the model location only for a closed tunnel. Therefore, since it is possible to obtain essentially constant interference along the wing chord (although not zero) for the two-dimensional tunnel, it should be possible to obtain constant and zero interference for the three-dimensional tunnel.

*ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389
Contract F40600-72-C-0003

16 *Kroeger, R.A.: **Wind Tunnel Design for Testing V/STOL Aircraft in Transition Flight. Final Report.** ARO-OMD-TR-72-102; AEDC-TR-72-119; Sept. 1972, 103 pp.

AD 749 154 N73-13278#

The problems arising from the use of wind tunnels for V/STOL aircraft experimental research and development testing are discussed. Even though wind tunnels have afforded the best potential for studying regions of aerodynamic uniqueness of V/STOL aircraft, they have been of limited value because of magnitude of the flow interference they introduce. A new wind tunnel concept is described which offers the potential for covering the spectrum of transition testing from hover throughout wing sustained flight. The wall interference corrections are physically produced by the structure of the wall which is set in position by theoretical calculations involving the model induced flow there. A small scale tunnel was designed, constructed, and tested employing this concept. Data from a small rotor model were obtained in the new tunnel and a large conventional one as a basis for comparative evaluation. The operation of the new tunnel was simple, and no instabilities or operational difficulties appeared. The data correlated favorably at high jet to free-stream mass flow rates. However as this ratio increased, deviations appeared which could be attributed to the inadequate test section length. The floor exhauster system should undergo further development than was provided for in this study. The results show the concept to have sufficient potential to warrant extended studies.

*ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389
Contract F40600-71-C-0002

17 *Menard, M.; and *Vayssaire, J.-Ch.: **An Example of the Use of a Perforated Variable Geometry Wind Tunnel.** Presented at the 9th

AAAF Conference on Applied Aerodynamics, Paris, France, Nov. 1972. Also, Rep. No. DGT-8652, 45 pp., 15 refs. (*in French*).

A73-32818#
N73-22212#

The Σ 4 Transonic Wind Tunnel of the Institute of Aerotech., St.-Cyr. is described. This tunnel has a mechanical system capable of continuously varying the permeability of the walls in the longitudinal direction. The horizontal walls are perforated and can be deformed with the aid of jacks with 60 mm travel. The upstream and downstream throats are adjustable also in order to fix longitudinal pressure gradients in the test section. Results from a test of a complete transport airplane model are given.

*Avions Marcel Dassault-Breguet Aviation, 92210, Saint-Cloud, France

18 *Lukasiewicz, J. (editor): **Aerodynamic Test Simulation: Lessons From the Past and Future Prospects.** AGARD Report 603 (N73-18250), 1972, pp. 21—22.

These pages consist of remarks on the importance of controlling wind tunnel wall interference in future transonic, high RN wind tunnels by **Antonio Ferri and ***William R. Sears.

*Carleton Univ., Ottawa, Canada
**New York Univ., Washington Square, New York, NY 10003
***Cornell Univ., Ithaca, NY 14850

19 *Ferri, A.; and *Baronti, P.: **A Method for Transonic Wind-Tunnel Corrections.** AIAA Journal, vol. 11, no. 1, Jan. 1973, pp. 63-66.

A73-17105#

A method for the determination of wind-tunnel corrections at transonic speed is described. The method consists of measuring pressure and streamline deflection at the walls of the tunnel and analytically determining the streamline deflection corresponding to the measured pressure and the pressure corresponding to the measured streamline deflection for external uniform freestream conditions at the same Mach number as the test. The comparison between measured and computed pressures and measured and computed streamline deflections is then utilized to determine the wall porosity characteristics which eliminate wall interference or to calculate the wall corrections to be applied to the experimental results.

*Advanced Technology Labs., Inc., Jericho, NY 11753
Contract N00014-72-C-0201

20 *Baronti, P.; *Ferri, A.: and *Weeks, T.: **Analysis of Wall Modification in a Transonic Wind Tunnel.** ATL-TR-181; AFOSR-73-1900 TR; Feb. 1973, 55 pp.

AD 767 629 N74-12971#

A method for transonic wind tunnel corrections based on the concept of measuring streamline deflection and pressure in the vicinity of the tunnel walls, and of analytically determining the streamline deflection that corresponds to the measured pressure, and the pressure that corresponds to the measured streamline for external uniform free stream conditions at the same Mach number of the test, was experimentally investigated. The method involves the additional step of determining the required wall porosity variation or proper wind tunnel cross sectional areas variation, and then making the requisite wind tunnel adjustments to obtain interference-free flow. Two, two-dimensional, 6% thick circular-arc airfoils were tested at several angles of attack and at free stream Mach numbers of 0.91 and 0.95 in the AFFDL Tri-Sonic Gasdynamics Facility at Wright-Patterson AFB. Only the portion of the data related to zero angle of attack is analyzed in this report. The analysis provides a verification of the experiments themselves, gives some indication of the characteristics of the tunnel ventilated walls, indicates the sensitivity required of the measurements, and defines the wall modifications which are required for interference-free conditions.

*Advanced Technology Labs., Inc., Westbury, NY 11590
Contract N00014-72-C-0201, A.F. Project 9781

21 *Sears, W.R.: **Self Correcting Wind Tunnels.** The Sixteenth Lanchester Memorial Lecture, May 3, 1973. (Published in the Aeronautical Journal, vol. 78, Feb./Mar. 1974 (no. 25 in this bibliography). Note: This lecture is one of two papers included in no. 39 in this bibliography.

Today's transonic tunnels are facilities that provide the conditions of unconfined flow in their working sections by virtue of such design features as ventilated walls. The case of a two-dimensional incompressible flow is investigated. The iterative approach to unconfined flow is considered, giving attention to the development of self-correcting wind tunnels in which the iterative scheme is carried out in automated fashion. A two-dimensional self-correcting transonic tunnel is described, taking into account questions of wall control, sensors, functional relationships, control logic and convergence, the required accuracy, and the test program.

*Cornell Univ., Ithaca, NY 14850
Research supported by U.S. Navy and Air Force

22 *Sears, W.R.: **Self-Correcting Wind Tunnels.** CALSPAN-RK-5070-A-2, July 1973, 48 pp.

AD 764 957 N73-32161#

The familiar technique of accounting for wind-tunnel boundary effects by correcting measured data fails in some of the most important flight regimes, such as the transonic and V/STOL. In such domains, typically strongly nonlinear, it seems necessary that the wind tunnel provide the same flow conditions in the vicinity of the model as in flight, since corrections are virtually impossible. Present-day slotted and perforated tunnels, for example, are intended to do this, but are often inadequate. However, unconfined flow is characterized by certain functional relationships among the flow variables at points on a surface within the tunnel; it is always possible to ascertain whether unconfined-flow conditions are actually present, by measuring such quantities and verifying that these relationships are indeed satisfied. These relationships are independent of the configuration being tested. It is proposed here that wind tunnels be provided with sensors to measure such selected quantities on a convenient surface and means to vary wall geometry so as to approach such conditions in an interative process.

*Calspan Corp., Buffalo, NY 14221
Contract N00014-72-C-0102

23 *Erickson, J.C., Jr.; and *Nenni, J.P.: **A Numerical Demonstration of the Establishment of Unconfined-Flow Conditions in a Self-Correcting Wind Tunnel.** CALSPAN-RK-5070-A-1, Nov. 1973, 38 pp.

AD 771 450 N74-17992#

Sears' self-correcting wind tunnel concept for achieving unconfined, interference-free flow conditions about a model by controlling the flow at the test section walls is simulated. A numerical model for the flow within the test section is used in conjunction with the functional relationships which must be satisfied to insure that the flow is unconfined. The basic iterative nature of the concept is examined, and it is demonstrated that the iteration converges readily to unconfined-flow conditions. The effects on the flow about the model of truncating the controllable portion of the test section walls at 4.5 chord lengths upstream and downstream of the model quarterchord is shown to be negligible.

*Calspan Corp., Buffalo, NY 14221
Contract N00014-72-C-0102, NR Project 061-199

24 *Vidal, R.J.; *Catlin, P.A.; and *Chudyk, D.W.: **Two-Dimensional Subsonic Experiments With a NACA 0012 Airfoil.** CALSPAN-RK-5070-A-3, Dec. 1973, 54 pp.

AD 775 880 N74-22628

Two-dimensional tests were made with a 6-inch chord NACA 0012 section in the Calspan 8-Foot Transonic Wind Tunnel to obtain section data with minimum wall interference effects. The measurements included three-component force data, surface pressure distributions and oil flow observations, and were made at Mach numbers ranging from 0.4 to 0.95 and at a chord Reynolds number of 1,000,000. Comparisons of the lift curve data with available theory indicate that the results are within about 1% of being two-dimensional.

*Calspan Corp., Buffalo, NY 14221
Contract N00014-72-C-0102, NR Project 061-199, sponsored in part by AFOSR.

25 *Sears, W.R.: **Self Correcting Wind Tunnels.** Aeronautical Journal, vol. 78, Feb./Mar. 1974, pp. 80-89.

A74-27592#

For another form of this paper and an abstract see no. 21 in this bibliography. Also, this paper is one of two that are included in no. 39 in this bibliography.

*Cornell Univ., Ithaca, NY 14850
Research supported by U.S. Navy & Air Force

26 *Coe, P.L., Jr.; and *Newsom, W.A., Jr.: **Wind-Tunnel Investigation to Determine the Low-Speed Yawing Stability Derivatives of a Twin-jet Fighter Model at High Angles of Attack.** NASA TN D-7721, Aug. 1974, 39 pp.

N74-31506#

An investigation was conducted to determine the low-speed yawing stability derivatives of a twin-jet fighter airplane model at high angles of attack. Tests were performed in a low-speed tunnel utilizing variable-curvature walls to simulate pure yawing motion. The data presented herein were obtained in a low-speed tunnel (previously known as the Langley stability tunnel) which has a 1.83- by 1.83-m (6- by 6-ft) curved-flow test section. The tunnel was acquired by the Virginia Polytechnic Institute in 1958 and is currently operated at that institute. The tunnel is used with a straight test section to obtain conventional static test data. The tunnel also has a unique capability in that the vertical sidewalls of the test section are designed with sufficient flexibility so that they may be deflected into a curve, thus creating a curved airflow past the model. Jackscrews are positioned at regular intervals along each wall to allow the curvature to be set at prescribed values. In order to simulate flight in a curved path it is also necessary to redistribute the velocity profile in the radial direction. This is accomplished by installing vertical wire screens in the flow upstream of the test section. These screens vary in mesh across the wind tunnel, with the densest portion of the screens located nearer the center of curvature. A sketch showing a typical curved-flow test arrangement is shown.

*NASA Langley Research Center, Hampton, VA 23665

27 *Legendre, R.G.: **Self-Correcting Transonic Wind Tunnels (Souffleries Transsoniques Autocorrectrices).** Extracted from *"Omaggio a Carlo Ferrari" - Librairie Universitaire Levrotto et Bella, Turin, Dec. 1974, p. 487—498.* Also, ONERA-TP-1975-33, 1975, pp. 487-498 (in French).

A76-14451

The development of the ONERA wind tunnels since the creation of this Institute is first recalled. Recent research work, by Chevallier et al., almost parallel to that carried out in America, but less advanced, particularly as regards experimental checking, is then presented. The author then presents his contribution to this recent evolution, formulating a few personal opinions which might be supplemented by publications from the main initiators of original ideas.

*ONERA, BP 72, 92322 Chatillon Cedex, France

28 *Bernstein, S.; and *Joppa, R.G.: **Development of Minimum Correction Wind Tunnels.** Presented at the 13th AIAA Aerospace Sciences Meeting, Pasadena, Calif., Jan. 20-22, 1975, 8 pp. Also, Journal of Aircraft, vol. 13, no. 4, Apr. 1976 (no. 44 in this bibliography).

AIAA Paper 75-144 A75-18342#

Flow distortions due to wind tunnel wall interference may be accounted for if the model to tunnel ratio is small, but the theory becomes less reliable as the model becomes larger. This paper presents theoretical analysis and experimental evidence which supports a new concept of wind tunnel. The method employs active control of flow through the walls so that the model is in approximately free air conditions during the test. Practical considerations in the design of such a tunnel are presented. Results indicate that a minimum correction wind tunnel may be achieved with active walls of relatively low porosity.

*Univ. of Washington, Seattle, WA 98195
Grant NGL-48-002-010

29 *Bernstein, S.: **The Minimum Interference Wind Tunnel.** Ph.D. Thesis, Univ. of Washington, Mar. 1975, 117 pp. (Available from Univ. Microfilms, Order no. 75-28319.)

N76-13416

Flow distortions due to wind tunnel wall interference may be accounted for if the model to tunnel ratio is small, but the theory becomes less reliable as the model becomes larger. An alternate concept to the conventional wind tunnel is presented here by theoretical analysis and experimental evidence. The method employs active control of flow through the walls so that the model is in approximately free air conditions during the test. The amount of regulated flow through the wall is computed by potential flow method using the actual measured lift. Theoretical analysis substantiates this concept of simulation and presents the general theory of operation and convergence of the technique to free air conditions. In practice, only portions of the tunnel wall are controlled so that if the necessary momentum throughout the wall is equated to the momentum through the regulated wall portion, a mass flow mismatch would result and vice versa. The amount of mismatching is analytically extended to relate to the expected error in a given tunnel. An experimental facility was constructed to demonstrate the concept and the results indicate that a minimum interference wind tunnel may be achieved with relatively low porosity of active walls.

*Univ. of Washington, Seattle, WA 98195

30 *Wolf, S.W.D.: **Turbine Blade Cascade Testing in a Flexible-Walled Wind Tunnel.** Project for B.Sc. Honours Degree in Aeronautical Engineering, University of Southampton. Apr. 1975, 104 pp.

N86-70067

The work was mainly experimental and was concerned with the investigation of a new technique for cascade blade testing using a low-speed flexible walled test section with a single turbine blade fitted. The design of the test section for simulating large changes in flow angle is discussed. A testing technique was devised to study the streamlining criterion. The flexible walls were contoured to identical streamline shapes above and below the model. Claims were made that the technique is feasible but blade data could not be verified.

*The University, Southampton S09 5NH, Hampshire, U.K.

31 *Pindzola, M.; *Binion, T.W., Jr.; and **Chevallier, J.-P.: **Comments on Wall Interference—Control and Corrections.** Presented at the Conference on "Flight/Ground Testing Facility Correlations," June 9—13, 1975. In: AGARD-CP-187 (N76-25266), Apr. 1976, paper no. 4A, 5 pp.

N76-25273

A brief synopsis of meetings on the Design of Transonic Working Sections held under the auspices of the AGARD MiniLaws Working Group of the Fluid Dynamics Panel is presented. The status of work being done on adaptive walls is given.

*ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389
**ONERA, BP 72, 92322 Chatillon Cedex, France

32 *McDevitt, J.B.; *Levy, L.L., Jr.; and *Deiwert, G.S.: **Transonic Flow About a Thick Circular-Arc Airfoil.** Presented at the AIAA 8th Fluid and Plasma Dynamics Conference, Hartford, Conn., June 16—18, 1975, 9 pp. Also, AIAA Journal, vol. 14, no. 5, May 1976, pp. 606—613 (no. 45 in this bibliography).

AIAA Paper 75-878 A75-33962#

The present study of the transonic flow over a thick airfoil was undertaken specifically to provide information relevant to the evaluation of a new viscous-turbulent code under development at the Ames Research Center. A new facility was constructed and the airfoil and test-section geometry specifically chosen so as to achieve the desired results. A brief description of the new facility, the Ames High Reynolds Number Channel, is given. The first experimental tests conducted in the new facility are described and results presented and discussed. The facility is of the blow-down type and is designed for operation at Reynolds numbers per foot up to 40 million for subsonic flows and to 200 million for supersonic flows. Interchangeable test channel configurations are to be used, each designed specifically for the test flow to be studied. In order to eliminate upper and lower wall interference effects, and to prevent premature choking of the tunnel by the transonic airfoil shock, these walls were contoured to follow the airfoil free-air streamlines for the chosen nominal test condition. Also, incorporated in the design of the upper and lower test section channel walls were removable inserts contoured to simulate the flow streamlines about the airfoil in free air at the chosen design Mach number and Reynolds number—an effective means for eliminating wall interference effects. The effect of small changes in channel upper and lower wall contouring was studied; the measured airfoil surface pressure distributions were not overly sensitive to these changes. Thus, streamline contouring, if reasonably accurate, and if the channel is not completely choked by the airfoil, is an effective way to minimize wall interference effects.

*NASA Ames Research Center, Moffet Field, CA 94035

33 *Goodyer, M.J.: **The Self Streamlining Wind Tunnel.** NASA TM-X-72699, Aug. 1975, 45 pp.

N75-28080#

A two-dimensional test section in a low speed wind tunnel capable of producing flow conditions free from wall interference is presented. Flexible top and bottom walls, and rigid sidewalls from which models were mounted spanning the tunnel are shown. All walls were unperforated, and the flexible walls were positioned by screw jacks. To eliminate wall interference, the wind tunnel itself supplied the information required in the streamlining process, when run with the model present. Measurements taken at the flexible walls were used by the tunnel's computer to check wall contours. Suitable adjustments based on streamlining criteria were then suggested by the computer. The streamlining criterion adopted when generating infinite flowfield conditions was a matching of static pressures in the test section at a wall with pressures computed for an imaginary inviscid flowfield passing over the outside of the same wall. Aerodynamic data taken on a cylindrical model operating under high blockage conditions are presented to illustrate the operation of the tunnel in its various modes, including cascade and ground effect.

*The University, Southampton, S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

34 *Coe, P.L., Jr.; *Graham, A.B.; and *Chambers, J.R.: **Summary of Information on Low-Speed Lateral-Directional Derivatives Due to Rate of Change of Sideslip $\dot{\beta}$.** NASA TN D-7972, Sept. 1975, 51 pp.

N75-30190#

The present paper summarizes the experience obtained by NACA and NASA concerning the low-speed lateral-directional aerodynamic derivatives due to the rate of change of sideslip $\dot{\beta}$, and includes a comprehensive bibliography on this and related subject matter. The results presented show that the magnitudes of the aerodynamic stability derivatives due to rate of change of sideslip become quite large at high angles of attack for swept- and delta-wing configurations, and that such derivatives have large effects on the calculated dynamic stability of these configurations at high angles of attack. The paper also summarizes the wind-tunnel test techniques used to measure the $\dot{\beta}$ derivatives and discusses various approaches used to predict them. Persons using this bibliography may be interested in the description of the Langley stability tunnel which was designed and constructed by the NACA at Langley in the early 1940's. The square test section had a unique capability for creating a curved airflow past the model. Jackscrews and wire screens were used to allow the walls to be set at predetermined values. A complete description of this tunnel is given in no. 26 in this bibliography.

*NASA Langley Research Center, Hampton, VA 23665

35 *Pindzola, M.; *Binion, T.W., Jr.; and **Chevallier, J.-P.: **Design of Transonic Working Sections.** A Further Review of Current Research Aimed at the Design and Operation of Large Wind Tunnels, AGARD-AR-83 (N76-11110#), Sept. 1975, Appendix 8, pp. 119—124.

N76-11110#, pp. 119-124

The concept of Sears and Ferri was under study to replace the passive boundary condition at the wall. Active control of the wall was based upon the computation of a fictitious external flowfield to insure the compatibility of the measured conditions near the wall with the conditions of unperturbed flow at infinity. Three approaches in the application of the new concept were underway.

*Arnold Engineering Development Center, Arnold Air Force Base, Tullahoma, TN 37389
**ONERA, BP 72, 92322 Chatillon Cedex, France

36 *Vidal, R.J.; *Erickson, J.C., Jr.; and *Catlin, P.A.: **Experiments With a Self-Correcting Wind Tunnel.** Presented at Symposium on "Wind Tunnel Design and Testing Techniques," London, England, Oct. 6-8, 1975. In: AGARD-CP-174 (N76-25213#), Mar. 1976, paper no. 11, 13 pp.

N76-25224#

Note: This paper is one of two that are included in no. 39 in this bibliography.

The feasibility of controlling the flow actively through the walls of a transonic, porous wall wind tunnel in order to minimize wall interference effects on a test model is demonstrated. The method is based upon measuring the components of the disturbance velocity at discrete points along an imaginary surface in the flow field within the tunnel. A mathematical formulation of the flow field exterior to the surface including the boundary condition for unconfined flow, i.e., that all disturbances vanish at infinity, is used to determine if these measured velocity components are consistent with that boundary condition. If they are not, the theory provides a better approximation to the velocity component for unconfined flow, and the flow through the tunnel walls is readjusted iteratively until the measured quantities are consistent with unconfined flow. A brief review of theoretical methods is followed by a description of the Calspan self-correcting wind tunnel design and operation, calibration with and without active wall control. Typical results obtained by approximating a conventional porous wall wind tunnel for an 0012 airfoil show that active wall control largely reproduces the correct shock wave position, eliminates wall interference of lift and drag, and reduces the interference effects on pitching moment to 10%.

*Calspan Corp., Buffalo, NY 14221
Contract N00014-72-C-0102, sponsored by ONR, AFOSR, and NASA Ames Research Center

37 *Chevallier, J.-P.: **Adaptive Wall Transonic Wind Tunnels (Soufflerie Transsonique a Parois Auto-Adaptables).** Presented at Symposium on "Wind Tunnel Design and Testing Techniques," London, England, Oct. 6—8, 1975. In: AGARD-CP-174 (N76-25213#), Mar. 1976, paper no. 12, 8 pp. (in French). Also ONERA-TP-1975-119, 10 pp. (in French).

N76-25225# (French)
A76-14462# (French)

Note: For an English translation of this paper, see no. 56 in this bibliography.

To remedy the difficulties at application of wall correction effects in high transonic flow with nonlinear phenomena, a new concept has been proposed. It consists of active control of the perturbation component normal to the wall, based on the iterative calculation of the virtual flow in an unlimited domain outside the tunnel section. The paper deals with the principle and the application means of the new testing process, preliminary study of a pilot facility, the first results obtained in two dimensional flow, and the conclusions concerning the development of this process. Extension into three-dimensions is discussed.

*ONERA, BP 72, 92322 Chatillon Cedex, France

38 *Goodyer, M.J.: **A Low Speed Self Streamlining Wind Tunnel.** Presented at the Symposium on "Wind Tunnel Design and Testing Techniques," London, England, Oct. 6-8, 1975. In: AGARD-CP-174 (N76-25213#), Mar. 1976, paper no. 13, 8 pp.

N76-25226#

A two-dimensional test section in a low speed wind tunnel produces flow conditions free from wall interference. The test section has flexible top and bottom walls, and rigid sidewalls from which the models are mounted spanning the tunnel. All walls are unperforated, and the flexible walls are positioned by screw jacks. To eliminate wall interference, the wind tunnel itself supplies the information required in the streamlining process, when run with the model present. Measurements taken at the flexible walls are used by the tunnel computer to check wall contours. When the static pressure distribution in the test section along a contoured flexible wall matches that computed for an imaginary flowfield passing over the outside of the same contour, the wall is a streamline in an infinite flowfield and the test section flow is free from wall interference. A series of iterations brings the walls from straight to streamlines. Illustrative aerodynamic data are presented, taken on a bluff body and a lifting wing.

*The University, Southampton S09 5NH, Hampshire, U.K.
Sponsored by a NASA grant

39 *Sears, W.R.; *Vidal, R.J.; *Erickson, J.C., Jr.; and *Catlin, P.A.: **Self-Correcting Wind Tunnels: Concept and Demonstration** (two reprints). CALSPAN-RK-5070-A-4, Oct. 1975, 30 pp., 35 refs.

AD A016 029 N76-18158#

Note: These two papers are also nos. 25 and 36 in this bibliography.

This report consists of two reprints, "Self-Correcting Wind Tunnels" by W.R. Sears published in the Aeronautical Journal, vol. 78, no. 758/759, February/March 1974, pp. 80-89, and "Experiments with a Self-Correcting Wind Tunnel" by R.J. Vidal, J.C. Erickson, Jr., and P.A. Catlin presented at the "Symposium on Wind Tunnel Design and Testing Techniques" organized by the AGARD Fluid Dynamics Panel in London on October 6-8, 1975.

*Calspan Corp., Buffalo, NY 14221
Contract N00014-72-C-0102

40 *Chevallier, J.-P.: **Self-Correcting Walls for a Transonic Wind Tunnel.** Presented at the 12eme Colloque d'Aerodynamique Appliquee, ENSMA/CEAT, Poitiers, France, Nov. 5-7, 1975. Also, AAAF-NT-76-10; 1976, 22 pp. (in French).

ISBN-2-7170-0388-6 N77-10080#

Note: For an English translation, see no. 57 in this bibliography.

The concept of self-correcting walls to remedy the difficulties of application of wall correction effects in high transonic flow with nonlinear phenomena is discussed. The method involves active control of the perturbation component normal to the wall, based on the iterative calculation of the virtual flow in an unlimited domain outside the tunnel section. The principle and the means of application of the new testing process are dealt with and the preliminary study of a pilot facility and the first results obtained in two-dimensional flow are presented.

*ONERA, BP 72, 92322 Chatillon Cedex, France

41 *Baronti, P.; and *Ferri, A.: **On the Development of Interference-Free Transonic Wind Tunnels.** ATL-TR-223, Dec. 1975, 14 pp.

AD A022 754 N76-32206#

A series of analyses and experiments has been performed to explore the feasibility of a method of wall corrections leading to adaptive walls for interference-free conditions in transonic wind tunnels. A summary of the relevant results is presented. The investigation has indicated that with a modification of a slotted wall by a contouring of the slats a substantial improvement towards interference-free conditions was achieved. The modification, however, was not capable of producing a substantial displacement of the shock toward expected interference-free values. The reasons for this result are discussed and attributed, most likely, to the effect of a pressure at the end of the test section higher than the free stream value.

*Advanced Technology Labs., Inc., Westbury, NY 11590
Contract N00014-73-C-0201, NR Project 061-205

42 Sychev, V.V.; and Fonarev, A.S.: **Noninductive Wind Tunnels for Transonic Investigations.** TsAGI, Uchenye Zapiski, vol. 6, no. 5 1975, pp. 1-14 (in Russian).

A78-19708# (Russian)

Note: For an English translation, see no. 69 in this bibliography.

It is shown analytically that slit or hole perforations of the test section reduce but do not eliminate wall interference in transonic wind tunnels. Murman's (1972) boundary condition for a perforated wall is extended to the case of unlike pressures in the unperturbed flow and in the chamber about the test section. Based on the results of the analysis, a method of reducing the influence of a perforated test-section by regulating the pressure in the test section chamber is proposed. A scheme of correlating the operation of a wind tunnel with a digital computer to obtain the proper sequence of pressure corrections in the chamber is presented and discussed.

43 *Bernstein, S.; and *Joppa, R.G.: **Reduction of Wind-Tunnel Wall Interference by Controlled Wall Flow.** NASA CR-2654, Mar. 1976, 57 pp.

N76-18154#

Corrections for wind tunnel wall interferences are applied successfully to high lift models when the model to tunnel size ratio is small. The accuracy of the corrections becomes poorer when larger models are tested. An alternate method of testing was developed in which flow through the porous walls of the tunnel was actively controlled so as to approximate free air conditions in the neighborhood of the model during the test. The amount and distribution of the controlled flow through the walls is computed using a potential flow representation of the model based on measured lift. Theoretical analysis is presented to prove the convergence of the method to free air conditions and to substantiate the general three-dimensional theory of operation when the normal flow distribution is continuous. A two-dimensional tunnel was constructed to evaluate the concept. Results show that substantial reduction of wall interference may be achieved with relatively low values of porosity of actively controlled walls.

*University of Washington, Seattle, WA 98195
Grant NGL-48-002-010

44 *Bernstein, S.; and *Joppa, R.G.: **Development of Minimum Correction Wind Tunnels.** Journal of Aircraft, vol. 13, no. 4, Apr. 1976, pp. 243—247.

AIAA Paper 75-144R

For abstract, see no. 28 in this bibliography.

*Univ. of Washington, Seattle, WA 98195
Grant NGL-48-002-010

45 *McDevitt, J.B.; *Levy, L.L., Jr.; and *Deiwert, G.S.: **Transonic Flow About a Thick Circular-Arc Airfoil.** AIAA Journal, vol. 14, no. 5, May 1976, pp. 606—613.

AIAA Paper 75-878R

For abstract see no. 32 in this bibliography.

*NASA Ames Research Center, Moffet Field, CA 94035

46 *Sears, W.R.: **Some Experiences With the Exploitation of Measurements of the Perturbation Field in a Wind Tunnel To Improve Simulation.** Presented at AGARD Specialists' Meeting on "Numerical Methods and Windtunnel Testing," Rhode-St.-Genese, Belgium, June 23—24, 1976. In: AGARD-CP-210 (N77-11969#), Oct. 1976, paper no. 5, 4 pp.

N77-11974#

The essential feature is that both the flow within the tunnel and the computed exterior field are iteratively adjusted to achieve the matching. The tunnel flow is adjusted by mechanical changes of tunnel wall geometry, for example, by varying the pressures in subdivided plenum chambers surrounding the working section and communicating with the tunnel through porous walls or slots. The exterior flow field is adjusted by altering the boundary values prescribed at S, on the basis of measurements of flow perturbation distributions at or near S.

*Univ. of Arizona, Tucson, AZ 85721

47 *Judd, M.; *Goodyer, M.J.; and *Wolf, S.W.D.: **Application of the Computer for On-Site Definition and Control of Wind Tunnel Shape for Minimum Boundary Interference.** Presented at AGARD Specialists' Meeting on "Numerical Methods and Windtunnel Testing," Rhode-St.-Genese, Belgium, June 23—24, 1976. In: AGARD-CP-210 (N77-11969#), Oct. 1976, paper no. 6, 14 pp.

N77-11975#

The use is described, of flexible top and bottom walls, as a means of eliminating or minimizing wall interference effects on two-dimensional wind tunnel models. Strategies for producing streamline contours and their extension to three dimensions are discussed. Errors due to theoretical assumptions and practical implementation are explored so that computational resolution can be made consistent. The need for efficient and rapidly convergent algorithms for wall adjustment is stressed and discussed. These must be developed in order to reduce the current data acquisition times and make feasible the present aim to incorporate an on-line minicomputer for automatic wall control. Results are presented showing the correctness of the strategies used with manual wall adjustment.

*The University, Southampton S09 5NH, Hampshire, U.K.

48 *Vayssaire, J.-Ch.; **Langot, M.; and **Menard, M.: **Adaptation of the Joppa Method to a Wind Tunnel With Variable Permeability (Adaptation de la Methode de Joppa a une Soufflerie a Permeabilite Variable).** Presented at AGARD Specialists' Meeting on "Numerical Methods and Windtunnel Testing," Rhode-St.-Genese, Belgium, June 23—24, 1976. In: AGARD-CP-210 (N77-11969#), Oct. 1976, paper no. 7, 17 pp. (in French).

N77-11976#

The Joppa calculation method divides the walls of a wind tunnel working section into rectangular elements with an unknown vortex ring strength and takes account of the test section dimensions and boundaries. The relative position of the model, as well as its geometry and lift distribution spanwise, allow the calculation of the theoretical permeability in any point of the ventilated walls to minimize or cancel its effect in the area of the model. Inside the plenum chambers which are around the test section of the Sigma 4 wind tunnel, flexible, solid, and movable plates are found. The movement of the plates contributes to the variation of the permeability in any point of the working section perforated walls.

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**Institut Aerotechnique de Saint-Cyr, 15 rue Marat, 78210 Saint-Cyr-l'Ecole, France

49 *Wu, J.M.; and *Moulden, T.H.: **A Survey of Transonic Aerodynamics.** Presented at AIAA 9th Fluid and Plasma Dynamics Conference, San Diego, Calif., July 14—16, 1976, 38 pp.

AIAA Paper 76-326 A76-39855#

The history of research on transonic regimes is reviewed, with remarks on the typical phenomenology of transonic flows. The current status of research into transonic flow behavior is reviewed extensively, covering the topics: local supersonic flow region, generation of shock waves, waves and drag rise, shock-free airfoils, approximation techniques and finite difference methods, hodograph techniques, inviscid unsteady flow, wall interference, wind tunnels with adaptive walls, viscous-inviscid interactions, flow separation, interactions of shocks and boundary layer wake/separation interaction, and high Reynolds number tunnels. For information on adaptive walls, see pages 17—18 and 27.

*University of Tennessee Space Inst., Tullahoma, TN 37388
Research supported by U.S. Army and Air Force

50 *Judd, M.; *Wolf, S.W.D.; and *Goodyer, M.J.: **Analytical Work in Support of the Design and Operation of Two-Dimensional Self**

Streamlining Test Sections—Semiannual Progress Report, Oct. 1975—Mar. 1976. NASA CR-145019, July 1976, 67 pp.

N76-26223#

A method has been developed for accurately computing the imaginary flow fields outside a flexible walled test section, applicable to lifting and nonlifting models. The tolerances in the setting of the flexible walls introduce only small levels of aerodynamic interference at the model. While it is not possible to apply corrections for the interference effects, they may be reduced by improving the setting accuracy of the portions of wall immediately above and below the model. Interference effects of the truncation of the length of the streamlined portion of a test section are brought to an acceptably small level by the use of a suitably long test section with the model placed centrally.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

51 *Goethert, B.H.: **Technical Evaluation Report on** (the Fluid Dynamics Panel Symposium on) **"Windtunnel Design and Testing Techniques."** AGARD-AR-97, Aug. 1976, 22 pp.

N76-30236

Note: The Proceedings of the AGARD Fluid Dynamics Panel Symposium on Windtunnel Design and Testing Techniques held in London, Oct. 6—8, 1975, are published as AGARD CP-174 (N76-25213#). Three papers from the symposium are included in this bibliography as nos. 36, 37, and 38.

This Advisory Report reviews and evaluates the Fluid Dynamics Panel Symposium and establishes recommendations for future research activities. It is observed that recent advanced design concepts, technologies, techniques and instrumentation have emerged which offer great potential for the development of highly sophisticated transonic wind-tunnel systems as well as upgrading of existing facilities. Future advanced transonic wind-tunnel systems will be able to incorporate such concepts and technologies as: cryogenic condition of the windtunnel gas; adjustable walls or adjustable cross-flow through partially opened walls; magnetic suspension and force-and-moment measuring systems; and remote measuring and scanning systems. Additional research is required to realize the full potential of each technology area. Sufficient knowledge is available today to initiate construction of advanced technology windtunnels with designs that will accommodate the future expected advances in test section wall technology, mounting systems, instrumentation, etc.

*AGARD (Advisory Group for Aerospace R&D), NATO, 7 rue Ancelle, 92200 Neuilly sur Seine, France

52 *Erickson, J.C., Jr.; and *Vidal, R.J.: **Wind Tunnel Wall Effects—Adaptive Flow Distribution.** Final Report, Nov. 15, 1971-Sept. 30, 1976, 9 pp.

AD A037 532 N77-26103#

This document summarizes a study of work done on the concept of a self-correcting wind tunnel, i.e., one which uses active control of the flow by the walls in conjunction with functional relationships among measured flow disturbance quantities to insure that unconfined-flow conditions exist in the test section. A transonic wind tunnel applying this concept has been underway at Calspan and is summarized in this report.

*Calspan Corp., Buffalo, NY 14221
Contract N00014-72-C-0102

53 *Erickson, J.C., Jr.: **Application of the Adaptive-Wall Concept to Three-Dimensional Low-Speed Wind Tunnels.** NASA CR-137917; CALSPAN-RK-5717-A-1; Sept. 1976, 77 pp.

N76-32200#

Three methods for evaluating the functional relationships required to obtain interference-free flows about a model in a wind tunnel have been developed. The first, the original multipole expansion (MPE) procedure, is based on a series of point singularities which satisfy the governing Prandtl-Glauert equation. The second, the modified MPE, provides an improved representation of finite-span wings and thereby extends the range of validity of the original MPE to larger ratios of span-to-control-surface-width. The third method is more general and is based on source distributions over the control surface. Several numerical examples are presented to help establish the range of validity of these methods. An accuracy-assessment procedure, which combines the original MPE procedure with classical wall-correction theory, has been developed to estimate the degree of interference at the model if the functional relationships are not satisfied exactly. Several numerical examples are presented for representative wings and bodies.

*Calspan Corp., Buffalo, NY 14221
NASA Contract NAS2-8777

54 *Sears, W.R.; **Vidal, R.J.; **Erickson, J.C., Jr.; and **Ritter, A.: **Interference-Free Wind-Tunnel Flows by Adaptive-Wall Technology.** Presented at the 10th Congress of the International Council of the Aeronautical Sciences, Ottawa, Canada, Oct. 3—8, 1976, 13 pp. Also, CALSPAN-RK-6040-A-1, Jan. 1977, 25 pp. Also, Journal of Aircraft, vol. 14, no. 11, Nov. 1977, pp. 1042—1050 (no. 64 in this bibliography).

ICAS Paper 76-02 A76-47351#
AD A034 889 N77-24155#

The adaptive-wall or self-correcting wind tunnel has been proposed for such regimes as transonic and V/STOL where wall effects are large and cannot be corrected for. The power and generality of the concept are pointed out. In a two-dimensional transonic embodiment in the Calspan One-Foot Tunnel, the scheme has been shown to work at lower transonic Mach numbers. Several practical problems are cited, including instrumentation, the nature of the wall modification, and convergence of the iterative procedure. Moreover, questions of shock-wave neutralization at the wall and probable configuration of three-dimensional embodiments are discussed.

*Univ. of Arizona, Tucson, AZ 85721
**Calspan Corp., Buffalo, NY 14221
Contracts N00014-72-C-0102, N00014-77-C-0052, and NAS2-8777

55 *Kemp, W.B., Jr.: **Transonic Wind-Tunnel Wall Interference.** Presented at workshop on "High Reynolds Number Research," Hampton, Va., Oct. 27—28, 1976. In: NASA CP-2009 (N77-27139), 1977, pp. 65—71.

N77-27143#

A method for analyzing wall interference is described which avoids the assumption of linear superposition of perturbations in extracting the wall induced velocity field. Measurements of pressure distribution on or near the tunnel walls during the actual wind tunnel test, are imposed as boundary values to be matched. Instead of applying wall interference corrections to the wind tunnel data, some property of the wall is adjusted until a calculated interference free criterion is satisfied for each tunnel data point. The mode of operation for the National Transonic Facility, envisioned as a correctable interference transonic tunnel, combines the capability for accurate assessment of wall interference with a limited capability for wall control.

*NASA Langley Research Center, Hampton, VA 23665

56 *Chevallier, J.-P.: **Adaptive Wall Transonic Wind Tunnels.** ESA-TT-326, Oct. 1976, 26 pp.

N77-13085#

For the original French version of this paper and an abstract, see no. 37 in this bibliography

*ONERA, BP 72, 92322 Chatillon Cedex, France

57 *Chevallier, J.-P.: **Self-Correcting Walls for a Transonic Wind Tunnel.** NASA TT F-17254, Oct. 1976, 28 pp.

N76-33222

This is an English translation, with drawings by Kanner (Les) Associates, Redwood City, Calif. For the original French version and an abstract, see no. 40 in this bibliography.

*ONERA, BP 72, 92322 Chatillon Cedex, France
Contract NASw-2790 (for translation)

58 *Levy, L.L., Jr.: **An Experimental and Computational Investigation of the Steady and Unsteady Transonic Flow Fields About an Airfoil in a Solid-Wall Test Channel.** Presented at the AIAA 10th Fluid and Plasma Dynamics Conference, Albuquerque, N. Mex., June 27—29, 1977. Also, AIAA Journal, vol, 16, June 1978, pp. 564—572 (no. 74 in this bibliography).

AIAA Paper 77-678 A77-37029#

An experimental and computational investigation of the steady and unsteady transonic flow field about a thick airfoil is described. An operational computer code for solving the two-dimensional, compressible Navier-Stokes equations for flow over airfoils was modified to include solid-wall, slipflow boundary conditions to properly assess the code and help guide the development of improved turbulence models. Steady and unsteady flow fields about an 18% thick circular arc airfoil at Mach numbers of 0.720, 0.754, and 0.783 and a chord Reynolds number of 11×10^6 are predicted and compared with experiment. For the first time, computed results for unsteady turbulent flows with separation caused by a shock wave were obtained which qualitatively reproduce the time-dependent aspects of experiments. Features such as the intensity and reduced frequency of airfoil surface-pressure fluctuations, oscillatory regions, trailing-edge and shock-induced separation, and the Mach number range for unsteady flows were all qualitatively reproduced. The upper and lower test-section walls were contoured to the shape of streamlines computed using an inviscid code.

*NASA Ames Research Center, Moffet Field, CA 94035

59 *Marschner, B.W.; *Young, R.L.; *Broome, L.E.; et al.: **Summer Faculty Systems Design Program. Integrating Wind Tunnels and Computers. Vol. 2: Details of Summer Design Study USAF/OSR/ASEE. Final Report June 13—Aug. 19, 1977.** AFOSR-78-0057 TR-Vol-2, 288 pp.

AD A050 071 N78-21167#

The design problem selected for this report was the general area of the interaction between developments in computers and the obtaining of design data from wind tunnels. One of the sub-areas was "Control of the Tunnel Parameters for Wind Tunnel Tests." In Section 2, entitled "Wind Tunnel Testing," the history of "intelligent walls" is discussed (pp. 73-82). A table includes the names of investigators and their location, types of test sections used, and names of experiments and their funding agencies. Several specific intelligent wall concepts are considered, and references are cited for these. This section concludes with suggestions for future work on adaptive walls. Pages 205—211 discuss computer systems required.

*University of Tennessee Space Inst., Tullahoma, TN 37388
Contract AF-AFOSR-3289-77

60 *AGARD: **A Review of Current Research Aimed at the Design and Operation of Large Windtunnels.** AGARD-AR-68, Mar. 1974; AGARD-AR-83, Sept. 1975; and AGARD-AR-105, Aug. 1977.

N74-21899#(AR-68)
N76-11110#(AR-83)
N77-32177#(AR-105)

This series of Advisory Reports was prepared for the Fluid Dynamics Panel of AGARD. Portions of these reports, on results and planned effort for studies and research underway in many countries, could be of interest to persons involved in adaptive wall research. Pages containing material on adaptive walls are

AGARD-AR-68, pp. 26, 27, and 46
AGARD-AR-83, pp. 20, 23, 47, 121, and 122
AGARD-AR-105, pp. 23, 24, 50, 110, 111, and 112

*AGARD (Advisory Group for Aerospace R&D), NATO, 7 rue Ancelle, 92200 Neuilly sur Seine, France

61 *Sears, W.R.: **A Note on Adaptive Wall Wind Tunnels.** Zeitschrift fuer Angewandte Mathematik und Physik, vol. 28, Sept. 25, 1977, pp. 915—927 (in English).

A78-11634

The scheme proposed by Ferri/Baronti and by Sears, in which the walls of a wind tunnel are iteratively adjusted in accordance with certain flow-perturbation measurements, is reviewed briefly. The iterative process is then simulated, within the scope of the theory of small-perturbation subsonic flows, for three cases of sinusoidal bodies in two-dimensional and circular tunnels. One of these cases is that of a lifting sinusoidal wing of small span tested in a circular tunnel. It is shown that convergence occurs in all cases if the "relaxation parameter" k, which is the fraction of the measured discrepancy distribution employed after each iteration, is chosen anywhere within a rather wide range of positive values. It is suggested that the results of this study cast light on the adaptive-wall scheme in general.

*Univ. of Arizona, Tucson, AZ 85721
Contract AFOSR-76-2954

62 *Wolf, S.W.D.; and *Goodyer, M.J.: **Self Streamlining Wind Tunnel: Low Speed Testing and Transonic Test Section Design—Semiannual Progress Report, Apr. 1976-Dec. 1976.** NASA CR-145257, Oct. 1977, 70 pp.

N78-13076#

Comprehensive aerodynamic data on an airfoil section were obtained through a wide range of angles of attack, both stalled and unstalled. Data were gathered using a self-streamlining wind tunnel and were compared to results obtained on the same section in a conventional wind tunnel. The reduction of wall interference through streamlining was demonstrated.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

63 *Capelier, C.; *Chevallier, J.-P.; and *Bouniol, F.: **A New Method for Correcting Two-Dimensional Wall Interference.** Presented at the 14th Applied Aerodynamics Colloquium, Toulouse, France, Nov. 7-9, 1977. Also, La Recherche Aerospatiale, no. 1978-1, Jan.-Feb. 1978, pp. 1-11 (in French). English translation, ESA-TT-491, Aug. 1978, pp. 1-30.

A78-32035 (French)
N79-11997 (English)

The new method proposed for the correction of wind-tunnel wall effects departs from the classical methods by doing away with the traditional boundary conditions, which are questionable for ventilated walls and are not suitable for deformed walls. It replaces them by directly introducing wall velocity measurements, thus eliminating the uncertainty in reference readings: it also avoids the need to resort to unnecessary tests to determine the porosity characteristics. Compared with recently published methods of the same type, it offers the advantage of not requiring the solution of large linear systems, but only the numerical integration of simple functions of the differences between the velocities measured at the walls and the velocities due to the model, which are calculated classically using representative singularities in free flow. After the formulation, based on a conformal mapping of the flow, some examples of application are presented: the theoretical case of the flow around a vortex in a perforated working-section; the NACA 0012 aerofoil in a closed working-section, treated numerically for an ideal fluid; specific test cases for wind-tunnels with adaptive or perforated walls.

*ONERA, BP 72, 92322 Chatillon Cedex, France

64 *Sears, W.R.; **Vidal, R.J.; **Erickson, J.C., Jr.; and *Ritter, A.: **Interference-Free Wind-Tunnel Flows by Adaptive-Wall Technology.** Journal of Aircraft, vol. 14, no. 11, Nov. 1977, pp. 1042—1050.

For abstract see no. 54 in this bibliography.

*Univ. of Arizona, Tucson, AZ 85721
**Calspan Corp., Buffalo, NY 14221
Contracts N00014-72-C-0102 and NAS2-8777

65 *Lo, C.-F.; and *Kraft, E.M.: **Convergence of the Adaptive-Wall Wind Tunnel.** AIAA Journal, vol. 16, no 1, Jan. 1978, pp. 67—72.

A78-18232#

Analytical functional relationships for exterior and interior regions with respect to the control surface inside a two-dimensional wind tunnel are used to investigate the iteration procedure for an adaptive-wall wind tunnel. Convergence to interference-free conditions is proven for any symmetric model in subsonic flow. Also, formulas are presented for determining interference-free conditions directly from two measured flow variables at the measuring plane, thus enabling an adaptive-wall wind tunnel to achieve unconfined flow in a single adjustment. A wavy-wall model and an NACA 0012 airfoil are used as examples to examine the convergence and validate the derivation. In addition, a numerical solution to the transonic small disturbance equation is used to demonstrate the convergence of the adaptive-wall iterative procedure for supercritical flow on an airfoil.

ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389

66 *Goodyer, M.J.: **Developments in Airfoil Testing Techniques at University of Southampton.** Presented at the Conference on Advanced Technology Airfoil Research," Hampton, Va., Mar. 7—8, 1978. In: NASA CP-2045, Vol. I, Pt. 1 (N79-20030), Mar. 1979, pp. 415—423.

N79-20056#

The evolution in Europe of the flexible walled test section, as applied to two-dimensional testing at low and transonic speeds, is traced from its beginnings at NPL, London, in the early 1940's, and is shown to lead logically to the latest version now nearing completion at Southampton University. The principal changes that have taken place are improvements in the methods of choosing wall contours such that they rapidly follow appropriate streamlines, and reductions in the depth of test section. Most effort is directed to the simulation of an indefinite two dimensional flowfield around a single isolated airfoil. Test data illustrate the large reductions of wall interference obtained as the wall contours are moved from straight to streamline in an infinitely deep flowfield. The latest transonic test section presently under assembly at Southampton is described, the design drawing on the accumulated past experience. It has as its principal new feature the facility for the automation of wall streamlining with the aid of an on-line computer. The versatility of the flexible walled test section is emphasized by reference to the simulation of alternative flows including cascade, steady pitching in an infinite flowfield, and ground effect. Finally, sources of error in streamlining are identified, with methods for their alleviation.

*The University, Southampton S09 5NH, Hampshire, U.K.
Partly supported by NASA Grant NSG-7172

67 *Ladson, C.L.: **A New Airfoil Research Capability.** Presented at the Conference on "Advanced Technology Airfoil Research" Hampton, Va., Mar. 7—8, 1978. In: NASA CP-2045, Vol. I, Pt. 1 (N79-20030), Mar. 1979, pp. 425-432.

N79-20057#

The design and construction of a self streamlining wall test section for the Langley 0.3-Meter Transonic Cryogenic Tunnel has been included in the fiscal year 1978 construction of facilities budget for Langley Research Center. The design is based on the research being carried out by M.J. Goodyer at the University of Southampton, Southampton, England, and is supported by Langley Research Center. This paper presents a brief description of the project. Included are some of the design considerations, anticipated operational envelope, and sketches showing the detail design concepts. Some details of the proposed operational mode, safety aspects, and preliminary schedule are presented.

*NASA Langley Research Center, Hampton, VA 23665

68 *Vidal, R.J.; and *Erickson, J.C., Jr.: **Research on Self-Correcting Wind Tunnels.** Presented at the Conference on "Advanced Technology Airfoil Research," Hampton, Va., Mar. 7—8, 1978. In: NASA CP-2045, Vol. I, Pt. 2 (N79-19989), Mar. 1979, pp. 487—498.

N79-19992#

The Calspan self-correcting wind tunnel is a two-dimensional facility in which the flow field in the vicinity of the walls is actively controlled, and a theoretical evaluation is used in conjunction with flow field measurements to confirm that wall interference was minimized. The facility is described, and the results of experiments with a 6-percent-blockage model are presented to show that iterative application of wall control effectively eliminates the interference. Experiments were performed at conditions where the flow at the walls was supercritical, and a new operating procedure is described for these conditions. The results of an analysis of the flow in the auxiliary suction system and test section illustrate the tradeoffs available in the design of self-correcting wind tunnel test sections and in model sizing for such tunnels.

*Calspan Corp., Buffalo, NY 14221
Contracts N00014-72-C-0102, N00014-77-C-0052, and F40600-76-C-0011

69 Sychev, V.V.; and Fonarev, A.S.: **Noninductive Wind Tunnels for Transonic Investigations.** Foreign Technology Division, Air Force Systems Command, Wright-Patterson AFB, Apr. 12, 1978, 29 pp.

AD B033 716L X81-72169

This translation is available to U.S. Government Agencies only. For the original Russian version and an abstract, see no. 42 in this bibliography.

70 *Vidal, R.J.; and *Erickson, J.C., Jr.: **Experiments on Supercritical Flows in a Self-Correcting Wind Tunnel.** Presented at the AIAA

10th Aerodynamic Testing Conference, San Diego, California, Apr. 19-21, 1978. In: Technical Papers, pp. 136-141.

AIAA Paper 78-788 A78-32345#

The Calspan Self-Correcting Wind Tunnel is a two-dimensional facility in which the flow field in the vicinity of the walls is actively controlled, and a theoretical evaluation is used in conjunction with flow-field measurements to confirm that wall interference has been minimized. The facility is described and the results of experiments with a 6%-blockage model are presented to show that iterative application of wall control effectively eliminates the interference. Experiments were performed at conditions where the flow at the walls was supercritical, and a new operating procedure is described for these conditions. A method is reported for designing self-correcting test sections. This method is based upon a detailed analysis of the flow in the auxiliary suction system and test section. The results of the analysis illustrate the tradeoffs available in design studies and in sizing models.

*Calspan Corp., Buffalo, NY 14221
AFOSR and ONR Contracts N00014-72-C-0102 and N00014-77-C-0052; AEDC Contract F40600-76-C-0011

71 *Lo, C.-F.: **Tunnel Interference Assessment by Boundary Measurements.** AIAA Journal, vol. 16, no. 4, Apr. 1978, pp. 411-413.

A78-30689#

An approach is proposed which avoids the difficulties encountered in the classical method of assessing and correcting wind tunnel interference. This approach requires only the measurement of flow variables at a control surface near the tunnel wall inside the test section. A two-dimensional example is chosen to illustrate the formulation of the computation procedure. The Fourier transform technique is applied to the subsonic flow case for obtaining the interference flowfield and the flow variables under free-air conditions at the control surface. To validate the approach, a numerical demonstration is performed by simulating the flow in a wind tunnel with the inviscid transonic small-disturbance equation. The approach is also verified experimentally for a two-dimensional 15.24-cm-chord airfoil, the tunnel test section configuration consisting of variable perforated walls for the top and bottom walls and solid plexiglass sidewalls.

*ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389

72 *Atkinson, A.J.: **Three-Dimensional Low Speed Minimum Interference Wind Tunnel Simulation Based on Potential Modeling.** M.S. Thesis, Dept. of Aeronautics and Astronautics, Univ. of Washington, May 1978, 150 pp. (Microfiche available from Univ. of Washington.)

The purpose of the minimum interference wind tunnel is to closely match the free air flow field inside the tunnel test section. Consequently, the validity of the experimentally obtained test data for high lift vehicles is significantly improved. A computer model is developed to simulate a three-dimensional low speed minimum interference wind tunnel. The wind tunnel interference is minimized by controlling the flow through the active portions of the tunnel walls. It is believed that control need be exerted over only part of the tunnel walls to closely approximate free air flow conditions inside the tunnel. Results from the analytical study of the actively controlled wall tunnel, matching free air flow boundary conditions at the active wall portions of the tunnel, demonstrate that it is possible to substantially reduce the amount of tunnel wall interference and apply corrections to account for the small remaining effects. In particular the pitching moment correction attributed to the reduced wall interference is minor and may be ignored in most instances.

*Univ. of Washington, Seattle, WA 98185

73 *Lo, C.-F.; and *Sickles, W.L.: **A Hybrid Method of Transonic Computation With Application to the Adaptive Wind Tunnel.** Presented at the Eighth U.S. National Congress of Applied Mechanics, Los Angeles, Calif., June 26—30, 1978, 21 pp. In: Proceedings, published on behalf of the Congress by Western Periodical Co., 1979.

TA350.N3, 1978

For transonic flow with subsonic free-stream Mach number, the far field remains subsonic. In the finite difference computation, the far-field boundary conditions may be treated analytically by the subsonic small perturbation equation. A hybrid method is formulated to reduce the size of the discretized finite difference region with an analytic solution matching at a selected control surface in an iterative process. For subcritical flow, no iteration is required for the hybrid method since the analytic expression is derived from the subsonic equation. For supercritical flow, only a few iterations are needed to make the solution convergent. In addition to reducing computation time, the functional relationship derived can be applied to the adaptive wall wind tunnel for accelerating convergence of the tunnel wall boundary in achieving interference-free conditions.

ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389

74 *Levy, L.L., Jr.: **Experimental and Computational Steady and Unsteady Transonic flows About a Thick Airfoil.** AIAA Journal, vol. 16, June 1978, pp. 564—572.

AIAA Paper 77-678 A77-37029#

For abstract, see no. 58 of this bibliography.

*NASA Ames Research Center, Moffett Field, CA 94035

75 *Wolf, S.W.D.: **Self Streamlining Wind Tunnel: Further Low Speed Testing and Final Design Studies for the Transonic Facility.** NASA CR-158900, June 1978, 37 pp.

N78-30144#

Work was continued with the low speed self streamlining wind tunnel (SSWT) using the NACA 0012-64 airfoil in an effort to explain the discrepancies between the NASA Langley low turbulence pressure tunnel (LTPT) and SSWT results obtained with the airfoil stalled. Conventional wind tunnel corrections were applied to straight wall SSWT airfoil data, to illustrate the inadequacy of standard correction techniques in circumstances of high blockage. Also one SSWT test was re-run at different airspeeds to investigate the effects of such changes (perhaps through changes in Reynolds number and freestream turbulence levels) on airfoil data and wall contours. Mechanical design analyses for the transonic self streamlining wind tunnel (TSWT) were completed by the application of theoretical airfoil flow field data to the elastic beam and streamline analysis. The control system for the transonic facility, which will eventually allow on-line computer operation of the wind tunnel, was outlined.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

76 *Igeta, Y.: **Konstruktion und Erprobung von flexiblen Wanden fur die MeBstrecke des ILR-Hochgeschwindigkeits-Windkanals. (Construction and Test of Flexible Walls for the Throat of the ILR High-Speed Wind Tunnel).** ILR Technical Univ. Berlin, Studienarbeit, Sept. 1978 (in German).

For translation into English and an abstract, see no. 158 in this bibliography.

*Institut fur Luft- und Raumfahrt Technische Universitat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)

77 *Dowell, E.H.: **A Compliant Wall, Supersonic Wind Tunnel.** The Aeronautical Journal, vol. 82, Oct. 1978, pp. 448-451. (An author's

errata is contained in The Aeronautical Journal, vol. 83, Aug. 1979, p. 322.) Also, presented at the AIAA 17th Aerospace Sciences Meeting, New Orleans, La., Jan. 15-17, 1979.

AIAA Paper 79-0110 A79-19537#

The concept of the self-correcting wind tunnel is broadened to allow at least the magnitude of the wall shape to vary with flow conditions, e.g., flow dynamic pressure. Two-dimensional supersonic flow is considered in the context of small perturbation theory, and the compliant wall is modeled as rigid hinged segments whose compliance is determined by attached springs. Single segments with the hinge at the leading edge or at the trailing edge are investigated, conditions for zero wall interference are obtained, and the generalization to multiple wall segments that would be required for an airfoil with arbitrary downwash is briefly outlined. The analysis indicates that a wall segment with a leading-edge hinge is more promising than one with a trailing-edge hinge because the latter is subject to aeroelastic divergence and that a compliant-wall wind tunnel shows real promise as a concept for reducing wind-tunnel wall interference.

*Princeton Univ., Princeton, NJ 08540
Grant AF-AFOSR-77-3337

78 *Vidal, R.J.; and *Erickson, J.C., Jr.: **Research on Adaptive Wall Wind Tunnels. Final Report, May 1976-Nov. 1977.** CALSPAN-RK-5934-A-1; AEDC-TR-78-36; Nov. 1978, 66 pp.

AD A062 110 N79-20144#

The objective of this research was to investigate the utility of the Calspan self-correcting wind tunnel for minimizing or eliminating wall interference effects in two-dimensional transonic flows when shock waves from the test model extend to the tunnel walls. This report summarizes the experimental research performed with two-dimensional airfoils in the Calspan self-correcting wind tunnel and the theoretical research accomplished in support of the experiments. The experiments were performed with airfoil models having 4% and 6% solid blockage. The initial experiments with the 6%-blockage model were devoted to determining a practical mode of operation when shock waves from the model extend to the wall. The most practical mode is to use wall control to obtain the desired distribution of longitudinal velocity components for subcritical walls. The Mach number is then increased and the wall control is readjusted, sequentially, until the desired test condition is achieved. At the high Mach numbers of interest, however, the available wall control was limited locally, and tunnel system changes were required. A method is reported for analyzing self-correcting wind tunnels with porous walls.

*Calspan Corp., Buffalo, NY 14221
Contract F40600-76-C-0011

79 *Dowell, E.H.; and *Bliss, D.B.: **Wind Tunnel Wall Interference —Interim Report, Apr. 1, 1977-April 1, 1978.** AFOSR-78-1057TR, 1978, 50 pp.

AD A055 735 N78-32112#

A progress report on two aspects of theoretical research on improved understanding and reduction of wind tunnel wall interference is given. In part one, the compliant wall concept is studied for steady, two-dimensional supersonic flow. The compliant wall is modeled as a hinged plate with a torsional spring restraint. The combinations of flow dynamic pressure, wall geometry, and wall compliance which lead to minimum wall interference with the flow over a lifting airfoil are identified. In part 2, an improved theoretical model for flow over and through a slotted wall is constructed. The model takes into account streamline curvature in the direction of flow as well as flow through the slot perpendicular to the direction of flow. The theoretical relationship which is obtained between pressure differential across the slot and mass flow through the slot shows both the linear and quadratic regimes observed in experiments. Quantative agreement with existing experimental data is also encouraging.

*Princeton Univ., Princeton, NJ 08540
Grant AF-AFOSR-77-3337

80 *Poisson-Quinton, P.: **Some New Approaches for Wind-Tunnel Testing Through the Use of Computers.** Presented at the 1st Intersociety Atlantic Aeronautical Conference, Williamsburg, Va., Mar. 26—28, 1979. In: Technical Papers (A79-27351), pp. 158-171. Also, ONERA-TP-1979-24, 1979, 14 pp.

AIAA Paper 79-0707 A79-27367#

New approaches for wind-tunnel testing methods designed by ONERA are described. Section C, pp. 9-11, "Development of a Transonic Test-Section with Self-Adaptive Walls" is concerned with the ONERA/CERT T2 transonic tunnel and the adaptive wall work there. The test section was coupled with the computer in closed-loop in order to reduce transonic wall interference. This new method of wall effect correction was extended to periodic three-dimensional flow making it possible to consider the use of such a two-dimensional, self-adaptive test section for tests on models of arbitrary shape. This approach to a better simulation of transonic flow is an interesting first example of a sophisticated integration of the computer with the wind tunnel.

*ONERA, BP 72, 92322 Chatillon Cedex, France

81 *Ganzer, U.: **Wind Tunnels With Adapted Walls for Reducing Wall Interference (Windkanale mit adaptiven Waden zur Beseitigung von Wandinterferenzen).** Zeitschrift fur Flugwissenschaften and Weltraumforschung, vol. 3, no. 2, Mar.—Apr. 1979, pp. 129-133 (in German).

Note: For an English translation, see no. 85 in this bibliography.

The basic principle of adaptable wind tunnel walls is explained. First results of an investigation carried out at the Aero-Space Institute of Berlin Technical University are presented for two-dimensional flexible walls and an NACA 0012 airfoil. With five examples exhibiting very different flow conditions it is demonstrated that it is possible to reduce wall interference and to avoid blockage at transonic speeds by wall adaptation.

*Institut fur Luft- und Raumfahrt, Technische Universitat Berlin, Marchstrasse 14, Sekr. F2 D-1000 Berlin 10, West Germany (FRG)

82 *Erickson, J.C., Jr.: **Adaptive-Wall Technology for V-STOL Testing.** Presented at a Workshop on V/STOL Aircraft Aerodynamics, Monterey, Calif., May 16-18, 1979. In: Proceedings, Vol. 1 (N80-19074#), WADC.

AD A079 115 N80-19074, pp. 444-461

The adaptive-wall wind tunnel concept has been proposed for both V/STOL and transonic testing where wall interference effects are large and corrections cannot be made. The tunnel walls are used actively to control the flow field, and a theoretical calculation is used in conjunction with flow-field measurements to confirm that wall interference has been minimized, if not eliminated. For the transonic case, a 2-dimensional, adaptive-wall test section is under investigation in the Calspan One-Foot Wind Tunnel. This test section is described and experimental results with a 6%-blockage airfoil model are presented to demonstrate that iterative application of wall control effectively eliminates wall interference. The V/STOL application is based on the same principles as the transonic.

*Calspan Advanced Technology Center, Buffalo, NY 14221

83 *Sears, W.R.: **Adaptive Wind Tunnels With Imperfect Control.** Journal of Aircraft, vol. 16, May 1979, pp. 344-348.

A79-34598#

Note: For another form of this paper see no. 139 in this bibliography.

An earlier study of the convergence of the adaptive-wall wind-tunnel scheme for a sinusoidal model in a two-dimensional tunnel is extended to the case where ideal matching at the interface cannot be achieved. It is assumed that in place of the desired sinusoidal correction, a correction including an extraneous harmonic always occurs. Two different assumptions are made regarding the fitting of this distorted sinusoid to the observed error signal. It is found that the iteration converges for the same range of relaxation constants as for the ideal case, but that unconfined flow is not achieved. For reasonable numerical values, the iteration nevertheless appears to make substantial improvement in a flow involving boundary interference.

*Univ. of Arizona, Tucson, AZ 85721
Grant AF-AFOSR-76-2954E

84 *Pollock, N.: **A Proposal for Aerodynamically Actuated Self Streamlining Subsonic Wind Tunnel Walls.** ARL-Aero-Note-392; AR-001-739; June 1979, 27 pp.

N80-29374#

An arrangement is described which ensures that solid flexible two-dimensional subsonic wind tunnel walls will automatically and continuously assume a shape approximating an unconstrained streamline under the action of a model pressure field. Such a tunnel wall would minimize interference. Each wall consists of a streamwise tensioned membrane with a series of pressure tappings. These pressure tappings communicate with a number of flexible bellows which apply appropriate local forces to the membrane. Methods covering the extension of this concept to a three-dimensional configuration are also discussed.

*Aeronautical Research Labs., Melbourne, Victoria 3001, Australia

85 *Ganzer, U.: **Wind Tunnels With Adapted Walls for Reducing Wall Interference.** NASA TM-75501, Aug. 1979, 14 pp.

N79-31230#

This is an English translation by Kanner (Leo) Associates, Redwood City, Calif. For the original German, see no. 81 in this bibliography.

*Institut fur Luft und Raumfahrt, Technishe Universitat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)
NASw-3199 (for translation)

86 *Wolf, S.W.D.; and *Goodyer, M.J.: **Studies of Self Streamlining Wind Tunnel Real and Imaginary Flows—Progress Report to July 1978.** NASA CR-158831, Aug. 1979, 75 pp.

N79-20142#

Checks on the Predictive Method for Rapid Wall Adjustment have revealed that the wall streamlines selected by this method are satisfactory. Wake surveys behind an airfoil model in near free air conditions and in SSWT are roughly the same. Imperfections in the test environment prevent a more positive claim. However, the surveys in SSWT suggest that a reason for lift data disparity may be the absence of zones of potential flow near the downstream portions of the flexible walls when the model was at a high angle of attack. Measurements of purely rotary derivatives with high blockage models in a streamlined test section agree well with theory. The operating mechanics and the empty-test-section aerodynamics of the new transonic flexible walled test section have proved satisfactory.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

87 *Kraft, E.M.; and *Parker, R.L., Jr.: **Experiments for the Reduction of Wind Tunnel Wall Interference by Adaptive-Wall Technology—Final Report, Oct. 1977-Sept. 1978.** AEDC-TR-79-51, Oct. 1979, 43 pp.

AD A076 555 N80-17088#

Experiments were conducted in the AEDC Aerodynamic Wind Tunnel (1T) to evaluate the applicability of adaptive-wall technology to reduce wall interference in a transonic wind tunnel. Data were obtained on a six-percent-blockage, two-dimensional, NACA 0012 airfoil section with two different, adaptable porous wall configurations. One configuration featured variable longitudinal control of the local hole angle and the other featured global porosity control. The experiments demonstrated that adaptive-wall techniques could be used to significantly reduce wall interference effects. Although neither wall configuration could be adjusted to duplicate the pressure distributions (calculated at the tunnel boundary control surface with adaptive-wall technology) to produce interference-free conditions, matching the pressure level upstream of the model and minimum pressure in the vicinity of the model adequately reduced the wall interference. One of the most effective means for matching these global parameters was plenum pressure adjustment; thus, some refinement may be obtained through segmented plena control.

*ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389

88 *Lo, C.-F.; and *Sickles, W.L.: **Analytic and Numerical Investigation of the Convergence for the Adaptive-Wall Concept—Final Report, Oct. 1977-Mar. 1978.** AEDC-TR-79-55, Nov. 1979, 40 pp.

AD A078 203 N80-19134#

Convergence of the iteration for the adaptive wall concept is analytically proved for two-dimensional and axisymmetric subsonic flows. One-step convergence formulae which determine the unconfined boundary conditions directly from two measured flow variables at the measuring surface are presented to accelerate the iterative procedure. The application of the one-step formulae to numerical examples of an NACA 0012 airfoil illustrates the capability of these formulae for subcritical as well as supercritical flows.

*ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389

89 *Harney, D.J.; and *White, H.L.: **An Assessment of Solid and Ventilated Sidewalls for Transonic Wind Tunnels.** AFFDL-FX 79-1, 1979, 11 pp.

N82-77331

The question of solid versus adaptive or ventilated sidewalls has been revisited to evaluate the use of versatile, high visibility solid sidewalls for an advanced transonic wall employing upper and lower adaptive walls for 2-D, half span, and 3-D model tests. Using a variable slotted transonic tunnel with and without solid sidewalls, it appears that solid sidewalls do not grossly distort the 3-D data. The agreement is quite good for a 6% open area test section with either solid or slotted sidewalls for $0.70 \leq M \leq 0.95$. The limited results from this study make it difficult to justify the additional complexity of adaptive transonic sidewalls at the expense of reduced or no flow visualization.

*Air Force Flight Dynamics Lab., (AFFDL), Wright-Patterson AFB, OH 45433

90 *Wolf, S.W.D.: **Application of Data Acquisition Systems for On-Line Definition and Control of Wind Tunnel Shape,** 46 pp. In: Data Acquisition Systems and Data Analysis in Fluid Dynamics, Von Karman Inst. for Fluid Dynamics (N80-12354), 1979.

N80-12356#

Improvements in wind tunnel design to reduce test and flight discrepancies are analyzed. Flexible wall streamlining, criteria for tunnel streamlining, and error assessment are discussed. It is concluded that the concept of self-streamlining wind tunnels is suited for on-line computer control.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

91 *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.** Presented at the AIAA 18th Aerospace Sciences Meeting, Pasadena, Calif., Jan. 14-16, 1980, 7 pp. Also, Journal of Aircraft, vol. 18, Sept. 1981, pp. 707-711 (no. 118 in this bibliography). Also, Flow Research Rep. No. 164, May 1980.

AIAA Paper 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 program 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 Company, 21414 68th Ave. South, Kent, WA 98031

**New York Univ., 251 Mercer, New York, NY 10012
Contract F40600-79-C-001

92 *Parker, R.L., Jr.; and *Sickles, W.L.: **Application of Adaptive-Wall Techniques in a Three-Dimensional Wind Tunnel With Variable Wall Porosity.** Presented at AIAA 18th Aerospace Sciences Meeting, Pasadena, Calif., Jan. 14-16, 1980, 10 pp. Also, Journal of Aircraft, vol. 18, no. 3, Mar. 1981, pp. 176-183, (no. 112 in this bibliography).

AIAA Paper 80-0157 A80-18370#

The adaptive-wall concept requires that to obtain unconfined flow conditions in a wind tunnel in the presence of any model it is necessary and sufficient to match independent measured flow variables on a surface near the tunnel boundary with flow variables which satisfy the unconfined, undisturbed boundary condition at infinity. The technique was employed at a limited number of test conditions to individually adjust the variable porosity walls of the AEDC Aerodynamic Wind Tunnel (4T) to minimize wall interference effects on a generalized transonic model configuration. Data improvement was demonstrated for each set of conditions. A procedural description and results of the experiment are presented.

*ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389

93 *Ziemann, J.: **Convergence Behavior that Controls Adaptable Wind Tunnel Walls in the Test Section in the High Angle of Attack Range (Das Konvergenzverhalten der Regelung adaptiver Windkanalwande bei Profiluntersuchungen im Hochanstellwinkel-Bereich).** ILR-Mitt. 66, Technical Univ. Berlin, Jan. 1980, 76 pp. (in German).

Note: For an English translation see no. 148 in this bibliography.

The NACA 0012 profile at Mach 0.5 was investigated in a wind tunnel with adaptive walls. It is found that adaptation of the flexible walls is possible in the high angle of attack range on both sides of maximum lift. Oil film photographs of the flow at the profile surface show three-dimensional effects in the region of the corners between the profile and the sidewall. It is concluded that pure two-dimensional separated flow is not possible.

*Institut fur Luft- und Raumfahrt, Technische Universitat Berlin, Marchstraβe 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)

94 *Bodapati, S.; **Schairer, E.; and **Davis, S.: **Adaptive-Wall Wind-Tunnel Development for Transonic Testing.** Presented at the AIAA 11th Aerodynamic Testing Conference, Colorado Springs, Colo., Mar. 18-20, 1980, 11 pp. Also, Journal of Aircraft, vol. 18, no. 4, Apr. 1981, pp. 273-279, (no. 113 in this bibliography).

AIAA Paper 80-0441 A81-31367

In principle, the adaptive-wall wind tunnel is an attractive alternative to traditional methods of accounting for wind-tunnel wall interference. The concept has been successfully demonstrated for two-dimensional flows at moderately supercritical Mach numbers, but more work needs to be done before the method can be used in production testing. In this paper experimental techniques for rapid assessment and correction of wall interference are described. The method is based on laser velocimetry measurements on two control surfaces and on the use of a dedicated computer for rapid data processing. The experimental arrangement and instrumentation are described and typical results from an experiment on a nonlifting NACA 0012 airfoil at M = 0.78 are discussed.

*Joint Institute for Aeronautics & Acoustics, Dept. of Aeronautics & Astronautics, Stanford Univ., Stanford, CA 94305-2186
**NASA Ames Research Center, Moffett Field, CA 94035

95 *Goodyer, M.J.; and *Wolf, S.W.D.: **The Development of a Self-Streamlining Flexible Walled Transonic Test Section.** Presented at the AIAA 11th Aerodynamic Testing Conference, Colorado Springs, Colo., Mar. 18-20, 1980. In: Technical Papers, CP801 (A80-26929), pp. 325-335. Also, AIAA Journal, vol. 20, no. 2, Feb. 1982, pp. 227-234 (no. 125 in this bibliography).

AIAA Paper 80-0440-CP A80-26964#

This design eliminates the uncertainties in data from conventional transonic test sections. Sidewalls are rigid, and the flexible floor and ceiling are positioned by motorized jacks controlled by an on-line computer to minimize run times. The tunnel-computer combination is self-streamlining without reference to the model. Data are taken from the model only when the walls are good streamlines, and are corrected for the small, known but inevitable residual interferences. Two-dimensional validation testing in the Mach range up to about 0.85 where the walls are just supercritical shows good agreement with reference data using a height:chord ratio of 1.5. Techniques are under development to extend Mach number above 1. This work has demonstrated the feasibility of almost eliminating wall interferences, improving flow quality, and reducing power requirements or increasing Reynolds number. Extensions to three-dimensional testing are outlined.

*The University, Southampton S09 5NH, Hampshire, U.K.

NASA Grant NSG-7172; research also partly supported by the Science Research Council of England.

96 *Whitfield, J.D.; *Pate, S.R.; *Kimzey, W.F.; and *Whitfield, D.L.: **The Role of Computers in Aerodynamic Testing.** Computers and Fluids, vol. 8, Mar. 1980, pp. 71—99.

A80-27413#

This paper describes some of the progress that has been achieved by interfacing the digital computer with the major developmental wind tunnels and engine test units at the USAF Arnold Engineering Development Center. Present trends and future testing needs are identified, and the role of the digital computer in future aerodynamic testing is discussed. Section 5.3 (pp. 88-91), "Development of Adaptive Walls for Transonic Wind Tunnels," is of special interest to persons using this bibliography. The research described was performed by the Arnold Engineering Development Center, Air Force Systems Command.

*Sverdrup Technology, Inc., 600 William Northern Boulevard, P.O. Box 884, Tullahoma, TN 37388

97 *Erickson, J.C., Jr.; and *Wittliff, C.E.: **Development of an Interference-Free Self-Adjusting, Transonic Wind Tunnel—Quarterly Progress Report** Feb. 1, 1980-April 30, 1980, 9 pp.

N82-72454

The development of an interference-free, self-adjusting, transonic wind tunnel is continuing. Effort is being devoted to experimental research in the two-dimensional, perforated-wall, segmented-plenum test section of the Calspan One-Foot Tunnel. The experiments will investigate the operational characteristics of the test section at high-subsonic free-stream Mach numbers. An important aspect of the research was the investigation of a static-pipe measuring technique for determining the normal velocity distributions.

*Aerodynamic Research Dept., Calspan Advanced Technology Center, Buffalo, NY 14221
Contract N00014-77-C-0052, NR Proj. 061-199

98 *Holst, H.: **German Activities on Wind Tunnel Corrections.** Presented at a round table discussion following the AGARD Fluid Dynamics Symposium, Munich, Germany, May 8, 1980. In: Wind Tunnel Corrections for High angle of Attack Models, AGARD-R-692 (N81-24120), Feb. 1981, paper no. 4, 23 pp.

N81-24124#

Wind tunnel interference factors were calculated for open, closed, slotted, and perforated walls using the vortex lattice method with a homogeneous boundary condition. A more realistic pitching moment correction is obtained when the lift dependent relocation of the trailing vortices is taken into account. The inhomogeneities of lift and blockade interference parameters throughout the test section were investigated for models large in comparison to the test section dimensions. A method was developed using measured wall pressures for the correction of drag in transonic wind tunnels. For closed test sections, the image method and a modified vortex lattice method were used to evaluate wall pressure signals for correction purposes.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FGR)

99 *Young, A.D.: **Wind Tunnel Corrections for High Angles of Attack: A Brief Review of Recent UK Work.** Presented at a round table discussion following the AGARD Fluid Dynamics Symposium, Munich, Germany, May 8, 1980. In: Wind Tunnel Corrections for High Angle of Attack Models, AGARD-R-692 (N81-24120), Feb. 1981, paper no. 7, 11 pp.

N81-24127#

The use of adaptive walls, a panel method of model and wake representation for a two-dimensional model in a wind tunnel with solid walls, the use of measured pressure distributions on tunnel floor and roof also for a two-dimensional model and solid walls, a vortex lattice representation of the tunnel walls to take account of wake curvature, interference limitations on tests on V/STOL models with lifting jets, and work on blockage corrections on models with reverse thrust are discussed. Some discussion is offered on the limitations on the validity of current methods for determining wind tunnel corrections and it is argued that these limitations are least severe with the use of adaptive walls.

*Queen Mary College, London, England

100 *Erickson, J.C., Jr.; *Wittliff, C.E.; and *Daughtery, D.C.: **Further Investigations of Adaptive-Wall Wind Tunnels—Final Report, Aug. 1978-Dec. 1979.** CALSPAN-6374-A-1, May 1980; AEDC-TR-80-34, Oct. 1980. 72 pp.

AD A091 774 N81-13977#

The objective of this investigation was to continue the assessment of the Calspan perforated-wall, segmented-plenum adaptive-wall wind tunnel for flows in which the tunnel walls are supercritical. An important aspect of the investigation was the development of a static pipe measuring technique for determining the normal velocity distributions. This technique was developed to overcome the limitations on the number of flow angle probe measurements that could be made in the Calspan tunnel. The flow about a static pipe in the presence of model/wall induced disturbances was analyzed within the framework of slender body theory to give the relationship between differential pressure measurements across the pipe and the streamwise derivative of the normal velocity at the pipe centerline.

*Calspan Corp., Buffalo, NY 14221
Contract F40600-78-C-0003

101 *Barg, J.: **The Development of Computer Control for Application to Flexible Wind Tunnel Walls (Entwicklung einer prozeBrechnergesteuerten Regeleinrichtung fur die Adaption flexiblen Windkanalwanden.)** ILR Mitt. 70, Technical Univ. Berlin, July 1980, 50 pp. (in German).

Note: For the English translation of this report see no. 144 in this bibliography.

Measurements made in a wind tunnel test section from model tests are generally inaccurate due to wall interference effects. However, with adaptable flexible test section walls such inaccuracies may, to a large extent, be avoided by lessening the blockage in the test section. The basic idea of adaptable walls has been successfully proven in various research establishments. With the first experiments, it became clear that delay times in setting up the walls had to be decreased if the application to commercial tunnels was to be successful. There are three problem categories:

1. Ascertainment of the wall pressure distribution
2. Calculation of the wall contour
3. Shaping of the walls

The present study describes how these problems were solved for the high speed wind tunnel of the Technical University of Berlin.

*Institut fur Luft- und Raumfahrt, Technische Universitat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)

102 *Pollock, N.: **Self Streamlining Wind Tunnels Without Computers.** 7th Australasian Conference on Hydraulics and Fluid Mechanics, Brisbane, Australia, Aug. 18-22, 1980. In: Preprints of Papers (A82-26176), Institution of Engineers (Barton, Australia), 1981, pp. 123-126.

A82-26181#

A brief review of wind tunnel wall interference is presented with particular emphasis on "self correcting" and "correctable interference" tunnels. Two simple methods of modifying tunnel walls to approximate unconstrained flow streamlines are presented. One method, which requires only very limited computation, involves the use of an analytic expression for the far field flow, and the other, which requires no computation, uses purely mechanical wall arrangement which deflects appropriately under the applied pressure field.

*Aeronautical Research Labs., Melbourne, Victoria 3001, Australia

103 *Shindo, S.; and *Joppa, R.G.: **An Experimental Investigation of Three Dimensional Low Speed Minimum Interference Wind Tunnel for High Lift Wings.** NASA CR-164439, Sept. 1980, 24 pp.

N81-25037#

As a means to achieve a minimum interference correction wind tunnel, a partially actively controlled test section was experimentally examined. A jet flapped wing with 0.91 m (36 in.) span and AR = 4.05 was used as a model to create moderately high lift coefficients. The partially controlled test section was simulated using an insert, a rectangular box 0.96 × 1.44 m (3.14 × 4.71 ft) open on both ends in the direction of the tunnel air flow, placed in the University of Washington Aeronautical Laboratories (UWAL) 2.44 × 3.66 m (8 × 12 ft) wind tunnel. A tail located three chords behind the wing was used to measure the downwash at the tail region. The experimental data indicate that within the range of momentum coefficient examined, it appears to be unnecessary to actively control all four sides of the test section walls in order to achieve the near interference free flow field environment in a small wind tunnel. The remaining wall interference can be satisfactorily corrected by the vortex lattice method.

*Univ. of Washington, Seattle, WA 98195
NASA Grant NSG-2260

104 *Wolf, S.W.D.: **Selected Data From a Transonic Flexible Walled Test Section—Semiannual Progress Report to May 1980.** NASA CR-159360, Sept. 1980, 108 pp.

N80-32404#

Twenty-four test runs of the Transonic Self-Streamlining Wind Tunnel were performed with the flexible walls 'streamlined' around a two-dimensional section of four inch chord, over the Mach number range 0.3 to 0.89. Relevant wall and model data for the streamlined cases are presented.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

105 *Ganzer, U.: **Adaptable Wind Tunnel Walls for 2D and 3D Model Tests.** Presented at the AIAA 12th Congress of International Council of the Aeronautical Sciences, Munich, West Germany, Oct. 12-17, 1980. In: Proceedings (A81-11601), pp. 808-816.

ICAS Paper 23-3 A81-11671

Two-dimensional model tests were made in a test section with flexible top and bottom wall. A conventional NACA 0012 aerofoil and a supercritical CAST 7 aerofoil were used with a tunnel height to chord ratio of 1.5. It was shown that wall interference effects can be reduced by wall shaping and that transonic blockage can be avoided. The same test section was used for 3-component force-measurement of a simple swept-wing-body combination to demonstrate convergence of the adaption process for 3D model tests.

*Institut fur Luft- und Raumfahrt, Technische Universitat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)

106 *Becker, J.V.: **The High-Speed Frontier. Case Histories of Four NACA Programs, 1920-1950.** NASA SP-445, 1980, 196 pp.

TL521.B39
N81-15969#

A listing of transonic facilities in the appendix of this Special Publication includes a flexible-walled wind tunnel in Ottobrun, Germany. A recently released 1945 RAE document by A. S. Hartshorn and H. B. Squire discussed this never used 7-ft. tunnel of maximum useful M=1.

Langley Research Center library number
6800-Germany
1945/2

*NASA Langley Research Center, Hampton, VA 23665

107 Gruzdev, A.A.: **Low-Speed Wind Tunnels With Deformable Walls (Ob aerodinamicheskikh trubakh malykh skorostei s deformiruemymi granitsami).** Aviatsionnaia Tekhnika, no. 4, 1980, pp. 23-26 (in Russian). English translation, Soviet Aeronautics, Vol. 23, No. 4, 1980, pp. 18-20.

A81-29304# (Russian)
A82-11462 (English)

Attention is given to the development of self-streamlining or self-correcting wind tunnels. Linear theory under the assumption of potential flow is used to study the shape of streamline surfaces near a wing of finite aspect ratio moving near a screen. The characteristics of flow macrostructure in the wake are analyzed; and it is shown that in contrast to the case of two-dimensional flow, it is not possible to streamline the walls of the tunnel in the absence of a vortex wake in the case of three-dimensional flow.

108 *Erickson, J.C., Jr.; and *Homicz, G.F.: **Numerical Simulations of a Segmented-Plenum, Perforated, Adaptive-Wall Wind Tunnel.** Presented at the AIAA 19th Aerospace Sciences Meeting, St. Louis, Mo., Jan. 12-15, 1981, 15 pp. Also AIAA Journal, vol. 20, no. 5, May 1982, pp. 612-623 (no. 137 in this bibliography).

AIAA Paper 81-010 A81-20640#

Note: A copy of this report is appended to no. 110 in this bibliography.

Flow within the tunnel is simulated by modeling the incompressible interaction of the transpired turbulent boundary layers on the walls with the flow over the airfoil. Despite the fact that a finite number of plenum chambers can exert only imperfect control over the flow, it is demonstrated that one can still achieve what is for all practical purposes unconfined flow about the airfoil. Velocity differences produced at control surfaces outside the boundary layers by changing the pressure in one plenum chamber at a time, holding the other chamber pressures constant, are presented as influence functions. Implications of the analysis on tunnel design and automation are described.

*Calspan Advanced Technology Center, Buffalo, NY 14221
Research sponsored by U.S. Navy & Air Force

109 *Sears, W.R.: **On the Definition of Free-Stream Conditions in Wind-Tunnel Testing.** Presented at the Symposium on Numerical and Physical Aspects of Aerodynamic Flows, Long Beach, Calif., Jan. 19-21, 1981. 4 pp. In: Proceedings (A81-32571), California State Univ., 1981.

A81-32761#

The paper investigates the utility of the adaptive-wall scheme in solving the problem of determination of the free-stream vector. Adaptive-wall iterations simulated for low-speed flow by a simple panel method are presented which demonstrate how errors in tunnel speed and flow inclination are eliminated and how an arbitrarily chosen stream vector can be achieved.

*Univ. of Arizona, Tucson, AZ 85721
Contract N00014-79-C-0010-P00001

110 *Erickson, J.C., Jr.; *Wittliff, C.E.; *Padova, C.; and *Homicz, G.F.: **Adaptive-Wall Wind-Tunnel Investigations—Final Tech. Report, Nov. 1, 1976-Oct. 31, 1980.** CALSPAN-RK-6040-A-2, Feb. 1981, 83 pp.

AD A096 325 N81-21088#
AIAA Paper 81-0160 (Appendix)

The results of a program of research on transonic wind tunnels with adaptive walls for eliminating wall interference are presented. A description is given of related experimental research performed at other laboratories using several alternative methods for controlling the flow. Features of the segmented plenum, perforated wall, two-dimensional test section of the Calspan One Foot Tunnel and the associated instrumentation for measuring the flow disturbance quantities are reviewed. Necessary modifications made to the original experimental configuration are also described. Details of adaptive-wall iteration experiments with a 4%-blockage NACA 0012 airfoil model are presented, particularly those at a free-stream Mach number of 0.9 and nominal angles of attack of 3, 2 and 1 deg. (In these experiments, regions of supercritical flow terminated by shock waves extended to the tunnel walls.) The results of the experiments indicate that successful iterations toward interference free flow conditions are achieved. For another phase of the research, conceptual design studies of a three-dimensional transonic adaptive wall test section using the segmented plenum, perforated wall method of flow control are reported. Finally, numerical simulations of low speed flow within the Calspan test section, including the interaction of the transpired boundary layer at the walls with the flow over the model, are described in AIAA Paper No. 81-0160 (no. 108 in this bibliography), and which also is appended to this report.

*Calspan Advanced Technology Center, Buffalo, NY 14221
Contract N00014-77-C-0052

111 *Parker, R.L., Jr.; and *Sickles, W.L.: **Two-Dimensional Adaptive-Wall Experiments—Final Report, Oct. 1979-Sept. 1980.** AEDC-TR-80-63, Feb. 1981, 55 pp.

AD A095 199 N81-20087#

Experiments conducted in the Arnold Engineering Development Center (AEDC) Propulsion Wind Tunnel Facility Aerodynamic Wind Tunnel (1T) were part of a continuing program to develop adaptive-wall technology for the elimination of wall interference in transonic wind tunnels. The test section arrangement consisted of uniformly variable-porosity porous walls enclosed by a variable pressure plenum. Two subplena were attached to both the top and bottom walls in the region of the test model location. Two subplena locations were investigated. One location was established by test section boundary flow-angle criteria, and the other by test section boundary pressure criteria. The subplena location was shown to significantly affect the results. The test model was a six percent solid blockage, two-dimensional NACA-0012 wing. The experiments were conducted for both lifting and nonlifting conditions including those conditions for which the supercritical flow regions extended to the test section boundary.

*ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389

112 *Parker, R.L., Jr.; and *Sickles, W.L.: **Application of the Adaptive Wall Concept in Three Dimensions.** Journal of Aircraft, vol. 18, no. 3, Mar. 1981, pp. 176-183.

AIAA Paper 80-0157R

For abstract see no. 92 in this bibliography.

ARO, Inc., Arnold Air Force Station, Tullahoma, TN 37389

113 *Bodapati, S.; **Schairer, E.; and **Davis, S.: **Adaptive-Wall Wind-Tunnel Development for Transonic Testing.** Journal of Aircraft, vol. 18, no. 4, Apr. 1981, pp. 273-279. (See no. 94 in this bibliography for the conference paper.)

AIAA Paper 80-0441R A81-31367

Experimental techniques for rapid assessment and correction of wall interference in an adaptive-wall wind tunnel are described. The experimental arrangement allows laser velocimetry measurements on two control surfaces and incorporates a dedicated computer for data processing. The apparatus and its instrumentation are described, and typical results from an experiment on a nonlifting NACA 0012 airfoil at M = 0.78 are discussed. It is concluded that the time to acquire laser Doppler velocimeter data should be decreased, and the possibility of using one-step algorithms should be investigated.

*Stanford Univ., Stanford, CA 94305-2186
**NASA Ames Research Center, Moffet Field, CA 94035

114 *Wolf, S.W.D.: **Model and Boundary Aerodynamic Data From High Blockage Two-Dimensional Airfoil Tests in a Shallow Unstreamlined Transonic Flexible Walled Test Section—Semi-Annual Progress Report to Oct. 1980.** NASA CR-165685, Apr. 1981, 90 pp.

N81-21087#

Two-dimensional NACA 0012-64 airfoil lift and drag data are presented from tests in the Transonic Self-Streamlining Wind Tunnel with the test section's nonporous boundaries set aerodynamically "straight." The test section was shallow (height: model chord = 1.5) and the model blockage was 8% at zero angle of attack. Data were conveniently gathered at Mach 0.3, 0.5 and 0.7, and corrected for wall induced interferences by conventional techniques. One technique bases corrections to model angle of attack, camber and freestream on the wall loading, due to the floor and ceiling of the test section being unstreamlined. The other technique devised by Allen and Vincenti provides corrections to model angle of attack, lift and drag. It is shown that model corrections from wall loading can be adequate up to Mach 0.7. These data provide a severe test case for any new interference correction methods for transonic wind tunnel testing.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

115 *Archambaud, J.P.; *Seraudie, A.; and *Gobert, J.L.: **Tests of a 150 mm NACA 0012 Airfoil using the Adaptive Walls of the ONERA/CERT T2 Wind Tunnel (Rapport d'essais sur le profil NACA 0012 de 150 mm de corde en presence de parois adaptables à la soufflerie T2 de l' ONERA/CERT).** Rep. 22/3075, July 1981, 108 pp. (in French).

Results are given of tests run in the adaptive wall T2 wind tunnel using a NACA 0012 airfoil of 150 mm chord. Each tunnel run provided one iteration of the convergent process toward the simulation of infinite flow about the model. The tests were carried out with fixed transition with the model in the center of the test section. Test envelope was M = 0.60 to 0.85, and α = -2° to +6° at approximately ambient stagnation temperature.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

116 *Mayo, W.T., Jr.; *Smart, A.E.; *Hermes, R.J.; and *Trolinger, J.D.: **Flow Velocity and Angularity Measurements in the FDL Trisonic Gasdynamics Facility and Self-Adaptive Wall Wind Tunnels With a Laser Transit Anemometer—Final Report, Apr.-Nov. 1980.** AFWL-TR-81-3081; SDL-81-2162-05FR; Aug. 1981, 143 pp.

AD A108 427 N82-19119#

The measurement of a backscatter laser transit anemometer was tested in the FDL Trisonic Gasdynamics Facility (TGF) and the nine-inch Self-Adaptive Wall (SAW) wind tunnel. The tests in the TGF included flow analysis in the two foot by two foot subsonic, transonic and supersonic test sections as well as the fifteen-inch transonic test section insert. The magnitude and flow angle precisions were as good as 0.3% and 0.3 deg, respectively, as limited by the statistical fluctuations of the data. Calculations indicate that the minimum natural particle size observed in the TGF was approximately 0.2 micron in diameter. Flow speed and angle were mapped about a microfighter flow field in the TGF fifteen-inch transonic test section at Mach number 0.7 and 0.9 to develop a data base for evaluation of the Self-Adaptive Wall wind tunnel concept. Measurements were then made to the same model in the FDL nine-inch Self-Adaptive Wall wind tunnel. These indicated that the precision of the instrument exceeded the current precision to establish and repeat flow conditions in the tunnel. The SAW results indicated non-uniform particle content of the flow which adversely affected the available angle precision; however, velocity measurements were good. Presentation of the equipment and measurement results of the present project are included.

*Spectron Development Labs., Inc., 3303 Harbor Blvd., Suite G-3,
Costa Mesa, CA 92626
Contract F33615-79-C-3030

117 *Davis, S.S.: **A Compatibility Assessment Method for Adaptive-Wall Wind Tunnels.** AIAA Journal, vol. 19, no. 9, Sept. 1981, pp. 1169-1173, 22 refs.

AIAA Paper 81-4226 A81-44444#

A new method is described for assessing the compatibility between inner and outer flow regimes in adaptive-wall wind tunnels. The method is applicable to both two- and three-dimensional flows and, unlike other schemes, requires the measurement of only one velocity component. Moreover, a complete solution to the outer flowfield is not required with the new method. Computer simulations of two- and three-dimensional flows are presented along with data from a two-dimensional pilot wind tunnel test using the new method.

*NASA Ames Research Center, Moffett Field, CA 94035

118 *Mercer, J.E.; *Geller, E.W.; *Johnson, M.L.; and **Jameson, A.: **Transonic Flow Calculations for a Wing in a Wind Tunnel.** Journal of Aircraft, vol. 18, Sept. 1981, pp. 707-711.

AIAA paper 80-0156

Note: For an earlier form of this paper and an abstract see no. 91 in this bibliography.

A computer program has been developed to calculate inviscid transonic flow over a swept wing in a wind tunnel with constant rectangular cross sections and with specified normal or tangential flow at the walls. An approximately orthogonal computational grid that 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. Sample calculations show the effect of tunnel walls. Comparisons with experimental and other theoretical results are presented.

*Flow Research Co., 21414 68th Ave. South, Kent, WA 98031
**Princeton Univ., Princeton, NJ 08540

119 *Wang, S.-C.: **Convergence to Unconfined Flow of the Three-Dimensional Transonic Self-Correcting Wind Tunnel.** Computer Methods in Applied Mechanics and Engineering, vol. 28, Sept. 1981, pp. 191-205.

A82-15451

The mixed difference method (Murman and Cole, 1971) is used to investigate the convergence problem of the three-dimensional transonic self-correcting wind tunnel. The interior wind tunnel and the exterior unconfined flow-fields are described by the transonic small disturbance equation. In order to determine whether the unconfined-flow is obtained in the interior tunnel, two flow variables at a control surface are needed. They are the perturbation velocity components parallel to the free stream and perpendicular to the control surface. Their distributions are evaluated at the control surface for both the interior and exterior regions. The results of the numerical calculations indicate that after several iterations of the one flow variable at the control surface, the interior wind tunnel flowfield converges to the free-air flowfield.

*Chinese Aeronautical Establishment, Harbin Aeronautical Aerodynamic Institute, Harbin, People's Republic of China

120 *Dowell, E.H.: **Control Laws for Adaptive Wind Tunnels.** AIAA Journal, vol. 19, no. 11, Nov. 1981, pp. 1486-1488.

AIAA Paper 81-4298 A82-10985#

A control law is developed which will permit the systematic modification of wind tunnel wall conditions in order to minimize the interference about a model. The approach is valid for both three-dimensional and lifting flows and, subject to the assumption of linearity, is not dependent on any particular theoretical description of the fluid. In addition, unlike previous control schemes, the present method does not require an iterative approach.

*Princeton Univ., Princeton, NJ 08540
Research supported by Princeton Univ.

121 ***ONERA (Office National d'Etudes de la Recherche Aerospatiales) Activities—1980.** 1981, 238 pp. (in English).

N82-14958#

This annual publication (yearbook) describes the ONERA organization, lists the personnel, and gives a short description of the activities of each department. ONERA publications and patents announced during the year are also listed. In this 1980 issue, a test is described on a CAST 7 profile made in the T2 tunnel with adaptive walls. Theoretical results were compared with the experimental values (see pages 43 and 44).

*ONERA, BP 72, 92322 Chatillon Cedex, France

122 *Kraft, E.M.; and *Dahm, W.J.A.: **Direct Assessment of Wall Interference in a Two-Dimensional Subsonic Wind Tunnel.** Presented at AIAA 20th Aerospace Sciences Meeting, Orlando, Fla., Jan. 11-14, 1982, 11 pp.

AIAA Paper 82-0187 A82-22062#

A theory for assessing wall interference for linear, subsonic flow over a thin lifting airfoil in a two-dimensional wind tunnel is presented. The concept requires measurement of two flow variables such as the static pressure and flow angle at a surface near the tunnel boundary. It is established that measurement of two flow variables eliminates the need for both knowledge of the wall characteristics and analytical synthesis of the model. Furthermore, corrections can be applied directly to the force and moment coefficients of the model, thereby eliminating corrections to Mach number and angle of attack or implied alterations of the camber distribution typical of classical wall interference theories. The theory is also extended to provide formulae that can be used to determine directly the flow variables required at the reference surface to adjust an adaptive wall wind tunnel to interference-free conditions.

*Calspan Field Services, Inc., Arnold Air Force Station, Tullahoma, TN 37389

123 ***ONERA now has a Cryogenic Wind Tunnel (L'ONERA a l'heure des Souffleries Cryogeniques).** Aviation (International) Magazine, no. 818, Jan. 15-31, 1982, pp. 28-32 (in French).

ONERA has completed its transformation of the T2 tunnel. This tunnel, located at Centre d'Etudes et de Recherches de Toulouse (CERT), operates at very low temperatures in the neighborhood of 100 K (-173°C). The facility is described. Insulating materials are discussed. The tunnel can attain a Reynolds number of 37 million with models of 150 mm. The wind tunnel also has adaptable walls.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

124 *Whitfield, J.D.; *Jacocks, J.L.; *Dietz, W.E.; and *Pate, S.R.: **Demonstration of the Adaptive Wall Concept Applied to an Automotive Wind Tunnel.** Presented at the 1982 SAE International Congress and Exposition, Detroit, Mich., Feb. 22-26, 1982. Also presented at the AIAA 12th Aerodynamic Testing Conference, Williamsburg, Va., Mar. 22-24, 1982, 10 pp.

SAE Paper 820373
AIAA Paper 82-0584

An adaptive wall test section concept applicable to automotive-type wind tunnels has been developed. Experiments conducted in a subsonic wind tunnel (1 ft × 2 ft test section) have established the feasibility and practicality of the concept. A test program utilizing three geometrically similar automotive-type models of cross-sectional area corresponding to conventional model/tunnel blockages of 10, 20, and 30 percent was conducted with the models positioned at yaw angles of 0° and 10°. Pressure distribution data obtained using the adaptive test section demonstrated the elimination of wall interference by properly deforming the tunnel walls using the adaptive wall technique. These experimental tests have shown that the adaptive wall test section concept will allow significantly larger blockage ratios than permissible in conventional wind tunnels to be tested with negligible wall interference.

*Sverdrup Technology, Inc., 600 William Northern Blvd., P.O. Box 884, Tullahoma, TN 37388

125 *Goodyer, M.J.; and *Wolf, S.W.D.: **Development of a Self-Streamlining Flexible Walled Transonic Test Section.** AIAA Journal, vol. 20, no. 2, Feb. 1982, pp. 227-234.

AIAA Paper 80-0440R

For abstract, see no. 95 in this bibliography.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

126 *McDevitt, J.B.; *Polek, T.E.; and *Hand, L.A.: **A New Facility and Technique for Two-Dimensional Aerodynamic Testing.** Presented at AIAA 12th Aerodynamic Testing Conference, Williamsburg, Va., Mar. 22-24, 1982, 23 pp. In: Technical Papers (A82-24651), pp. 273-295. Also, Journal of Aircraft, vol. 20, June 1983, pp. 543-551 (no. 164 in this bibliography).

AIAA Paper 82-0608 A82-24677#

The design and operational characteristics of a new test leg for the High Reynolds Number Facility at Ames Research Center are presented, and the unique features of a test section for obtaining two-dimensional airfoil data are reviewed. The new facility operates at unit Reynolds numbers ranging from 1×10^6/ft to 30×16^6/ft. Boundary-layer suction panels are used in the test section (16 in. wide by 24 in. high) to minimize side-wall interference effects. Flexible, easily adjustable upper and lower walls allow test-channel area-ruling, so as to nullify Mach number changes induced by mass removal, to correct for longitudinal boundary-layer growth, and to provide contouring compatible with the streamlines of the model in free air.

*NASA Ames Research Center, Moffett Field, CA 94035

127 *Michel, R.; and *Mignosi, A.: **Adaptation and First Cryogenic Operation of T2 ONERA/CERT Wind Tunnel.** La Recherche Aerospatiale (English Edition), No. 2, Mar.-Apr. 1982, pp. 75-85.

A82-42531#
N84-13143#

A description is given of the transformation of the ONERA/CERT induction-driven transonic wind tunnel into a blowdown, cryogenic wind tunnel which employs high pressure air as a driving gas and liquid nitrogen as a coolant. An analysis of results from the first series of low temperature tests follows. The users of this bibliography may be interested in knowing that the T2 tunnel is equipped with adapting walls which allow wing profiles of 15 cm chord to be studied. It does not seem that any major problem will be encountered in using these walls at cryogenic temperatures.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

128 *Binion, T.W., Jr.; **Chevallier, J.-P.; and edited by ***Laster, M.L.: **Report of the Conveners Group on Transonic Test Sections.** In: Windtunnel Capability Related to Test Sections, Cryogenics, and Computer-Windtunnel Integration, AGARD-AR-174 (N82-29334#), Apr. 1982, Appendix 1, 15 pp., 36 refs.

N82-29334#, Appendix 1

The meetings were concerned with discussions of the research activities affecting the development of improvements to transonic test sections. Adaptive walls were discussed as a matter of great interest. Experts from the USA and Canada met on March 13-14, 1980, at NASA Langley, Hampton, Virginia, and the European experts met May 8-9, 1980, at the Hochschule der Bundeswehr, Munich-Neubiberg, Germany. A summary of current and planned research and recommendations from the two groups is presented. (This report contains good drawings of many tunnels.)

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**ONERA, BP 72, 92322 Chatillon Cedex, France
***Arnold Engineering Development Center, Arnold Air Force Station, Tullahoma, TN 37389

129 *AGARD: **Wall Interference in Wind Tunnels.** 50th Fluid Dynamics Panel Specialists' Meeting, London, England, May 19-20, 1982, AGARD-CP-335, 228 pp.

ISBN-92-835-0321-X N83-20957#

Note: For a technical Evaluation Report of this meeting see no. 159 in this bibliography. Also, for a summary or review, see no. 169.

Current usage and basic developments for wind tunnel wall corrections are addressed including Reynold's number corrections, wall and support interference, flow quality and aeroelasticity. Solid wall, ventilated wall, and adaptive wall wind tunnels are among the topics discussed. Progress in the area of wind tunnel correction is evident with adaptive walls to reduce or eliminate wall interference.

*AGARD (Advisory Group for Aerospace R&D), NATO, 7 rue Ancelle, 92200 Neuilly sur Seine, France

130 *Vaucheret, X.: **Reevaluation des Resultats Corriges der Profil CAST 7 a S3MA,** Appendix to paper no. 5 in Wall Interference in Wind Tunnels, AGARD-CP-335 (N83-20957#), May 19-20, 1982, pp. 5-12—5-16 (in French).

N83-20962#, pp. 5-12—5-16

This appendix compares results on the CAST 7 airfoil in the S3MA tunnel with the adaptive wall T2 tunnel results on the same airfoil.

*ONERA, BP 72, 92322 Chatillon Cedex, France

131 *Ganzer, U.: **On the Use of Adaptive Walls for Transonic Wind Tunnel Testing.** Presented at the 50th AGARD Fluid Dynamics Panel Specialists' Meeting on "Wall Interference in Wind Tunnels," London, England, May 19-20, 1982; In: AGARD-CP-335, (N83-20957#), paper no. 13, 8 pp.

N83-20969#

A wind tunnel test section with two adaptive walls for aerofoil testing and another one with eight flexible walls for 3-D model tests have been developed at the TU Berlin. They are described with respect to their constructional features, the calculation procedure for determining the adapted wall configuration and the computer-based automatic control system. Test results obtained for the supercritical aerofoil CAST 7 are presented to demonstrate the potentiality of the adaptive wall concept in 2-D model tests. First test results with the 3-D test section using an ONERA C 5 body of revolution are shown to verify the feasibility of the adaptive-wall technique for 3-D model tests. An alternative 3-D test section design as developed by DFVLR is discussed in some detail.

*Institute fur Luft- und Raumfahrt, Technische Universitat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)

132 *Archambaud, J.P.; and **Chevallier, J.-P.: **Use of Adaptive Walls in Two-Dimensional Tests (Utilisation de parois adaptables pour les essais en courant plan).** Presented at the 50th AGARD Fluid Dynamics Panel Specialists' Meeting on "Wall Interference in Wind Tunnels," London, England, May 19-20, 1982. In: AGARD-CP-335 (N83-20957), paper no. 14, 14 pp., 38 refs. (in French). Also, ONERA TP no. 1982-38, 15 pp. (in French).

N83-20970 #
A82-42813

Note: For an English translation and an abstract see no. 179 in this bibliography.

*ONERA, BP 72, 92322 Chatillon Cedex, France
**ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

133 *Wolf, S.W.D.; *Cook, I.D.; and *Goodyer, M.J.: **The Status of Two- and Three-Dimensional Testing in the University of Southampton Transonic Self-Streamlining Wind Tunnel.** Presented at the 50th AGARD Fluid Dynamics Panel Specialists' Meeting on "Wall Interference in Wind Tunnels," London, England, May 19-20, 1982. In: AGARD-CP-335 (N83-20957#), paper no. 15, 14 pp.

N83-20971#

An automated test section has been used to validate and develop a flexible walled testing technique which eliminates some sources of uncertainty in boundary interference effects which exist in conventional transonic test sections. The flexible floor and ceiling of the test section have been adjusted to contours which produce a constant Mach number distribution along each wall with no model present. These "aerodynamically straight" contours form the basis for all streamlining. With a model in the test section, the "wall data" is shown to contain information on the model's performance, including quite good information on lift. Two-dimensional validation testing has continued with a cambered NPL 9510 section, larger and of more challenging design than an NACA 0012-64 section previously tested. Lift data up to Mach 0.87 is compared with reference data. Drag information on an NACA 0012-64 section is presented to indicate the powerful effects of streamlining. Preliminary three-dimensional testing in the two-dimensional test section has demonstrated that model and support blockage can be relieved by wall contouring. Further three-dimensional testing awaits the development of a suitable algorithm for calculating boundary interference effects and predicting the wall movements required to minimize these effects.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

134 *Schairer, E.T.; and *Mendoza, J.P.: **Adaptive-Wall Wind-Tunnel Research at Ames Research Center.** Presented at the 50th AGARD Fluid Dynamics Panel Specialists' Meeting on "Wall Interference in Wind Tunnels", London, England, May 19-20, 1982, AGARD-CP-335, (N83-20957#), paper no. 16, 13 pp. Also, NASA TM-84236, 1982, 16 pp.

N82-24214#
N82-20972#

Adaptive-wall wind-tunnel research conducted at NASA Ames Research Center is summarized. This research includes small-scale two- and three-dimensional wind-tunnel experiments and numerical experiments with a three-dimensional adaptive-wall simulator. In the two-dimensional experiment, an NACA 0012 airfoil was tested in a 25- by 13-cm slotted-wall test section. Airflow through the test section walls was controlled by adjusting the pressures in segmented plenums. Interference-free conditions were successfully attained in subsonic and transonic flows. Based on the design of this small-scale test section, an adaptive-wall test section is being constructed for the 2- by 2-Foot Transonic Wind Tunnel at Ames. For the three-dimensional experiment, the 25- by 13-cm wind tunnel was modified to permit cross-stream wall adjustments. The test model was a semi-span wing mounted to one sidewall. Wall interference was substantially reduced at several angles of attack at Mach 0.60. A wing-on-wall configuration was also modeled in the numerical experiments. These flow simulations showed that free-air conditions can be approximated by adjusting boundary conditions at only the floor and ceiling of the test section. No sidewall control was necessary. Typical results from these experiments are discussed.

*NASA Ames Research Center, Moffett Field, CA 94035

135 *Parker, R.L., Jr.; and *Erickson, J.C., Jr.: **Development of a Three-Dimensional Adaptive Wall Test Section With Perforated Walls.** Presented at the 50th AGARD Fluid Dynamics Panel Specialists' Meeting on "Wall Interference in Wind Tunnels," London, England, May 19-20, 1982, AGARD-CP-335 (N83-20957#), paper no. 17, 14 pp.

N83-20973#

A brief description of two-dimensional, porous adaptive wall development at the Calspan Advanced Technology Center and the Arnold Engineering Development Center (AEDC) is given. Three-dimensional exploratory experiments at AEDC employing adaptive techniques to adjust variable porosity walls individually to miminize the interference on a generalized transonic model are summarized. Recent work at AEDC has concentrated on the embodiment of the adaptive wall concept for three-dimensional applications. A fully automated, computer controlled, closed loop three-dimensional adaptive wall system has been designed, fabricated and assembled in the AEDC Aerodynamic Wind Tunnel (1T). Development of the subsystems has included the interface measurement instrumentation, the exterior-flow computation method, the actively controllable wall configuration, microprocessor-controlled hardware for the walls and instrumentation and the overall minicomputer based adaptive wall control algorithm. Specifically, a two-velocity-component static pipe system has been selected for the interface measurement system. Transonic small disturbance theory is being used to compute the exterior flow region and a segmented, variable porosity configuration has been selected for the test section walls.

*Calspan Field Services, Inc., Arnold Air Force Station, Tullahoma, TN 37389

136 *Laster, M.L. (chairman): **Round Table Discussion on "Wall Interference in Wind Tunnels."** Final discussion and review of the AGARD Fluid Dynamics Panel Specialists' Meeting, London, England, AGARD-CP-335 (N83-20957#) May 19-20, 1982, pp. RTD-1 through RTD-10.

The purpose of this specialists' meeting was to bring experimental aerodynamicists together to review and discuss current usage and basic developments for wind tunnel wall corrections. This specialists' meeting concentrated upon subsonic and transonic flow wall corrections. The meeting was organized into sessions of solid wall, ventilated wall, and adaptive wall wind tunnels and a summarizing round table discussion led by the session chairmen; Professor A.D. Young, Mr. L.H. Ohman, and Professor W.R. Sears.

*Arnold Engineering Development Center, Arnold Air Force Station, Tullahoma, TN 37389

137 *Erickson, J.C., Jr.; and *Homicz, G.F.: **Numerical Simulations of a Segmented-Plenum, Perforated, Adaptive-Wall Wind Tunnel.** AIAA Journal, vol. 20, no. 5, May 1982, pp. 612-623.

AIAA Paper 81-0160R

For abstract see no. 108 in this bibliography.

*Calspan Advanced Technology Center, Buffalo, NY 14221

138 *Wolf, S.W.D.; *Goodyer, M.J.; and *Cook, I.D.: **Streamlining the Walls of an Empty Two-Dimensional Flexible-Walled Test Section—Progress Report.** NASA CR-165936, May 1982, 9 pp.

N82-28304#

This is a progress report on work on self-streamlining the test section of a transonic wind tunnel. The report outlines the techniques and streamlining methods used, results, and conclusions from a series of tests aimed at closely defining sets of "aerodynamically straight" walls for the Transonic Self-Streamlining Wind Tunnel.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

139 *Sears, W.R.: **A Note on Adaptive Wind Tunnels With Imperfect Control—Final Report.** In: AFWAL—A Collection of Papers in the Aerospace Sciences, AFAPL-TR-79-2126 (N83-26787), pp. 191-207, June, 1982. Also, Journal of Aircraft, vol. 16, May 1979, pp. 344-348.

AD A122 667 N83-26792#

For an earlier publication and abstract of this paper see no. 83 in this bibliography.

*Univ. of Arizona, Tucson, AZ 85721
Grant AF-AFOSR-76-2954E

140 Fonarev, A.S.; and Sherstyuk, A.V.: **Algorithms and Methods for Computer Simulation of Transonic Flow.** Automatika i Telemekhanika, July 1982, pp. 8-18 (in Russian). English translation, Automation and Remote Control, vol. 43, no. 7, Dec. 10, 1982, pt. 1, pp. 843-852.

A83-19999 (English)

Some computer simulation methods of transonic flow are surveyed and their possible use for designing a permeable wall control system in wind tunnels is discussed. A mathematical model of transonic flow is considered in the form of the small-disturbance transonic equation. The equation can be approximated by the finite difference method and by the finite element method, and the nonlinear approximating equations are solved by linearization. The possible use of parallel computing facilities for the solution of this problem is considered.

141 *Ganzer, U.; and *Igeta, Y.: **Transonic Tests in a Wind Tunnel With Adapted Walls.** Presented at the 13th Congress of International Council of the Aeronautical Sciences (ICAS)/AIAA Aircraft Systems & Technology Meeting, Seattle, Wash., Aug. 22-27, 1982. In: Proceedings, Vol. 1 (A82-40876), AIAA 1982, pp. 752-760.

A82-40952#

Flexible walls are used for wind tunnel working sections to control the flow condition around the model. The wall shape is adjusted to provide streamline-curvature equivalent to that occurring under free flight condition. If such an adjustment can be achieved, the flow around the model will be free of wall interference and transonic blockage of the test section is avoided. Test results for the supercritical CAST 7 aerofoil were obtained in a test section with two flexible walls. Comparison with reference data obtained in a much larger tunnel demonstrate the ability of the adaptive wall technique for 2-D model tests. First results for a test section with eight flexible walls using a body of revolution as the model are presented. The results allow some conclusions about the general applicability of the adaptive wall technique for 3-D model testing.

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142 *Sears, W.R.: **Wind-Tunnel Testing of V/STOL Configurations at High Lift.** Presented at the 13th Congress of International Council of the Aeronautical Sciences (ICAS)/AIAA Aircraft Systems & Technology Meeting, Seattle, Wash., Aug. 22-27, 1982. In: Proceedings, Vol. 1, (A82-40876), AIAA, 1982, pp. 720-730. Also, Journal of Aircraft, vol. 20, Nov. 1983, pp. 968-974 (no. 177 in this bibliography).

A82-40949#

The results of a study of the problem of the large airstream deflections involved in wind-tunnel testing of V/STOL configurations are reported. The concept of adaptive wind-tunnel walls is utilized to eliminate, along with boundary interference, the inaccuracies of the usual tunnel calibration. Some numerical models of adaptive-wall tunnels are described and it is shown that the undisturbed stream direction and magnitude, arbitrarily chosen, are achieved by the iterative process of such a tunnel. The use of this type of tunnel in an extreme case is demonstrated by constructing and model testing an approximate panel representation of a jet-flap wing of finite span. The demonstration is completely successful, suggesting that the new tunnel would solve the recurring problem of V/STOL testing.

*Univ. of Arizona, Tucson, AZ 85721
Contract N00014-79-C-0010

143 *Wolf, S.W.D.: **Control Software for Two Dimensional Airfoil Tests Using a Self-Streamlining Flexible Walled Transonic Test Section—Semi-annual Progress Report to Feb. 1982.** NASA CR-165941, Aug. 1982, 92 pp.

N82-30314#

The current operation of the Transonic Self-Streamlining Wind Tunnel (TSWT) involves on-line data acquisition with automatic wall adjustment. A tunnel run consists of streamlining the walls from known starting contours in iterative steps and acquiring model data. Each run performs what is described as a streamlining cycle. The associated control software is presented here.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

144 *Barg, J.: **Development of a Process Control Computer Device for the Adaptation of Flexible Wind Tunnel Walls.** NASA TM-76979, Sept. 1982, 56 pp.

N83-33907#

Note: This is an English translation by Scientific Translation Service, Santa Barbara, Calif. For the original German form of this report see no. 101 in this bibliography.

In wind tunnel tests, the problems arise of determining the wall pressure distribution, calculating the wall contour, and controlling adjustment of the walls. This report shows how these problems have been solved for the high speed wind tunnel of the Technical University of Berlin.

*Institut fur Luft- und Raumfahrt, Technische Universitat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)
Contract NASw-3542 (for translation)

145 *Goodyer, M.J.: **Extraction of Model Performance from Wall Data in a Two-Dimensional Transonic Flexible Walled Test Section.** NASA CR-165994, Sept. 1982, 21 pp.

N82-12102#

Data obtained from the boundary of a test section provide information on the model contained within it. This report describes a method for extracting some of these data in two-dimensional testing. Examples of model data are included on lift, pitching moment and wake displacement thickness. A FORTRAN listing is also described, having a form suitable for incorporation into the software package used in the running of such a test section.

*The University, Southampton S09 5NH, Hampshire, U.K.
Contract NAS1-16000

146 *Wolf, S.W.D.: **A Wake Traverse Technique for Use in a 2-Dimensional Transonic Flexible Walled Test Section.** NASA CR-165995; AASU-Memo-82-3; Sept. 1982, 13 pp.

N83-16351#

Reported two-dimensional validation data from the Transonic Self-Streamlining Wind Tunnel (TSWT) concerns model lift. The models tested provided data on their pressure distributions. This information was numerically integrated over the model surface to determine lift, pressure drag and pitching moment. However, the pressure drag is only a small component of the total drag at nominal angles of attack and cannot be used to assess the quality of flow simulation. An intrusive technique for obtaining information on the total drag of a model in TSWT is described. The technique adopted is the wake traverse method. The associated tunnel hardware and control and data reduction software are outlined and some experimental results are presented for discussion.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

147 *Wedemeyer, E.: **Wind Tunnel Testing of Three-Dimensional Models in Wind Tunnels With Two Adaptive Walls.** VKI-TN-147, Oct. 1982, 30 pp.

N83-32781#

It is shown that wind tunnel walls can be adapted in such a way that wall interference becomes extremely small. A computational method which determines the required wall deflection from pressure measurements at the walls is described. It is based on the linearized perturbation potential for the disturbance flow. For a three-dimensional wind tunnel model with 4.4% blockage ratio, residual interferences are computed, and wind tunnel measurements which verify the predicted reduction of wall interferences by dimensional wall adaptation are performed.

*Von Karman Inst. for Fluid Dynamics, Chaussee de Waterloo, 72, B-1640 Rhode-Saint-Genese, Belgium

148 *Ziemann, J.: **Convergence Behavior That Controls Adaptive Wind Tunnel Walls Near the Test Section in the High Angle of Attack Range.** NASA TM-77006, Nov. 1982, 80 pp.

N83-30439#

Note: This is an English translation by Scientific Translation Service, Santa Barbara, Calif. For the original German form of this report see no. 93 in this bibliography.

Two-dimensional model tests have been made in a test section with flexible top and bottom wall at $M_\infty=0.5$ for a range of angle of attack. A conventional NACA 0012 has been used with a tunnel height to chord of 1.5. The main purpose of these tests was to clarify whether wall adaptation was possible with flow separation at the aerofoil. As a result it can be stated that adaptation was achieved even for angles of attack much beyond stall.

*Institut fur Luft- und Raumfahrt, Technische Universtat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)
Contract NASw-3542 (for translation)

149 *Wolf, S.W.D.: **Aerodynamic Data From a Two-Dimensional Cambered Airfoil Section in a Shallow Transonic Flexible Walled Test Section.** NASA CR-166005; AASU Memo No. 82/7; 1982, 146 pp.

N83-14070#

Further work to validate the flexible wall technique in two-dimensional testing has been carried out with the Transonic Self-Streamlining Wind Tunnel (TSWT) using a cambered NPL 9510 section, larger and perhaps of more challenging design than the NACA 0012-64 section previously tested. Model data on lift and drag were obtained over a Mach number range up to 0.87 and at angles of attack from zero to 6°. The results taken with the walls streamlined were then compared with two sources of reference data obtained in conventional slotted walled transonic test sections. The reference data cannot be considered interference free but are the best currently available at low Reynolds numbers, and has to provide a basis for assessing the quality of TSWT data. There were 52 runs of the test section in carrying out this programme, and some of the streamlining cycles were performed using an automated wall control system linked to a mini-computer. These runs provided further useful TSWT operational experience with a larger model than previously tested. Limits to both test Mach number and model angle of attack were found. NPL 9510 data from TSWT are presented as a library of numerical and graphical information which may prove useful to others engaged in the evaluation, design and use of transonic flexible walled test sections.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

150 *Barg, J.: **Setup for Fast Automatic Adaptation of Flexible Wind Channel Walls (Eine Einrichtung Zur Schnellen Automatischen Adaption von Flexiblen Windkanalwaenden)** ILR-53, Technical Univ. Berlin, 1982, 111 pp. (in German).

ISBN-3-7983-0832-2 N83-16357#
ISSN-0341-0587

Methods to determine the wall contour of two-dimensional adaptive wind channels were developed. An analogical wall adjusting system is proposed. A microprocessor controlled system is proposed for three-dimensional wind channels. Problems related to measurements in two-dimensional channels are discussed and an adaptation criterion enabling an automatic exploitation is defined.

*Institut fuer Luft- und Raumfahrt, Technische Universitat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)

151 *Chevallier, J.-P.: ***Survey of ONERA Activities on Adaptive-Wall Applications.*** Presented at a Workshop on "Wind Tunnel Wall Interference Assessment/Correction—1983," Hampton, Va., Jan. 25-26, 1983. In: NASA CP-2319 (N85-12011#), 1984, pp. 43-58. Also, ONERA-TP-1983-11, 1983, 15 pp.

N85-12013#
A83-36421#

The research undertaken concerning the computation and/or reduction of wall interference follows two main axes: improvement of wall correction determinations, and use of adaptive flexible walls. The use of wall-measured data to compute interference effects is reliable when model representation is assessed by signatures with known boundary conditions. When the computed interferences are not easily applicable to correcting the results (especially for gradients in two-dimensional cases), the flexible adaptive walls in operation in T2 are an efficient and assessed means of reducing the boundary effects to a negligible level, if the direction and speed of the flow are accurately measured on the boundary. The extension of the use of adaptive walls to three-dimensional cases may be attempted since the residual corrections are assumed to be small and are computable.

*ONERA, BP 72, 92322 Chatillon Cedex, France

152 *Holst, H.: **Wind-Tunnel Wall-Interference in Closed, Ventilated, and Adaptive Test Sections.** Presented at a Workshop on "Wind Tunnel Wall Interference Assessment/Correction—1983," Hampton, Va., Jan. 25-26, 1983. In: NASA CP-2319 (N85-12011#), 1984, pp. 61-78.

N85-12014#

A wall interference correction method for closed rectangular test sections was developed which uses measured wall pressures. Measurements with circular discs for blockage and a rectangular wing as a lift generator in a square closed test section validate this method. These measurements are intended to be a basis of comparison for measurements in the same tunnel using ventilated (in this case, slotted) walls. Using the vortex lattice method and homogeneous boundary conditions, calculations were performed which show sufficiently high pressure levels at the walls for correction purposes in test sections with porous walls. In Goettingen, an adaptive test section (which is a deformable rubber tube of 800 mm diameter) was built and a computer program was developed which is able to find the necessary wall adaptation for interference-free measurements in a single step. To check the program prior to the first run, the vortex lattice method was used to calculate wall pressure distributions in the nonadapted test section as input data for the one-step method. Comparison of the pressure distribution in the adapted test section with free-flight data shows nearly perfect agreement. An extension of the computer program can be made to evaluate the remaining interference corrections.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

153 *Goodyer, M.J.; and *Cook, I.D.: **Two- and Three-Dimensional Model and Wall Data From a Flexible-Walled Transonic Test Section.** Presented at a Workshop on "Wind Tunnel Wall Interference Assessment/Correction—1983", Hampton, Va., Jan. 25-26, 1983. In: NASA CP-2319 (N85-12011), 1984, pp. 79-88.

N85-12015#

Both two- and three-dimensional model testing is being carried out in the transonic flexible-walled wind tunnel test section. The test section has flexible top and bottom walls with rigid sidewalls. Interference is eliminated by adjustments based on data taken at walls in two dimensional models. Cast-7 data will illustrate agreement between various flexible-walled tunnels. In three-dimensional models interference cannot be eliminated but wall adjustments can control and relieve the principal sources of wall-induced errors. Estimates of magnitudes of the control which may be exercised on flow by movement of one wall jack are presented. A wall control algorithm (still in analytic development stage) based on use of this data is described. Brief examples of control of wall-induced perturbations in region of model are given.

*The University, Southampton S09 5NH, Hampshire, U.K.
NASA Grant NSG-7172

154. *Schairer, E.T.: **Assessment of Lift- and Blockage-Induced Wall Interference in a Three-Dimensional Adaptive-Wall Tunnel.** Presented at a Workshop on "Wind Tunnel Wall Interference Assessment/Correction—1983," Hampton Va., Jan. 25-26, 1983. In: NASA CP-2319 (N85-12011), 1984, pp. 89-100.

N85-12016#

A three-dimensional adaptive-wall wind tunnel experiment was conducted at Ames Research Center. This experiment demonstrated the effects of wall interference on the upwash distribution on an imaginary surface surrounding a lifting wing. This presentation demonstrates how the interference assessment procedure used in the adaptive-wall experiments to determine the wall adjustments can be used to separately assess lift- and blockage-induced wall interference in a passive-wall wind tunnel. The effects of lift interference on the upwash distribution and on the model lift coefficient are interpreted by a single horseshoe vortex analysis.

*NASA Ames Research Center, Moffett Field, CA 94035

155. *Sickles, W.L.: **A Data Base for Three-Dimensional Wall Interference Code Evaluation.** Presented at a Workshop on "Wind Tunnel Wall Interference Assessment/Correction—1983," Hampton, Va., Jan. 25-26, 1983. In: NASA CP-2319 (N85-12011#), 1984, pp. 101-116.

N85-12017#

A validation of a measured boundary condition technique was carried out to demonstrate the feasibility of a wall interference assessment/correction (WIAC) system. An experimental evaluation was also carried out to compare performances of various techniques, to define the number of necessary boundary measurements for accurate assessment/corrections and to define the envelope of test conditions for which accurate assessment/corrections are achieved. The relative merits of a WIAC system and an adaptive wall tunnel are compared. The measurement surface boundary data is performed with a system of two rotating pipes. These pipes sweep out a cylindrical measurement surface near the tunnel walls, approximately one inch from the wall at the closest point. The experimental model was specially designed and fabricated for the adaptive wall experiments. The model is a wing/tail/body configuration with swept lifting surface. The boundary data taken in Tunnel 1T with the rotating pipe system has been shown to offer several attractive features for WIAC code evaluation. Good spatial resolution of measurements is achieved and measurements are made upstream and downstream of the model. Also, two velocity components are determined.

*Calspan Field Services, Inc., Arnold Air Force Station, Tullahoma, TN 37389

156. *Wu, J.M.; and *Collins, F.G.: **Investigations of Flow Field Perturbations Induced on Slotted Transonic-Tunnel Walls.** Presented at a Workshop on "Wind Tunnel Wall Interference Assessment/Correction—1983," Hampton, Va., Jan. 25-26, 1983. In: NASA CP-2139 (N85-12011#) 1984, pp. 119-142.

N85-12018#

The free-stream interference caused by the flow through the slotted walls of the test sections of transonic wind tunnels has continuously been a problem in transonic tunnel testing. The adaptive-wall transonic tunnel is designed to actively control the near-wall boundary conditions by sucking or blowing through the wall. In order to make the adaptive-wall concept work, parameters for computational boundary conditions must be known. These parameters must be measured with sufficient accuracy to allow numerical convergence of the flow field computations and must be measured in an inviscid region away from the model that is placed inside the wind tunnel. The near-wall flow field was mapped in detail using a five-port cone probe that was traversed in a plane transverse to the free-stream flow. The initial experiments were made using a single slot and recent measurements used multiple slots, all with the tunnel empty. The projection of the flow field velocity vectors on the transverse plane revealed the presence of a vortex-like flow with vorticity in the free stream. The current research involves the measurement of the flow field above a multislotted system with segmented plenums behind it, in which the flow is controlled through several plenums simultaneously. This system would be used to control a three-dimensional flow field.

*University of Tennessee Space Inst., Tullahoma, TN 37388

157. *Everhart, J.L.: **A Method for Modifying Two-Dimensional Adaptive Wind-Tunnel Walls Including Analytical and Experimental Verification.** NASA TP-2081, Feb. 1983, 48 pp.

N83-18770#

The theoretical development of a simple and consistent method for removing the interference in adaptive-wall wind tunnels is reported. A Cauchy integral formulation of the velocities in an imaginary infinite extension of the real wind-tunnel flow is obtained and evaluated on a closed contour dividing the real and imaginary flow. The contour consists of the upper and lower effective wind-tunnel walls (wall plus boundary-layer displacement thickness) and upstream and downstream boundaries perpendicular to the axial tunnel flow. The resulting integral expressions for the streamwise and normal perturbation velocities on the contour are integrated by assuming a linear variation of the velocities between data-measurement stations along the contour. In an iterative process, the velocity components calculated on the upper and lower boundaries are then used to correct the shape of the wall to remove the interference. Convergence of the technique is shown numerically for the cases of a circular cylinder and a lifting and nonlifting NACA 0012 airfoil in incompressible flow. Experimental convergence at a transonic Mach number is demonstrated by using an NACA 0012 airfoil at zero lift.

*NASA Langley Research Center, Hampton, VA 23665

158. *Igeta, Y.: **Construction and Test of Flexible Walls for the Throat of the ILR High-Speed Wind Tunnel.** NASA TM-77005, Feb. 1983, 59 pp.

Note: This is an English translation by Kanner (Leo) Associates, Redwood City, Calif. For original German see no. 76 in this bibliography.

N83-18771#

Aerodynamic tests in wind tunnels are jeopardized by the lateral limitations of the throat. This influence expands with increasing size of the model in proportion to the cross-section of the throat. Wall interference of this type can be avoided by giving the wall the form of a stream surface that would be identical to the one observed during free flight. To solve this problem, flexible walls that can adapt to every contour of surface flow are needed. A two-dimensional adaptive test section with flexible walls was designed. A test-rig was constructed to test various materials for the flexible walls and to find the optimum position for the jacks. The tests were aimed at reducing the number of jacks to a minimum.

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Contract NASW-3541 (for translation)

159. *Binion, T.W., Jr.: **Technical Evaluation Report on Fluid Dynamics Panel Specialists' Meeting on Wall Interference in Wind Tunnels.** AGARD-AR-190, Mar. 1983, 12 pp.

ISBN-92-835-1447-5 N83-29277#

Note: The papers in this Specialists' Meeting concerning adaptive walls are nos. 130 through 136 in this bibliography.

On 19-20 May 1982, the AGARD Fluid Dynamics Panel held a specialists' meeting on Wall Interference in Wind Tunnels, in Westminster, London.

The Fluid Dynamics Panel has been concerned with stimulating activity to understand and quantify the effects of wind tunnel wall interference. Many research endeavours have been undertaken to learn how to correct wind tunnel data or to reduce the wall induced interference. Successful efforts have been largely limited to solid wall, low speed situations. The invention of ventilated wall tunnels did much to reduce the tunnel boundary induced interferences, the adaptive wall concept promises to finally provide a test environment with negligible wall interference. The primary purpose of the specialists' meeting was "to review and assess the current status of wall interference correction methods and adaptive wall research" in three sessions: Solid Wall Wind Tunnels, Ventilated Wall Wind Tunnels, Adaptive Wall Wind Tunnels. The Proceeding of the AGARD Fluid Dynamics Panel Specialists' Meeting on Wall Interference in Wind Tunnels, which was held in London, United Kingdom on 19-20 May 1982, are published as AGARD CP 335, September 1982 (no. 129 in this bibliography).

*Calspan Field Services, Inc., Arnold Air Force Station, Tullahoma, TN 37389

160 *Harney, D.J.; *Cain, M.R.; and *Ballard, B.L.: **Experimental Transonic Studies of a Three-Dimensional, Adaptive-Wall Wind Tunnel.** Presented at the 9th Annual Mini-Symposium on Aerospace Science and Technology, Wright-Patterson AFB, Ohio, Mar. 22, 1983. In: Proceedings (A83-42526), AIAA, 1983, pp. 7-2-1 to 7-2-6.

A83-42548#

Note: For a more comprehensive report and an abstract see the following citation.

*Air Force Flight Dynamics Laboratory (AFFDL), Wright-Patterson AFB, OH 45433

161 *Harney, D.J.: **Three-Dimensional Test Experience With a Transonic Adaptive-Wall Wind Tunnel—Final Report, Apr. 1981-Dec. 1982.** AFWAL-TR-83-3028, Mar. 1983, 86 pp.

AD A129 858 N84-10102#

A square 9-inch wind tunnel with solid sidewalls and flexible upper and lower rod walls capable of 3-D contouring was used to test an axisymmetric and a winged lifting model at M=0.50 to 0.95. The simple, direct analytical method for wall contouring uses the model geometry for solid blockage and iterative model force data to adapt for lift and for wake blockage. Solid sidewall effects and the convergence of the adaptation scheme are evaluated. Linear and nonlinear theory for solid blockage is compared. Interesting comparisons are also made between 2-D and 3-D wall contouring.

*Univ. of Dayton, Dayton, OH 45469
Contract F33615-79-C-3030

162 *Bliss, D.B.: **Wind Tunnel Wall Interference—Final Report, Apr. 1-Mar. 31, 1982.** AFOSR-83-0655TR, Apr. 1983, 20 pp.

AD A131 396 N84-11149#

The aerodynamic behavior of an isolated finite length slender slot in a wind tunnel wall was analyzed. Numerical and analytical solutions were obtained relating the pressure differential to the average flow rate through the slot as a function of slot geometry for subsonic and supersonic flow. These solutions apply to the cases of linear and quadratic behavior corresponding to small and large slot flow rates. The analysis was extended to include the effect of an imposed pressure gradient along the slot. The results obtained are applicable to low aspect ratio holes as well as slots, and thus provide insight into the behavior of both slotted and perforated walls. The pressure gradient effect on holes was found to introduce a pressure on tunnel walls. The effect of aerodynamic interference between holes in a perforated wall was studied for two- and three-dimensional configurations using a wavy wall model problem. It was found that the interference effect between wall elements is relatively local over a wide range of parameters, thereby allowing it to be represented by an additional term in the average wall boundary condition. The interference effect takes the form of a streamline curvature term. The concept of a compliant wall wind tunnel was explored by analysis of a model problem to demonstrate a particular flexible wall concept. In the area of adaptive wall wind tunnels, a method was developed which shows how control adjustments should be made to converge very rapidly to interference-free conditions.

*Princeton Univ., Princeton, NJ 08540
Grant AF-AFOSR-3337-77

163 *Ganzer, U.: **The Technology of Adaptive Wind-Tunnel Walls. (Die Technik adaptiver Windkanalwande).** Bundesministerium fur Forschung und Technologie, Statusseminar uber Luftfahrtforschung und Luftfahart-technologie, 3rd, Hamburg, West Germany, May 2-4, 1983, 22 pp. (in German).

A83-47226#

The theory of adaptive-wall 3-D wind tunnels and examples of the design and operation of both variable-porosity and flexible-wall wind tunnels are discussed. The problems involved in extrapolating wind-tunnel test measurements with tunnel-wall interference effects to real flight situations are outlined, and the principles of wall adaptation are introduced. The chief advantage of the variable-porosity method, as illustrated by the AEDC tunnel design, is seen in its use of available theoretical knowledge, practical experience, and tunnel geometry. The design and control electronics of the flexible-wall transonic tunnel built at the Technische Universitat Berlin are presented in detail, and some test results are summarized and illustrated.

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164 *McDevitt, J.B.; *Polek, T.E.; and *Hand, L.A.: **A New Facility and Technique for Two-Dimensional Aerodynamic Testing.** Journal of Aircraft, vol. 20, June 1983, pp.543-551.

(Note: For an earlier form and abstract of this paper see no. 126 in this bibliography.)

AIAA Paper 82-0608

*NASA Ames Research Center, Moffett Field, CA 94035

165 *Chevallier, J.-P.; **Mignosi, A.' **Archambaud, J.P.; and **Seraudie, A.: **T2 Wind Tunnel Adaptive Walls—Design, Construction, and Some Typical Results.** La Recherche Aerospatiale (English Edition), no. 4, July/Aug. 1983. pp. 1-19.

A85-18501#
N84-22589#

The development of adaptive walls requires a detailed analysis of basic principles concerning the coupling between the internal field (test section) and the external one (free stream computation) as well as the necessity of carrying out a fast-converging process and of defining an accurate reference speed. The application in the T2 wind tunnel is then described, specifying the control tests used for the adaptive wall operation and the technological means developed for automatic adaptation in a single run. Finally, results are presented, which show the quality of the tests emphasizing several experimental problems (side wall boundary layers, pressure hole diameters, boundary layer transition...).

*ONERA, BP 72, 92322 Chatillon Cedex, France
**ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

166 *Davis, S.S.: **The Evolution of Adaptive-Wall Wind Tunnels.** Presented at the International Symposium on "Recent Advances in Aerodynamics and Aeroacoustics," Stanford, Calif., Aug. 22-26, 1983, 31 pp. In: Proceedings, published by Springer-Verlag.

TL570.R373, 1984

Adaptive-wall wind tunnel technology is examined as a natural extension of the continuing effort to mitigate wall-induced wind tunnel interference. The state of the art in interference assessment is briefly surveyed starting from its inception in the 1920's to present-day practice. It is concluded that adaptive-wall wind tunnels will play a major role in future aerodynamic research, but that they will probably be used in a different manner than current wind tunnels. It is also concluded that more effort is needed to sort out the complex hardware/software/sensor relationships that will be required to support a large-scale, high-Reynolds-number, adaptive-wall wind tunnel.

*NASA Ames Research Center, Moffett Field, CA 94035

167 *Ganzer, U.: **Advances in Adaptive Wall Wind Tunnel Technique.** Presented at the International Symposium on "Recent Advances in Aerodynamics and Aeroacoustics," Stanford, Calif., Aug. 22-26, 1983, 40 pp. In: Proceedings, published by Springer-Verlag.

TL570.R373, 1984

A brief outline is given of the adaptive wall concept. The research projects on this subject—carried out during the past 10 years in the United States and Western Europe—are reviewed. The work done hereto at the Technical University of Berlin is discussed in some detail. It includes comprehensive tests of aerofoils in a tunnel with two flexible walls as well as tests of three-dimensional models in a tunnel with eight flexible walls. First complete wall adaptations for a lifting wing-body configuration were accomplished giving evidence of the feasibility of the adaptive wall concept for 3D-model tests.

*Institut fur Luft- und Raumfahrt, Technische Universitat Berlin, Marchstrasse 14. Sekr. F2, D-1000 Berlin 10, West Germany (FRG)

168 *Mignosi, A.; and *Dor, J.B.: **The ONERA/CERT T2 Cryogenic Wind Tunnel With Self-Adaptable Walls. (La soufflerie cryogenique a parois auto-adaptables T2 de l'ONERA/CERT).**

Presented at the Symposium on "Wind Tunnels and Testing Techniques," Cesme, Turkey, Sept 26-29, 1983. In: AGARD-CP-348 (N84-23564), Feb. 1984, paper no. 3, 12 pp. (in French). Also, ONERA TP no. 1983-117, 1983, 17 pp. (in French).

N84-23567#
A84-13630#

The transonic induction driven wind tunnel T2 at the ONERA Toulouse Research Center is equipped with a 0.4 x 0.4 sq. m test section, and is a pressurized closed circuit wind-tunnel, operating at ambient temperature with runs of 30 to 60 seconds. The wind tunnel was adapted for cryogenic operation using liquid nitrogen as a coolant and an internal thermal insulation. The main characteristics of the wind tunnel at low temperature and of the constituents used to perform airfoil tests with adaptive walls are described. The flow qualities are analyzed through an evaluation of the thermal gradients, pressure and thermal fluctuations studies, and the operating limit at very low temperature. Effects of various parameters able to influence test results are examined, such as boundary layer transition and differences between wall temperature and adiabatic wall recovery temperature.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

169 *Binion, T.W., Jr.; and *Kraft, E.M.: **A Review and an Update of the FDP Specialists' Meeting (London) on Wall Interference in Wind Tunnels.** Presented at the Symposium on "Wind Tunnels and Testing Techniques," Cesme, Turkey, Sept 26-29, 1983. In: AGARD-CP-348 (N84-23564), Feb. 1984, paper no. 6, 15 pp.

Note: See no. 129 in this bibliography for the meeting which this paper updates.

N84-23570#

The work reported at the Fluid Dynamics Panel London Specialists' Meeting on wall interference in wind tunnels is reviewed. While there are many outstanding issues still to be resolved, a final solution to the wind tunnel interference problem does appear achievable. Wall interference research has taken on renewed interest in recent years pushed by more stringent accuracy requirements for vehicle performance predictions. The research is directed toward increased prediction accuracy, particularly for ventilated tunnels operating at transonic conditions, development of interference assessment techniques from model and/or tunnel boundary measurement and interference avoidance via various adaptive wall schemes. In addition, since wall interference cannot be separated readily from the effects of other inherent tunnel and test properties such as wall boundary layers, noise, turbulence, model fidelity, etc., some research is being conducted to quantify the effect of other phenomena in order to verify the wall interference effects once they are identified.

*Calspan Field Services, Inc., Arnold Air Force Station, Tullahoma, TN 37389

170 *Ganzer, U.: **A Short Note on Recent Advances in the Adaptive Wall Technique for 3D-Model Tests at the TU-Berlin.** Presented at the Symposium on "Wind Tunnels and Testing Techniques," Cesme, Turkey, Sept. 26-29, 1983. In: AGARD-CP-348. (N84-23564), Feb. 1984, paper no. 6A, 2 pp.

N84-23571#

In the test section with eight flexible walls the first successful wall adaptations were carried out for a lifting wing body configuration at transonic speeds. The adaptive wall technique is an iterative procedure in which the boundary conditions at the test section walls are adjusted to the conditions of an unlimited flow field. In the TU-Berlin test section eight flexible walls are individually shaped such that a (nearly) streamlined three-dimensional wall configuration is formed. The starting configuration was the aerodynamically plane wall, i.e., the one which leads to constant Mach number along the empty test section (without model but with quadrant). The model in the test section creates a pressure distribution along each wall different from CP=0. The wall shape can be used as a boundary condition for an external flow field calculation, e.g., with a three-dimensional panel method. The pressure distribution calculated this way can then be compared with the measured pressure distribution. Only if the measured and calculated pressures are the same, the test section flow may be considered free of wall interference. The test results given demonstrate in principle the feasibility of the adaptive wall technique for three-dimensional model tests.

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171 *Schairer, E.T.: **Experiments in a Three-Dimensional Adaptive-Wall Wind Tunnel.** NASA TP-2210, Sept. 1983, 33 pp.

N83-34906#

Three-dimensional adaptive-wall experiments were performed in the Ames Research Center (ARC) 25- by 13-cm indraft wind tunnel. A semispan wing model was mounted to one sidewall of a test section with solid sidewalls, and slotted top and bottom walls. The test section had separate top and bottom plenums which were divided into streamwise and cross-stream compartments. An iterative procedure was demonstrated for measuring wall interference and for adjusting the plenum compartment pressures to eliminate such interference. The experiments were conducted at a free-stream Mach number of 0.60 and model angles of attack between 0 and 6°. Although in all the experiments wall interference was reduced after the plenum pressures were adjusted, interference could not be completely eliminated.

*NASA Ames Research Center, Moffett Field, CA 94035

172 *Ganzer, U.; *Igeta, Y.; *Klein, E.; and *Rebstock, R.: **Development of a Wind Tunnel Test Section With Adaptive Flexible Walls for Three-Dimensional Flow—Final Report, Oct. 1982.** Rept. No. BMFT-FB-W-83-026, Oct. 1983, 73 pp. (in German).

ISSN-0170-1339 N84-19776#

Adaptive wall wind tunnels for 3D transonic testing are described. A test section with eight flexible solid walls with shape adaptable to streamline curvature was built. A computer program was developed to calculate a 3D wall contour from a measured 3D wall pressure distribution and an automatic control device for adjusting and controlling the wall positions was also developed. Pressure measurements using a body of revolution and three-component force measurements for a wing body combination were made. Test results confirm the constructional conception and the working principle of the system.

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173 *Archambaud, J.P.; and *Seraudie, A.: **Study of Adaptive Walls for T2. (Etudes de parois adaptables a T2).** Presented at the Association of Aeronautique et Astronautique de France, Colloque d'Aerodynamique Appliquee, 20th, Toulouse, France, Nov. 8-10, 1983. Also, ONERA TP-1983-150, 1983, 55 pp. (in French).

A84-19936#

The design and operation of adaptive walls for the ONERA/CERT T2 induction-driven wind tunnel are reported. Theoretical aspects of the design of adaptive walls are considered, and an efficient design algorithm for coupling the test-section and free-stream fields and determining the reference speed is developed. The application of this scheme to the T2 facility is described and illustrated, and the factors affecting the quality of the adaptation are enumerated. Sample results from measurements on a CAST-7 profile (Elsenarr and Stanewsky; Archambaud et al., 1980 and 1982) are included.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

174 *Chevallier, J.-P.; and *Vaucheret, X.: **Wall Effects in Wind-Tunnels. (Effet de parois en soufflerie).** Presented at the Association of Aeronautique et Astronautique de France, Colloque d'Aerodynamique Appliquee, 20th, Toulouse, France, Nov. 8-10, 1983. Also, ONERA-TP-1983-143, 1983, 32 pp. (in French).

A84-19932#

A synthesis of current trends in the reduction and computation of wall effects is presented. Some of the points discussed include: (1) for the two-dimensional transonic tests, various control techniques of boundary conditions are used with adaptive walls offering high precision in determining reference conditions and residual corrections (a reduction in the boundary layer effects of the lateral walls is obtained at T2); (2) for the three-dimensional tests, the methods for the reduction of wall effects are still seldom applied due to a lesser need and to their complexity; (3) the supports holding the model or the probes have to be taken into account in the estimation of the perturbation effects in the tunnel. Other points considered are pressure distribution, wall porosity effects and comparisons of the corrected results with the manufacturers' requirements.

*ONERA, BP 72, 92322 Chatillon Cedex, France

175 *Everhart, J.L.: **FLEXWAL: A Computer Program for Predicting the Wall Modification for Two-Dimensional, Solid Adaptive-Wall Wind Tunnels.** NASA TM-84648, Nov. 1983, 54 pp.

N86-14250#

A program called FLEXWAL for calculating wall modifications for solid, adaptive-wall wind tunnels is presented. The method used is the iterative technique of NASA TP-2081 (no. 157 in this bibliography) and is applicable to subsonic and transonic test conditions. The program usage, program listing, and a sample case are given.

*NASA Langley Research Center, Hampton, VA 23665

176 *Mokry, M.: **Wind Tunnels With Adaptive Walls.** In: Two-Dimensional Wind Tunnel Wall Interference, AGARD-AG-281 (N84-20499#), Nov. 1983, pp. 167-186, 34 refs.

AD A138 964
ISBM-92-835-1463-7

This section is concerned with the adaptive wall concept, pointedly characterized as a marriage of state-of-the-art computational and experimental capabilities. Discussed are the operation principles of the adaptive ventilated walls, producing interference-free conditions by controlling the flowfield through suction and blowing, and the self-streamlining walls, effecting the same by assuming streamline shapes in unconfined flow. The minimization of wall interference by adaptive walls is essentially a variational problem, which is no less challenging than the evaluation of corrections for passive walls. Most of the work on adaptive walls is still in the technology-development phase; however the concept has been shown to be feasible, and it is likely that production facilities will be built before long. Besides this optimism there are also cautionary views that the new technological advances will have to be accompanied by more efficient flow analysis and wall control codes—particularly for transonic flows at the walls—to make the adaptive wall wind tunnel viable. Accordingly, special attention is paid to the question of initial wall setting and one-step adjustment schemes.

*National Aeronautical Establishment, National Research Council of Canada, Ottawa, Ontario K1A, OR6

177. *Sears, W.R.: **Adaptable Wind Tunnel for Testing V/STOL Configurations at High Lift.** Journal of Aircraft, vol. 20, Nov. 1983, pp. 968-974.

ISSN 0021-8669 A84-11048#

For an earlier form of this paper and an abstract see no. 142 in this bibliography.

*University of Arizona, Tucson, AZ 85721
Contract N00014-79-C-0010

178 *Goodyer, M.J.: **Tests on a CAST 7 Two-Dimensional Airfoil in a Self-Streamlining Test Section.** NASA CR-172291, Jan. 1984 44 pp.

N84-17136#

A unique opportunity has arisen to test one and the same airfoil model of CAST-7 section in two wind tunnels having adaptive walled test sections. The tunnels, at the Technical University of Berlin and at the University of Southampton, England, are very similar in terms of size and the available range of test conditions, but differ principally in their wall setting algorithms. This report includes detailed data from the tests of the model in the Southampton tunnel, with comparisons between various sources of data indicating that both adaptive walled test sections provide low interference test conditions.

*The University, Southampton S09 5NH, Hampshire, U.K.
Contract NAS1-16000 (Langley Research Center)

179 *Archambaud, J.P.; and **Chevallier, J.P.: **Use of Adaptive Walls in 2-D Tests.** NASA TM-77380, Feb. 1984, 14 pp.

N84-19359#

Note: This is an English translation by Kanner (Leo) Associates. Redwood City, Calif. For the original French see no. 132 in this bibliography.

A new method for computing the wall effects gives precise answers to some questions arising in adaptive wall concept applications: length of adapted regions, fairings with up and downstream regions, residual misadjustments effects, reference conditions. The acceleration of the iterative process convergence and the development of an efficient technology used in CERT T2 wind tunnels give in a single run the required test conditions. Samples taken from CAST 7 tests demonstrate the efficiency of the whole process to obtain significant results with considerations of tridimensional case extension.

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**ONERA, BP 72, 92322 Chatillon Cedex, France
Contract NASw-3541 (for translation)

180 *Ganzer, U.; **Stanewsky, E.; and *Ziemann, J.: **Sidewall Effects on Airfoil Tests.** AIAA Journal, vol. 22, Feb. 1984, pp. 297-299.

A84-21521#

A wind tunnel test evaluation is undertaken of theoretical methods for the treatment of wind tunnel sidewall effects. One assumption common to all theories in question is that sidewall interference effects may be accounted for by some global correction to the mainstream flow condition. Usually, a correction to incidence, lift or normal force is given. Some theories also estimate a Mach number correction. The present findings call into question the common assumption cited, since the effects are largely due to the three-dimensional character of the flow originating from the mutual interaction between sidewall boundary layers and the pressure field produced by the airfoil. This work was done in the adaptive wall wind tunnel.

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**DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

181 *LeSant, Y.: **Wall Adaptation at Mach 1.2. (Adaptation de parois a Mach 1.2)** ONERA-RTS-26/3075-AY-402, Feb. 1984, 41 pp. (in French).

N85-12873#

To minimize the wall effect in low supersonic wind tunnel tests, in the presence of strong three-dimensional shock waves, a self adaptable wall system is proposed. A method to analyze the wall effects in two-dimensional flow which also gives a minimum effect wall shape is described. The method is extendable to three dimensional flow.

*ONERA, BP 72, 92322 Chatillon Cedex, France

182 *Smith, J.: **A Theoretical Exploration of the Capabilities of 2D Flexible Wall Test Sections for 3D Testing.** Rept. no. NLR MP 84018 U, Feb. 29, 1984, 26 pp.

N86-17322#

The applicability of two-dimensional flexible solid wall test sections for three-dimensional testing is theoretically investigated for linearized subsonic flow. The method uses known interference velocity distributions along a target line (derived from a method of images for this particular study). From these, wall shapes are calculated that reduce or even eliminate the axial gradients of wall-induced upwash and blockage along this target line. The examples of residual wall interference presented, show that these gradients, as well as the overall blockage level, can substantially be reduced by means of quite acceptable wall displacements and test section lengths, even for half model testing.

*National Aerospace Laboratory (NLR), Anthony Fokkerweg 2, 1059 CM, Amsterdam, The Netherlands

183 *Harney, D.J.: **Three-Dimensional Testing in a Flexible-Wall Wind Tunnel.** Presented at the AIAA 13th Aerodynamic Testing Conference, San Diego, Calif., March 5-7, 1984. In: Technical Papers (A84-24176), pp. 276-283.

AIAA Paper 84-0623 A84-24203#

A square 9-inch wind tunnel with solid sidewalls and flexible upper and lower rod walls capable of 3-D contouring was used to test an axisymmetric and a winged lifting model at M=0.50 to 0.95. The simple, direct analytical method for wall contouring uses the model geometry for solid blockage and iterative model force data to adapt for lift and for wake blockage. Solid sidewall effects and the convergence of the adaptation scheme are evaluated. Linear and nonlinear theory for solid blockage is compared. Interesting comparisons are also made between 2-D and 3-D wall contouring.

*Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, OH 45433

184 *Parker, R.L., Jr.; and *Erickson, J.C., Jr.: **Status of Three-Dimensional Adaptive-Wall Test Section Development at AEDC.** Presented at the AIAA 13th Aerodynamic Testing Conference, San Diego, Calif., March 5-7, 1984, 10 pp.

AIAA Paper 84-0624 A84-25733#

A three-dimensional, transonic porous-adaptive-wall test section has been assembled and tested at Arnold Engineering Development Center (AEDC). Description of the components of the fully automated, computer-controlled, closed-loop test section is given. A preliminary calibration and evaluation program was completed recently for the test section which is installed in the AEDC Aerodynamic Wind Tunnel (1T). The program began with a conventional, empty-tunnel calibration. The automated systems were then exercised by using the adaptive technique to establish discrete, uniform Mach numbers with the test section from arbitrary nonuniform initial conditions. Finally, a representative transonic model was installed and adaptive experiments commenced. Repeatable, converged solutions were obtained in the adaptive mode of operation; however, the solutions did not agree exactly with wall-interference-free reference data for the test model. Extensive analysis of the results revealed that there was an error in the exterior computational code and that errors were being introduced by the interface flow-variable measurement system. These errors caused the adaptive-wall test section to adjust itself to erroneous interior-flow conditions.

*Calspan Field Services, Inc., AEDC Division, Arnold Air Force Station, Tullahoma, TN 37389

185 *Starr, R.F.; and *Varner, M.O.: **Application of the Adaptive Wall to High-Lift Subsonic Aerodynamic Testing—An Engineering Evaluation.** Presented at the AIAA 13th Aerodynamic Testing Conference, San Diego, Calif., Mar. 5-7, 1984. In: Technical Papers (A84-24176), pp. 284-291.

AIAA Paper 84-0626 A84-24204#

The streamline curvature around high-lift airfoils at low-speed conditions is reviewed to assess adaptive wall requirements for a three-dimensional test section. High-lift flapped airfoil cases ($C_L \sim 4$) with large flow separation zones and an extreme blown flap airfoil ($C_L \sim 12$) are considered. An engineering configuration for the adaptive wall test section, accounting for model to tunnel span, wind chord to tunnel height, lifting area to test section cross sectional area, and test section to wing chord length ratio, is developed. The multi-element adaptive wall selected is shown to meet deflection and radius of curvature requirements for the extreme lift, low advance ratio cases evaluated. Test sections about one-quarter of the cross sectional area of present moderate lift, low-speed testing tunnels can be utilized without blockage induced errors. Preliminary results indicate that blockage induced errors can be minimized even with flow impingement at the test section wall.

*Sverdrup Technology, Inc., 600 William Northern Blvd., P.O. Box 884, Tullahoma, TN 37388

186 *Lamarche, L.; and **Wedemeyer, E.: **Minimization of Wall Interference for Three-Dimensional Models With Two-Dimensional Wall Adaptation.** VKI-TN-149; DCAF E002628; Mar. 1984, 56 pp.

N85-12070#

A method is proposed to calculate two-dimensional wall adaptation to minimize wall interferences for three-dimensional flows. Theoretical formulations are presented for displacement and lift effects; an experimental verification for the displacement effect is included.

*Von Karman Institute for Fluid Dynamics, Chaussee de Waterloo, 72, B-1640 Rhode-Saint-Genese, Belgium
**DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

187 *Lewis, M.C.: **The Status of Analytical Preparation for Two-Dimensional Testing at High Transonic Speeds in the University of Southampton Self-Streamlining Wind Tunnel.** NASA CR-3785, Mar. 1984, 27 pp.

N84-20494#

Validation data from the Transonic Self-Streamlining Wind Tunnel has proved the feasibility of streamlining two-dimensional flexible walls at low speeds and up to transonic speeds, the upper limit being the speed where the flexible walls are just supercritical. At this condition, breakdown of the wall setting strategy is evident in that convergence is neither as rapid nor as stable as for lower speeds, and wall streamlining criteria are not always completely satisfied. The only major step necessary to permit the extension of two-dimensional testing into higher transonic speeds is the provision of a rapid algorithm to solve for mixed flow in the imagery flow fields. The status of two-dimensional high transonic testing in the Transonic Self-Streamling Wind Tunnel is outlined and, in particular, the progress of adapting an algorithm, which solves the Transonic Small Perturbation Equation, for predicting the imagery flow fields is detailed.

*The University, Southampton SO9 5NH, Hampshire, U.K.
NASA Grant NSG-7172

188 *Wolf, S.W.D.: **The Design and Operational Development of Self-Streamlining Two-Dimensional Flexible Walled Test Sections.** NASA CR-172328, Mar. 1984, 281 pp.

N84-22534#

Note: This paper was the author's Ph.D. Thesis, Univ. of Southhampton.

Self streamlining two-dimensional flexible walled test sections eliminate the uncertainties found in data from conventional test sections particularly at transonic speeds. The test section sidewalls are rigid, while the floor and ceiling are flexible and are positioned to streamline shapes by a system of jacks, without reference to the model. The walls are therefore self streamlining. Data are taken from the model when the walls are good streamlines such that the inevitable residual wall induced interference is acceptably small and correctable. Successful two-dimensional validation testing at low speeds has led to the development of a new transonic flexible walled test section. Tunnel setting times are minimized by the development of a rapid wall setting strategy coupled with on line computer control of wall shapes using motorized jacks. Two-dimensional validation testing using symmetric and cambered aerofoils in the Mach number range up to about 0.85 where the walls are just supercritical, shows good agreement with reference data using small height-chord ratios between 1.5 and unity.

*The University, Southampton SO9 5NH, Hampshire, U.K.
NASA Grant NSG-7172

189 *Michel, R.; and *Mignosi, A.: **First Cryogenic Tests of an Airfoil in ONERA/CERT T2 Wind Tunnel.** La Recherche Aerospatiale (English edition), no. 2, Mar.-Apr. 1984, pp. 69-71.

ISSN-0379-380X A84-46767#

The adaptation of the transonic T2 induction-driven wind tunnel at an ONERA research center for operation at low temperatures has required internal thermal insulation through the entire circuit; and to cool the flow, a liquid nitrogen injection device has been installed. Before entering the operational phase of studies on models in cryogenic flow, the cryogenic operation of the wind tunnel was maximized through the study of the establishment and stablization of temperature, the qualification of flow qualities, and the preparation of a preliminary operation to cool the models. Current studies involve tests of a CAST 7 airfoil subjected to different pressures and temperatures, and the determination of its aerodynamic characteristics through a range of Reynolds numbers. Two aspects are presented for the test technique: use of a gaseous nitrogen cooling device, and the use of adaptive walls which are formed to simulate boundary conditions very close to those of an infinite flow field. An initial cryogenic test program has been run on the CAST 7 airfoil, some results used to confirm temperature test validity conditions are presented, and a definition of the coefficient of lift variation with the Reynolds number is obtained.

*ONERA, BP 72, 92322 Chatillon Cedex, France

190 *Mignosi, A.; and *Imbert, R.: **First Cryogenic Test of the CAST 7 Profile in the T2 Wind Tunnel. Comparison with Calculations (Premiers essais cryogeniques du profil CAST 7 a la soufflerie T2. Comparaisons avec les caculs).** ONERA-RTS-58/1685-AY-035-D, Apr. 1984, 66 pp. (in French).

N85-13682#

The influence of the Reynolds number at 0.76 M was studied in natural and enhanced transition using a CAST 7 airfoil profile with 150 mm cord. The wind tunnel and the experimental technique are described. Studies on wall choice and on the thermal equilibrium of the model are included. Computations solving the transonic potential equation with inclusion of viscous effects are presented. Important differences between experiment and theory are observed.

*ONERA, BP 72, 92322 Chatillon Cedex, France
Contract DRET-83-34-135.

191 *Goodyer, M.J.: **Computation of Imaginary-Side Pressure Distributions Over the Flexible Walls of the Test Section Insert for the 0.3-m Transonic Cryogenic Tunnel.** NASA CR-172363, June 1984, 15 pp.

N84-27678#

Two-dimensional airfoil testing in an adaptive wall test-section wind tunnel requires the computation of the imaginary flow fields extending outward from the top and bottom test section walls. A computer program was developed to compute the flow field which would be associated with an arbitrary test section wall shape. The program is based on incompressible flow theory with a Prandtl-Glauert compressibility correction. The program was validated by comparing the streamline and the pressure field generated by a source in uniform flow with the results from the computer program. A listing of the program, the validation test results, and a sample program are included.

*The University, Southampton SO9 5NH, Hampshire, U.K.
Contract NAS1-16000

192 *Schairer, E.T.: **Two-Dimensional Wind-Tunnel Interference From Measurements on Two Contours.** Journal of Aircraft, vol. 21, June 1984, pp. 414-419.

ISSN 0021-8669 A84-34459#

This paper describes how wall-induced velocities near a model in a two-dimensional wind tunnel can be estimated from upwash distributions measured along two contours surrounding a model. The method is applicable to flows that can be represented by linear theory. It was derived by applying the Schwarz Integral Formula separately to the two contours and by exploiting the free-air relationship between upwashes along the contours. Advantages of the method are that only one flow quantity need be measured and no representation of the model is required. A weakness of the method is that it assumes streamwise interference velocity vanishes far upstream of the model. This method was applied to a simple theoretical model of flow in a solid-wall wind tunnel. The theoretical interference velocities and the velocities computed using the method were in excellent agreement. The method was then used to analyze experimental data acquired during adaptive-wall experiments at Ames Research Center. This analysis confirmed that the wall adjustments reduced wall-induced velocities near the model.

*NASA Ames Research Center, Moffett Field, CA 94035

193 *Wedemeyer, E.; and *Heddergott, A.: **The Rubber Tube Test Section of the DFVLR in Goettingen.** Rep. no. DFVLR-FB 85-18, July 1984, 43 pp.

Note: For another form of this report see no. 197 in this bibliography.

ISSN 0171-1342

To realize three-dimensional adaptive wind tunnel walls, a test section was constructed from a thick walled rubber tube. The new test section has a length of 240 cm and a circular cross section of 80 cm in diameter, and is installed in the high speed wind tunnel of the DFVLR in Goettingen. The cylindrical walls of the test section can be adapted to interference free boundary conditions by a set of 64 jacks which are driven by stepping motors. The measurement and evaluation of wall pressures, the computation of the interference free wall contour and the wall adaptation by the 64 jacks are computer-controlled and performed automatically. First model tests have demonstrated the achievement of interference free flow.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

194 *Joppa, R.G.; and *Parikh, P.C.: **Numerical Simulation of Controlled Flow Tunnel for V/STOL Testing.** Presented at the AIAA 2nd Applied Aerodynamics Conference, Seattle, Wash., Aug. 21-23, 1984, 10 pp.

AIAA Paper 84-2152 A84-41330#

A "smart" wind tunnel concept for V/STOL transition regime studies is presented and performance is projected with numerical simulations. The wind tunnel would provide a flow that faithfully represents free air flow and thereby permits accurate lift calculations for V/STOL aircraft. The design concept is based on free-air tunnels used for planar wings. Modifications are necessary to account for the highly deflected, vortical wake produced in low-speed take-off and landing situations. A three-step numerical procedure covering the potential flow of a high lift system in free-air, controlled flow data with a model in a wind tunnel and addition of the wall conditions to the simulation as a feedback loop to correct the closed-tunnel is described. The initial simulation is for three-dimensional full span jet flapped wings, and is derived from extended two-dimensional calculations. The results indicate that only partial control of the tunnel flow is sufficient to serve as a vital environment for V/STOL studies.

*Univ. of Washington, Seattle, WA 98195
NASA Grant NSG-2260

195 *Mendoza, J.P.: **A Numerical Simulation of Three-Dimensional Flow in an Adaptive Wall Wind Tunnel.** NASA TP-2351, Aug. 1984, 36 pp.

N84-28750#

Numerical simulations of three-dimensional flows in a prototype adaptive wall wind tunnel were conducted at the Mach number of 0.6 to investigate: (1) wind-tunnel wall interference, (2) active streamline control by varying air removal or injection along the walls, and (3) to develop a method for establishing wall boundary conditions for interference-free flows. It was found that wind-tunnel wall interference could be controlled by using only the vertical velocity components. For the configuration tested, it was found that interference-free flow with solid sidewalls can be approximated by using only floor and ceiling blowing/suction.

*NASA Ames Research Center, Moffett Field, CA 94035

196 *Ganzer, U.; *Igeta, Y.; and *Ziemann, J.: **Design and Operation of TU-Berlin Wind Tunnel With Adaptable Walls.** Presented at the 14th Congress of the International Council of the Aeronautical Sciences, Toulouse, France, Sept. 9-14, 1984. In: Proceedings, Vol. 1. (A84-44926), AIAA, 1984, pp. 52-65.

ICAS Paper 84-2.1.1 A84-44933#

At the Technical University of Berlin two test sections with adaptive walls have been developed: A 2-D section with flexible top and bottom wall is mainly used for aerofoil tests but also for some 3-D model tests. An octagon test section with eight flexible walls was specifically designed for the test of three-dimensional models. The test sections are described with particular reference to their constructional details and their automatic control system. Representative test results are exhibited and the problems which have occurred in course of the first years of operation are discussed. The implications of using the octagon test section at supersonic flow conditions are outlined in some detail.

*Institut fur Luft- und Raumfahrt, Technische Universitat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)

197 *Heddergott, A.; and *Wedemeyer, E.: **Deformable Adaptive Wall Test Section for Three-Dimensional Wind Tunnel Testing.** Presented at the 14th Congress of the International Council of the Aeronautical Sciences, Toulouse, France, Sept. 9-14, 1984. In: Proceedings, Vol. 1 (A84-44926), AIAA, 1984, pp. 66-75.

ICAS-84-2.1.2 A84-44934#

For an earlier form of this report and an abstract see no. 193 in this bibliography.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

198 *Grunnet, J.L.: **Transonic Wind Tunnel Wall Interference Minimization.** Journal of Aircraft, vol. 21, Sept. 1984, pp. 694-699, 18 refs.

ISSN 0021-8669 A84-44512#

Obtaining accurate predictions of aircraft aerodynamic coefficients from wind tunnel tests is a difficult task. Wind tunnel users have struggled with the effects of wall interference, model support interference, subscale Reynolds number, etc., for almost the entire history of powered flight. Since wall interference is one of the principal problems, this paper emphasizes the need to minimize it, especially in the near-sonic test regime. Practical ways of minimizing wall interference are identified. This is best accomplished for near-sonic testing by locally variable porosity with inclined hole perforations. A number of porosity setting schemes are identified, some of which are quite simple.

*FluiDyne Engineering Corp., 5900 Olson Memorial Hwy., Minneapolis, MN 55422-4917

199 *Ganzer, U.; and *Rebstock, R.: **Flexible, Adaptive Walls for Transonic Wind Tunnels in the Subsonic and Supersonic Regions (Flexible adaptive Wande fur Transsonik-Windkanale im Unter- und Uberschall).** Deutsche Gesellschaft fur Luft- und Raumfahrt, Jahrestagung, Hamburg, West Germany, Oct. 1-3, 1984, 15 pp. (in German).

DGLR Paper 84-108a A85-40325#

Problems arising during the adaptation of three-dimensional measurement sections of wind tunnels are discussed. It is shown how customary control methods using constant control factors have to be modified to guarantee a fast wall adaptation. Comparative calculations using a TSP procedure are used to demonstrate the usability of the panel method at high subsonic inflow Mach numbers, and a design method for calculating the wall deflection is presented. The use of adaptive wind tunnels in the supersonic range is discussed in detail.

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200 *Heddergott, A.; *Wedemeyer, E.; and *Kuczka, D.: **New Adaptive Test Section for the High-Speed Wind Tunnel of the DFVLR Goettingen. (Neue adaptive Messstrecke fur den Hochgeschwindigkeitskanal der DFVLR Goettingen).** Deutsche Gesellschaft fur Luft- und Raumfahrt, Jahrestagung, Hamburg, West Germany, Oct. 1-3, 1984, 28 pp. (in German).

DGLR Paper 84-108b A85-40326#

During the last few years, requirements related to the conduction of interference-free wind-tunnel measurements in the transonic Mach number region have led to the development of wind-tunnel test sections with adaptive walls. In these test sections, the walls are adapted to the streamlines of the unlimited interference-free flow. The principles involved were first described by Sears (1974) and Ferri and Baronti (1973). The present paper is concerned with the new adaptive test section which has been established in a wind tunnel of the Aerodynamic Experimental Institution in Goettingen, West Germany, The design of this test section is based on a principle of three-dimensional wall adaptation which utilizes a thick-walled, arbitrarily deformable rubber tube. Attention is given to details regarding the principle of the adaptive walls, a description of the adaptive test section, the calibration of the test section without models, measurements of pressure distribution at models, and certain problems and their solution.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

201 *Hornung, H.; and *Stanewsky, E. (editors): **Adaptive Wall Wind Tunnels and Wall Interference Correction Methods.** Oct. 15-17, 1984. Rep. no. DFVLR-IB-222-84-A-37, 1984, 42 pp.

Note: This report contains abstracts of the 29 papers presented and the program of the European Mechanics Colloquium No. 187, Goettingen, West Germany.

N85-27912

Wind tunnel tests involving adaptive wind tunnel walls, partially open wind tunnel walls, and side wall interference were discussed. Transonic, cryogenic, and supersonic wind tunnels were described.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

202 *Pittaluga, F.; and *Benvenuto, G.: **The Adaptive Wall Transonic Wind Tunnels of the University of Genova.** Presented at the 187th Euromech Colloquium on "Adaptive Wall Wind Tunnels and Wall Interference Correction Methods," Goettingen, West Germany, Oct. 15-17, 1984, 28 pp.

A85-43675#

Two transonic wind tunnel facilities at Genova University using continuously contourable upper and lower walls are described: a low-deflection blade cascade tunnel that is easily convertible (and was recently converted) into a variable-Mach-number probe calibration tunnel, and a high-deflection turbine blade cascade tunnel that was recently installed. Both facilities have atmospheric pressure inlets and work in the suction mode with continuous operation, having contourable diffusers that discharge into an air compressor. The test sections have widths of 50 mm and they can reach Mach numbers up to 2.0. Main features of the low-deflection tunnel are easily attained flow uniformity in the test section for different Mach numbers and the possibility of performing probe calibration under continuous Schlieren control. No other blade cascade tunnels are known to use flexible walls, but the design choices described should be directly applicable to larger tunnels.

*Universita di Genova Facolta di Ingegneria Istituto di Macchine Via Montallegro 1 I-16145 Genova, Italy

203 *ONERA/CERT, Department d'Etudes et de Recherches en Aerothermodynanique (D.E.R.A.T.): **Recherches Effectuees au D.E.R.A.T., (Oct. 1983-Sept. 1984) Bilan des Principaux Resultats Acquis (Research at D.E.R.A.T., (Oct. 1983-Sept. 1984) Summary of Principal Results Obtained).** Presented at the meeting of the Conseil d'Orientation (Guidance Council), Sept. 20, 1984, 41 pp. (in French).

Discussed are: (A) fundamental studies of viscous and turbulent flows, and (B) experimental methods and tests in subsonic-transonic flow. Some specific topics addressed are: wing-fuselage interference, boundary-layer transition, calculation of 3-dimensional boundary-layers, tests in the T2 cryogenic wind tunnel on adaptive walls and other corrections for wall interference, tests on the CAST 7 airfoil, problems related to the use of cryogenic tunnels, instruments for them such as friction gauges and the cryogenic wind tunnel balance for the T2.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

204 *Newman, P.A.; and *Barnwell, R.W. (editors): **Wind Tunnel Wall Interference Assessment/Correction—1983.** NASA CP-2319, Nov. 1984, 434 pp.

Note: For individual papers see nos. 151 through 156 in this bibliography.

N85-12011#

This report is a compilation of papers presented at the Wind Tunnel Wall Interference Assessment/Correction (WIAC) Workshop held January 25 and 26, 1983, at the Langley Research Center, Hampton, Virginia. The workshop was to provide an informal technical information exchange focused upon the emerging WIAC techniques applicable to conventional and passively or partially adapted wall transonic wind tunnels. The twenty-five presentations consisted of invited talks summarizing the foreign work on WIAC technology and solicited domestic talks concerning data bases suitable for WIAC validation and the status of WIAC strategies, codes, and applications.

*NASA Langley Research Center, Hampton, VA 23665

205 *Liu, X.; and *Luo, S: **On Relaxation of Transonic Flows Around Zero-Lift Airfoils and Convergence of Self-Correcting Wind Tunnels.** In: China Rep. Sci. and Technology, JPRS-CST-84-039 (N85-20206), Dec. 1984, p. 131. The abstract is translated into English in "Acta Aerodynamica Sinica" 1984, no. 3, pp. 34-41 (in Chinese).

N85-20214#

With the assumption of small transverse velocity components, the steady transonic potential flow around symmetric airfoil at zero angle of attack is computed by the mixed difference method. After some numerical experiments on the stability of various possible schemes of iteration in the relaxation, a stable scheme is found and used to verify the convergence of two kinds of transonic self-correcting wind tunnels which are based on the pressure distributions along (1) two control surfaces and (2) one control surface and the airfoil.

Northwestern Polytechnical University, Xian, China

206 *Parikh, P.C.: **A Numerical Study of the Controlled Flow Tunnel for a High Lift Model.** NASA CR-166572, 1984, 120 pp. Also, Ph.D. Thesis, Univ. of Washington, 1984. (Available from Univ. Microfilms, Order No. DA8404937.)

N84-25642#

A controlled flow tunnel employs active control of flow through the walls of the wind tunnel so that the model is in approximately free air conditions during the test. This improves the wind tunnel test environment, enhancing the validity of the experimentally obtained test data. This concept is applied to a three-dimensional jet flapped wing with full span jet flap. It is shown that a special treatment is required for the high energy wake associated with this and other

V/STOL models. An iterative numerical scheme is developed to describe the working of an actual controlled flow tunnel and comparisons are shown with other available results. It is shown that control need be exerted over only part of the tunnel walls to closely approximate free air flow conditions. It is concluded that such a tunnel is able to produce a nearly interference free test environment even with a high lift model in the tunnel.

*Univ. of Washington, Seattle, WA 98195
NASA Grant NSG-2260

207 *Davis, S.S.: **Generalized Adaptive-Wall Wind Tunnels.** Presented at the AIAA 23rd Aerospace Sciences Meeting, Reno, Nev., Jan. 14-17, 1985, 12 pp.

AIAA Paper 85-0225 A85-19601#

Adaptive-wall technology is being seriously considered for many aeronautical wind tunnel applications. A new degree of freedom is introduced into adaptive-wall wind tunnels. It is shown that the adaptive control system used to adjust wall boundary conditions may be used to select a wide variety of flow fields. These flow fields, in turn, may be directly related to many useful unconfined or semiconfined flows. The generalized adaptive-wall concept is demonstrated for both two- and three-dimensional flows using simple analytical techniques.

*NASA Ames Research Center, Moffett Field, CA 94035

208 *Dor, J.-B.: **The T2 Cryogenic Induction Tunnel in Toulouse.** Presented as paper no. 9 of the AGARD-FDP/VKI Special Course on Cryogenic Technology for Wind Tunnel Testing held at the von Karman Institute, Rhode-Saint-Genese, Belgium, April 22-26, 1985. In: AGARD-R-722, 1985, 24 pp.

N86-20424#

This paper summarizes the main results obtained by the experimental activity at the ONERA/CERT T2 induction tunnel in Toulouse since it was converted for cryogenic operation in 1981. It describes the main characteristics of this facility, operating by short pressurized transonic runs driven by induction, with a test section equipped with two self-adapting walls and its adaptation to cold flows: internal thermal insulation, cooling by injection of liquid nitrogen, system for precooling profile models and introducing them in the test section. The following subjects concerning cryogenic operation are then discussed: pressure and temperature fluctuations, thermal behavior of the walls, transverse temperature distributions in the flow, thermal equilibrium of a profile with the fluid, condensation phenomena in the cold flow and problems of particles. Finally, the test results at high Reynolds number conducted on a CAST 7 profile with a 150 mm chord are given.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

209 *Kilgore, R.A.: **The NASA Langley 0.3-m Transonic Cryogenic Tunnel.** Presented as paper no. 13 of the AGARD-FDP/VKI Special Course on Cryogenic Technology for Wind Tunnel Testing held at the von Karman Institute, Rhode-Saint-Genese, Belgium, April 22-26, 1985. In: AGARD-R-722, 1985, 15 pp.

N86-20428#

The Langley 0.3-m Transonic Cryogenic Tunnel (0.3-m TCT) can operate from ambient to cryogenic temperatures at absolute pressures from 1 to 6 bars. Since the 0.3-m TCT began operation in 1973, it has been used to develop instrumentation and operating techniques for cryogenic tunnels as well as for aerodynamic tests where advantage can be taken of the extremely wide range of Reynolds number available. This paper describes the present capabilities of the 0.3-m TCT and gives an overview of recent research activities which include both steady and unsteady testing. Emphasis is given to safety and the development of testing techniques for cryogenic tunnels. Results of studies aimed at establishing the lower limits of operating temperature are presented and the impact of these studies on tunnel operation is discussed. Finally, the design features and operating characteristics of a new self-streamlining wall test section recently installed in the tunnel circuit are described.

*NASA, Langley Research Center, Hampton, VA 23665

210 *McDevitt, John B.; and *Okuno, A.F.: **Static and Dynamic Pressure Measurements on a NACA 0012 Airfoil in the Ames High Reynolds Number Facility.** NASA TP-2485, Jan. 1985, 78 pp.

N85-27823#

The supercritical flows at high subsonic speeds over an NACA 0012 airfoil were studied to acquire aerodynamic data suitable for evaluating numerical-flow codes. The measurements consisted primarily of static and dynamic pressures on the airfoil and test-channel walls. Shadowgraphs were also taken of the flow field near the airfoil. The tests were performed at free-stream Mach numbers from approximately 0.7 to 0.8, at angles of attack sufficient to include the onset of buffet, and at Reynolds numbers from 1 million to 14 million. A test action was designed specifically to obtain two-dimensional airfoil data with a minimum of wall interference effects. Boundary-layer suction panels were used to minimize sidewall interference effects. Flexible upper and lower walls allow test-channel area-ruling to nullify Mach number changes induced by the mass removal, to correct for longitudinal boundary-layer growth, and to provide contouring compatible with the streamlines of the model in free air.

*NASA Ames Research Center, Moffett Field, CA 94035

211 *Murthy, A.V.: **Sidewall Boundary-Layer Effects in Two-dimensional Airfoil Testing.** NASA CR-176034, July 1985, 5 pp.

N85-31065#

Theoretical studies required to evaluate and validate the streamlined wall test section of the Langley 0.3 m Transonic Cryogenic Tunnel were initiated. The various aspects that are being considered presently are deviations of the real wall shape from the true streamline shape, wall adjustment strategy, and the influence of the sidewall boundary layers. Since the top and bottom walls are supported at a finite number of jack points, the true wall shape will be different from the ideal streamline shape. This is determined by calculating the structual shape for cases for which the exact streamline shape can be calculated. For the structural shape calculations, the MSCNASTRAN code is being used. To start with, comparisons are made using simple singularities for model representation and also for a flat plate at angle of attack.

*Old Dominion Univ. Research Foundation, P.O. Box 6369, Norfolk, VA 23508

NASA Grant NAG1-334

212 *Archambaud, J.P.; *Blanchard, A.; and *Seraudie, A.: **Instrumentation and Testing Techniques in the T2 Transonic Cryogenic Wind Tunnel at the ONERA-CERT.** Presented at the 11th International Congress on Instrumentation in Aerospace Simulation Facilities, Stanford, Calif., Aug. 26-28, 1985. In: ICIASF '85 RECORD, IEEE publ. 85CH2210-3.

TK7882.M415, 1985, pp. 9-25

T2 induction wind tunnel is equipped to reach high Reynolds numbers, up to 30 x 10^6. Three parameters are directly concerned with these high Reynolds numbers: pressure, model size, temperature. The T2 closed circuit can be pressurized up to 4 atm. Large models (c=200 mm) were tested in the 0.4 x 0.4 m testing chamber fitted with two-dimensional self-adaptive walls. The adaptation of the top and bottom solid walls is achieved by an iterative process which converges in a run. The air flow is cooled down to 110 K and consequently new model designs and manufacture proceedings are required. Before the run, the model must be precooled in an auxiliary facility. The measurement techniques were necessarily adapted to low temperature conditions. Measurements were made with skin friction gauges, cryogenic pressure transducer probes, and a three-component balance.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

213 *Gobert, J.L.: **Data Acquisition and Process Control in the Self-Correcting Cryogenic Wind Tunnel T2 at ONERA/CERT by Integration of Two Minicomputers.** Presented at the 11th International Congress on Instrumentation in Aerospace Simulation Facilities, Stanford, Calif., Aug. 26-28, 1985. In: ICIASF '85 RECORD, IEEE publ. 85CH2210-3.

TK7882.M415, 1985, pp. 26-35

The transonic induction T2 wind tunnel at CERT in Toulouse is equipped with adaptive walls and has been operating at cryogenic temperature since 1981. Problems were caused by the intermittent working of the tunnel. New operating techniques were developed such as control of the flow parameters and data acquisition while the walls were being used adaptively. Two linked computers satisfactorily defined conditions in the T2 wind tunnel during the testing of an airfoil.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

214 *Muller-Wichards, D.; and *Gulzow, V.: **Two Potential Theoretical Methods to Calculate the Contour of an Adaptive Test Section.** Paper presented at the 11th International Congress on Instrumentation in Aerospace Simulation Facilities, Stanford, Calif., Aug. 26-28, 1985. In: ICIASF '85 RECORD, IEEE publ. 85CH2210-3.

TK7882.M415, 1985, pp. 140-145

To realize a three-dimensional adaptive wind tunnel test section, it is necessary to develop a method for calculating the wall displacement. At the DFVLR, in Goettingen, two methods have been developed and are described. The first mehtod uses a spectral analysis, the other one is based on Green's theorem.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

215 *Bodapati, S.; and *Celik, Z.Z.: **Optimization Studies for the Development of an Adaptive Wall Wind Tunnel.** Paper presented at the 11th International Congress on Instrumentation in Aerospace Simulation Facilities, Stanford, Calif., Aug. 26-28, 1985. In: ICIASF '85 RECORD, IEEE publ. 85CH2210-3.

TK7882.M415. 1985, pp. 146-153

Two of the major problems involved in the design and operation of the ventilated adaptive wall wind tunnels are (1) the instrumentation is complex and (2) the total testing time is excessive. If the ventilated adaptive wall wind tunnels are to be used successfully for routine production testing, optimization studies are essential. It is proposed to investigate the problems cooperatively at the Stanford-NASA Ames Joint Institute. A new 25cm x 11cm adaptive wall wind tunnel test section was designed and calibrated to be used in the optimization studies. Currently the two required flow variables in the ventilated wall wind tunnel are obtained either using intrusive instrumentation like probes or a complex LDV (Laser-Doppler Velocimeter) System. Use of LDV is not only complex but currently requires excessive testing time. In order to simplify the instrumentation and reduce the total testing time, it is proposed to investigate the feasibility of using the side wall pressure distribution at two levels to obtain the two independent variables in the iterative process. Influence coefficients are obtained using the side wall pressure distribution and typical results are presented.

*Joint Institute for Aeronautics and Acoustics, Stanford Univ., Stanford, CA 94305-2186
NASA Grant NSG-2233

216 *Heddergott, A.; *Kuczka, D.; and *Wedemeyer, E.: **The Adaptive Rubber Tube Test Section of the DFVLR Goettingen.** Paper presented at the 11th International Congress on Instrumentation in Aerospace Simulation Facilities, Stanford, Calif., Aug. 26-28, 1985. In: ICIASF '85 RECORD, IEEE publ. 85CH2210-3.

TK7882.M415, 1985, pp. 154-164

The principle of wind tunnel wall adaptation, as described by Sears and Ferri and Baronti, was, so far, mainly applied to two-dimensional flows past wing sections. Fully three-dimensional wall adaptation is difficult to achieve and—with few exceptions—is realized by wall ventilation. The concept described in this paper uses a thick-walled rubber tube for the adaptive wall test section. The cylindrical tube with a length of 240 cm and a diameter of 80 cm can be deformed by a set of 64 motor-driven jacks to any desired wall contour. The new test section was designed so that it could be installed in the existing high speed wind tunnel (HWG) of the DFVLR Goettingen. First model tests have demonstrated the achievement of interference-free flow.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

217 *Lewis, M.C.: **The Status of Two-Dimensional Testing at High Transonic Speeds in the University of Southampton Self-Streamlining Wind Tunnel.** NASA CR-3919, Oct. 1985, 54 pp.

N86-12203#

This report briefly outlines the progress made during the last 2 years in extending the operational range of the Transonic Self-Streamlining Wind Tunnel (at the University of Southampton) into high subsonic speeds. Analytical preparation completed in order to achieve such an extension is outlined and a summary of the preliminary model validation tests is presented. Future work necessary to allow further validation and development is discussed.

*The University, Southampton SO9 5NH, Hampshire, U.K.
NASA Grant NSG-7172

218 *Goodyer, M.J.: **Derivation of Jack Movement Influence Coefficients as a Basis for Selecting Wall Contours Giving Reduced Levels of Interference in Flexible Walled Test Sections.** NASA CR-177992, Oct. 1985, 14 pp.

N86-12204#

This paper outlines the principle of a wall streamlining procedure for application particularly to three-dimensional testing. The procedure is based on the prerequisite that interference can be quantified in the form of wall-induced velocity perturbations, along the tunnel centerline for convenience. The notion is that the walls may be moved to adjust the centerline perturbations as desired, by making use of influence coefficients of individual jacks. The object of the work covered by this report was to assemble data on the influence coefficients for a single jack in the tunnel TSWT as a function of jack spacing and free-stream Mach number, applicable to small values of jack movement.

*The University, Southampton SO9 5NH, Hampshire, U.K.
Contract NAS1-16000

219 *Ganzer, U.: **A Review of Adaptive Wall Wind Tunnels.** Progress in Aerospace Sciences, vol. 22, Pergamon Press, 1985, pp. 81-111.

A86-17067

ISSN 0376-0421 TL500.P7 V.22

A brief outline is given of the adaptive wall concept. This is followed by a detailed description of the research facilities used to explore the concept. For tests of aerofoils, facilities with two adaptive walls are shown to yield results of very high quality. Wall adaptation was achieved even for fairly high subsonic Mach numbers. For tests of three-dimensional models, first results give hope that for subsonic flow the use of only two adaptive walls may be sufficient to reduce the wall interference to an acceptable level. On the other hand, test sections with three-dimensional adaptive walls have been employed successfully at subsonic main stream condition. Experimental results for low supersonic speeds are not yet available. From theoretical considerations, however, it can be expected that with three-dimensional adaptive walls one can achieve acceptably small wall interferences at low supersonic speeds.

*Institut fur Luft- und Raumfahrt, Technische Universitat Berlin, Marchstrasse 14, Sekr. F2, D-1000 Berlin 10, West Germany (FRG)

220 ***DFVLR Develops New Kind of Walls for Wind Tunnel.** In: West Europe Report: Science and Technology, JPRS-WST-85-015, (N86-15443), pp. 18—19. Translated into English from Frankfurter Zeitung/Blick Durch die Wirtschaft, Mar. 4, 1985.

N86-15446#

A three-dimensional adaptive wind tunnel test section was developed whose walls adapt to the air flow during the test. Initial calculations showed that a thick-walled, flexible rubber tube was found to be the most adaptive kind of material to air flow. The rubber tube is 240 cm long, has a diameter of 80cm and a wall thickness of 6 cm. A total of 64 spindles—each controlled by a positioning motor—make it possible to reduce the cylindrical test section or also, if required to increase the test cross-section by a maximum of 40 mm. This adaptive test section, also called thinking walls, in addition has 128 pressure holes connected to tiny sensors which permit precise determination of existing pressure directly on the test section wall. Without this exact information no conclusions about interference factors on the model could be made. The first sample measurements were made in the high-speed wind tunnel. Measurements were made on various so-called calibration models. The results achieved exceeded all expectations. They have proven identical to the test values which were previously arrived at by computer calculation.

*DFVLR Postfach 3267, D-3300 Braunschweig, Federal Republic of Germany

221 *Wedemeyer, E.; *Heddergott, A.; and *Kuczka, D.: **Deformable Adaptive Wall Test Section for Three-Dimensional Wind Tunnel Testing.** Journal of Aircraft, vol. 22, Dec. 1985, pp. 1085—1091.

A86-17786#

To create three-dimensional adaptive wind tunnel walls, a test section was constructed from a thick-walled rubber tube. The new test section with a length of 240 cm and a diameter of 80 cm is installed in the high-speed wind tunnel of DFVLR test facility at Goettingen. The cylindrical walls of the test section can be adapted to interference-free boundary conditions by a set of 64 jacks that are driven by stepping motors. The measurement and evaluation of the wall pressures, the computation of the interference-free wall contour, and the wall adaptation by the 64 jacks are computer controlled and performed automatically. First model tests have demonstrated the achievement of interference-free flow.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

222 *Davis, S.S.: **Applications of Adaptive-Wall Wind Tunnels.** Journal of Aircraft, vol. 23, Feb. 1986, pp. 158—160.

The purpose of this note is to introduce a new technique for processing flowfield data from an adaptive-wall wind tunnel. The basic premise is that it may not be necessary, or desirable, to force the adaptive-wall wind tunnel to simulate complete free-air conditions. Applications of adaptive-wall wind tunnels are introduced and demonstrated using simple analytical methods. More work remains to be done in the demonstration and subsequent acceptance of conventional adaptive-wall technology. Once this milestone has been reached, the methods described above may be useful tools for both precision aerodynamic testing and for the development and validation of advanced computational techniques.

NASA Ames Research Center, Moffett Field, CA 94035

223 *Barnwell, R.W.; *Edwards, C.L.W.; *Kilgore, R.A.; and *Dress, D.A.: **Optimum Transonic Wind Tunnel.** AIAA 14th Aerodynamic Testing Conference, West Palm Beach, Fla., Mar. 5—7, 1986. Technical Papers, pp. 173-182.

AIAA Paper 86-0755 A86-24743#

The optimum facility to complement existing high Reynolds number transonic wind tunnels is discussed. It is proposed that the facility be cryogenic, have a total pressure of five atmospheres or less, and have a test section on the order of 4- to 5-meters square. The large size is to accommodate complicated models such as those used in propulsion testing. It is suggested that magnetic suspension and wall interference minimization and correction procedures be used. Simplicity of initial design is stressed as a means of providing for future growth opportunities.

*NASA Langley Research Center, Hampton, VA 23665

Appendix

The following entries may not deal directly with adaptive walls, but are included here because they could be useful to persons using this bibliography. These publications are included in the indexes and are identified by the "A" in the citation number.

A1. *Hills, R. (editor): **A Review of Measurements on AGARD Calibration Models.** AGARDograph 64, Nov. 1961, 243 pp., 112 refs.

N63-13508

CONTENTS:

1. PART I. TESTS ON AGARD MODEL A R. Hills (Aircraft Research Assoc., Gt. Brit.) p. 7-34, 27 refs.
2. PART II. A REVIEW OF MEASUREMENTS ON AGARD CALIBRATION MODEL B IN THE TRANSONIC SPEED RANGE H. Valk and J.H. van der Zwaan (Nat. Aero- and Astro-nautical Research Inst., Neth.) p. 35-94, 15 refs.
3. PART III. A REVIEW OF MEASUREMENTS ON AGARD CALIBRATION MODEL B IN THE MACH NUMBER RANGE FROM 1.4 TO 8 J.P. Hartzuiker (Nat. Aero- and Astro-nautical Research Inst., Neth.) p. 95-136, 3 refs.
4. PART IV. A REVIEW OF MEASUREMENTS ON AGARD CALIBRATION MODEL C IN THE TRANSONIC SPEED RANGE H. Valk (Natl. Lucht- en Ruintevaartlab. Neth.) p. 137-211, 14 refs.
5. PART V. TESTS ON AGARD MODEL D R. Hills (Aircraft Research Assoc., Gt. Brit.) p. 213-227, 5 refs.
6. PART VI. TESTS ON AGARD MODEL E R. Hills (Aircraft Research Assoc., Gt. Brit.) p. 229-245, 18 refs.

*Aircraft Research Association, Ltd., Manton Lane, Bedford Beds MK41 7 PF, U.K.

A2. *Schneider, W.: **Three-Component Force Tests on AGARD Calibration Models B and C in the AVA Transonic Wind-Tunnel (Drei-Komponentenmessungen an den AGARD-Eichmodellen B und C im Transonischen Windkanal der AVA).** Rept. no. DLR-FB-66-10; AVA-FB-66-02; Feb. 1966, 38 pp. (in German).

N66-35045#

Three component force tests were conducted at the AVA in the Transonic wind tunnel on AGARD calibration models B and C. Mach number range was from M = 0.5 to M = 1.15. AGARD model B was tested,too in the supersonic test section of the tunnel at Mach numbers M = 1.52 and M = 1.97. Both models had 0.5-percent blockage. The Reynolds number was approximately $2.4.10^{6}$. Test results are presented in form of diagrams and are compared with results of other wind tunnels.

*DFVLR, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

A3. *Heyson, H.H.: **Theoretical Study of the Use of Variable Geometry in the Design of Minimal Correction V/STOL Wind Tunnels.** NASA TR R-318, Aug. 1969, 137 pp.

N70-14133#

Theory indicates that, if either the width-height ratio or the model height is properly scheduled, the vertical interference velocities at the lifting system can be reduced to zero in closed on bottom only tunnels. Reductions in interference at the tail, nonuniformity of interferences, and minimum speed for recirculation free testing can be obtained simultaneously; however, these reductions are much greater in the case of variable width-height ratio. Variable width-height ratio operation of a closed tunnel can reduce the interference at the lifting system by a factor of 2 or 3. This configuration, at low speeds, can reduce interference at the tail, nonuniformity of interference, and minimum speed for recirculation free testing to almost negligible values.

*NASA, Langley Research Center, Hampton, VA 23665

A4. *Muhlstein, L., Jr., and *Beranek, R.G.: **Experimental Investigation of the Influence of the Turbulent Boundary Layer on the Pressure Distribution Over a Rigid Two-Dimensional Wavy Wall.** NASA TN D-6477, Aug. 1971, 102 pp.

N71-33311#

The static-pressure distribution was measured on the surface of a series of five rigid sinusoidal wavy wall models at Mach numbers from M=0.80 to 1.35 and ratios of boundary-layer displacement thickness to model wavelength of 0.0025 to 0.13. Effects of wavelength and amplitude-to-wavelength ratio were examined. For the conditions of the tests, it is shown that the turbulent boundary layer causes a large attenuation of the pressure distribution at subsonic speeds and both an attenuation and a large phase shift relative to the inviscid case of supersonic speeds. These effects are greatest near M=1.0 and decrease rapidly with increasing or decreasing Mach numbers. At supersonic Mach numbers, the pressure coefficient multiplied by square root of M square minus 1 correlates closely with the thickness of the subsonic portion of the boundary layer. Results extrapolated to zero boundary-layer thickness are presented and compared with three inviscid theories.

*NASA, Ames Research Center, Moffett Field, CA 94035

A5. *Barritt, M.M.; and *Diprose, K.V.: **Calculation of Flexible Wall Shapes and Preparation of Control Tapes for the Bedford 8-ft. by 8-ft. Wind Tunnel.** In: Aerodynamic Research Program, Including Turbine, Nozzle Flutter, and Instrumentation Studies, Vol. 2, (N73-25020). British ARC.; 1971, pp. 1325-1357. Also, ARC-R/M-3187; RAE-R-MS-54; 33 pp.

N73-25041

An application of a digital computer to the aerodynamic design and automatic control of a large wind tunnel with flexible walls is described. The computational problem was threefold: first, calculation of the wall shapes for a set of pivotal operating speeds between M=1 and 2.8; second, computation of the necessary movements of the set of screw jacks which flex the walls; and finally, preparation of the set of digitally punched control tapes. A new mathematical approach was used for the first part in order to avoid singularities in the partial differential equations governing the flow in the convergent-divergent nozzle of the tunnel.

*Royal Aircraft Establishment, Bedford MK41 6AE, U.K.

A6. *Davis, J.W.: **An Empirical Technique for Optimization of Variable Porosity Transonic Wind Tunnel Flows.** Ph.D. Thesis, Oklahoma State Univ., July 1972, 138 pp. (Available from Univ. Microfilms, Order no. 73-15088).

N74-12039

A scientific procedure is developed by which the transonic flow wave cancellation process can be studied on a mathematical basis and which can be used to predict optimum values of variable porosity transonic wind tunnel parameters that can be expected to yield minimum wave interference on the aerodynamic test model. The significant parameters are identified by means of an analysis of thin wall and thick wall theory and by a review of past experimental work. By means of a quasi-linear multiple regression technique, a mathematical model is developed by which a performance index relating experimental results to known interference-free reference measurements can be used to solve for the optimum wind tunnel settings using the method of steepest ascent (descent). A technique has been developed which is capable of determining the optimum variable porosity transonic wind tunnel configuration for which reflected wave interference should be at a minimum level.

*Oklahoma State Univ., Stillwater, OK 74078

A7. *Yates, J.E.: **Linearized Integral Theory of the Viscous Compressible Flow Past a Wavy Wall.** ARAP-177; AFOSR-72-1335 TR; July 1972, 70 pp.

AD 746 332 N73-11278#

Two integral theories for compressible flow are derived from the calculation of pressure on a perturbed plane wall in the presence of viscous boundary layer. A simple theory is derived from the von Karman momentum integral equation, and a rational theory is derived by iteration from asymptotic perturbation theory, in both theories, the wall pressure amplitude and phase angle are functions of a single similarity parameter X which is proportional to boundary layer thickness. The two theories are compared with experimental results and with numerical calculations based on asymptotic perturbation theory. Qualitative and quantitative results based on the rational integral theory are compared with experimental results.

*Aeronautical Research Associates of Princeton, Inc., Princeton, N.J. Contract F44620-71-C-0132; AF Project 9782

A8. *Reed, T.D.; *Pope, T.C.; and *Cooksey, J.M.: **Calibration of Transonic and Supersonic Wind Tunnels.** NASA CR-2920, Nov. 1977, 273 pp.

N78-15058#

Section III.G.2 (pp. 165-169), **Adaptive Wall Studies,** is concerned with problems of boundary conditions and wall interference of adaptive walls.

*Vought Corp., Dallas, TX 75265
Contract NAS2-8606

A9. *Newman, P.A.; and **Anderson, E.C.: **Analytical Design of a Contoured Wind-Tunnel Liner for Supercritical Testing.** Presented at the Conference on "Advanced Technology Airfoil Research," Hampton, Va., Mar. 7-8, 1978. In: NASA CP-2045, Vol. I, Pt. 2 (N79-19989), Mar. 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 (LFC), 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 23665
**DCW Industries, Inc., Studio City, CA 91604
Contract NAS1-14517

A10. *Newman, P.A.; and **Anderson, E.C.: **Numerical Design of Streamlined Tunnel Walls for a Two-Dimensional Transonic Test.** NASA TM-78641, Apr. 1978, 22 pp.

N78-23105#

An analytical procedure is discussed for designing wall shapes for streamlined nonporous two-dimensional transonic wind 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.

*NASA Langley Research Center, Hampton, VA 23665
**DCW Industries, Inc., Studio City, CA 91604
Contract NAS1-14517

A11. *Barche, J. (Editor): **Experimental Data Base for Computers-Program Assessment: Report of the Fluid Dynamics Panel Working Group 04.** AGARD-AR-138, May 1979, 609 pp.

ISBN-92-835-1323-1 N79-31159#

The acquisition of highly reliable wind tunnel test data for aircraft design was investigated. (For an Addendum to this report see A21 in this bibliography.)

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)

A12. *Anderson, E.C.: **User Guide for STRMLIN: A Boundary-Layer Program for Contoured Wind Tunnel Liner Design — Final Report.** DCW-R-15-02; NASA CR-159058; 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.

*DCW Industries, Inc., Studio City, CA 91604
Contract NAS1-14517

A13. *Campbell, R.L.: **Computer Analysis of Flow Perturbations Generated by Placement of Choke Bumps in a Wind Tunnel.** NASA TP-1892, Aug. 1981, 42 pp.

N81-30082#

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 conditions 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 23665

A14. *Newman, P.A.; *Anderson, E.C.; and *Peterson, J.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., Mar. 21-24, 1982, 11 pp. In: Technical Papers, pp. 36-47.

AIAA Paper 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 streamlining 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. 23665

A15. *Om, D.; **Viegas, J.R.; and *Childs, M.E.: **Transonic Shock-wave/ Turbulent Boundary-Layer Interaction in a Circular Duct.** Presented at the 3rd AIAA and ASME Joint Thermophysics, Fluids, Plasma and Heat Transfer Conference, St. Louis, Mo., June 7-11, 1982. Also AIAA Journal, Vol. 23, May 1985, pp. 707-714, 27 refs. (no. A29 in this bibliography).

AIAA Paper 82-0990 A82-31951

Detailed pitot, static, and wall pressure measurements have been obtained for a transonic normal shockwave/turbulent boundary-layer interaction of free-stream Mach numbers of 1.28, 1.37, and 1.48, and at a constant unit Reynolds number of 4.92×10^6/m in an axisymmetric, internal flow. Measurements have also been obtained at a unit Reynolds number of 9.84×10^6/m at a free-stream Mach number of 1.29. The interaction depends very strongly on the Mach number. The effect of Reynolds number on the unseparated interaction is small. Flow blockage due to the wind tunnel wall boundary layer produces a weaker interaction and a much larger supersonic tongue than observed for planar flows. Comparisons are made with solutions to the time-dependent, mass-averaged, Navier-Stokes equations incorporating a two-equation, Wilcox-Rubesin turbulence model. The computations are in agreement with the experimental results.

*Univ. of Washington, Seattle, WA 98195
**NASA Ames Research Center, Moffett Field, CA 94035

A16. *Nenni, J.P.; *Erickson, J.C., Jr.; and *Wittliff, C.E.: **Measurement of Small Normal Velocity Components in Subsonic Flows by Use of a Static Pipe.** AIAA Journal, vol. 20, Aug. 1982, pp. 1077-1083.

AIAA 82-4184

A concept for measuring small normal velocity components in subsonic flows by use of a static pipe has been developed and tested. A theory is presented which allows one to relate measurements of the difference of static pressures across a static pipe in a slightly disturbed flow to the axial derivative of the velocity component normal to the pipe. This derivative may be integrated, after fixing the constant of integration, to give the normal velocity component distribution along the pipe. The theory is restricted to small normal velocity components relative to the main freestream flow which is aligned with the pipe axis. The theoretical development presented here is primarily concerned with two-dimensional disturbance fields, but results are given for three-dimensional disturbance fields also. An experimental application of the concept to measure the disturbance fields arising in a two-dimensional wind tunnel is described. These experiments show how the present static-pipe concept can be used in a practical experimental situation.

*Calspan Advanced Technology Center, Buffalo, NY 14221
Contract F40600-78-C-0003

A17. *Mateer, G.G.; and **Bertelrud, A.: **Contouring Tunnel Walls to Achieve Free-Air Flow Over a Transonic Swept Wing.** Presented at AIAA 16th Fluid and Plasma Dynamics Conference, Danvers, Mass., July 12-14, 1983, 10 pp.

AIAA Paper 83-1725 A83-37211#

The effects of wind-tunnel walls on the flow over a swept wing were greatly reduced by wall contouring. Significant reductions in spanwise pressure gradients were achieved by shaping all of the walls to conform to the streamlines over the model in free air. Surface pressure and oil-flow data were used to evaluate the effects of Mach and Reynolds numbers on the design. Comparisons of these data with inviscid calculations indicate that free-air flow is established at a Mach number of 0.74 and at Reynolds numbers above 4.7 million.

*NASA Ames Research Center, Moffett Field, CA 94035
**Aeronautical Institute of Sweden, Bromma, Sweden

A18. *Mokry, M.; *Chan, Y.Y.; and *Jones, D.J.; Edited by *Ohman, L.H.: **Two-Dimensional Wind Tunnel Wall Interference.** AGARD-AG-281, Nov. 1983, 195 pp.

AD A138 964 N84-20499#
ISBN-92-835-1463-7

Developments in the understanding of the wall interference problem associated with two dimensional wind tunnel testing at subsonic and transonic speeds are described: Wall boundary conditions, asymptotic analysis of wall interference, classical and extended wall interference theories, wall interference corrections from boundary measurements, integral equation formulation of subcritical wall interference, and effects of side wall boundary layer on two dimensional tests are discussed. Unsteady wall interference at subsonic and supersonic flow conditions is reviewed. Advances in the adaptive wall technique, which actively reduces or eliminates wall interference, are described.

*National Aeronautical Establishment, National Research Council, Montreal Rd., Ottawa, Ontario K1A OR6, Canada

A19. *Moses, D.F.: **Wind Tunnel Wall Corrections Deduced by Iterating From Measured Wall Static Pressure.** AIAA Journal, vol. 21, no. 12, Dec. 1983, pp. 1667-1673.

A84-13573#

An iterative method for calculating wall interference corrections to model lift and induced drag from simple flowfield measurements is presented. The method is applied to low-speed solid-wall wind tunnels, where the only measurements required are wall static pressures. The procedure for the iterations is described and the criterion for convergence to unconfined flow is given. The advantages of this method are that it easily handles cases having strong viscous effects, models with running propellers, etc. The viability of the procedure is demonstrated in a low-speed wind tunnel test of a wing model. A comparison shows that the standard method of images undercorrects, in this particular case, by about 20-30%.

*San Diego State Univ., San Diego, CA 92115

A20. *Gleyzes, C.; and *Cousteix, J.: **Calculations of Streamlines From Wall Pressures on a Fusiform Body:** La Recherche A'erospatiale (English Edition), no. 3, May-June 1984, pp. 69-77.

ISSN 0379-380X A85-14894#

The proposed method for calculating streamlines from a wall pressure distribution is based on the integration of the Euler equations. The initial conditions are determined by a preliminary calculation in the neighborhood of the stagnation point: the equations are integrated by marching against the flow and the direction of the velocity is adjusted by a shooting method in such a way that the streamlines cross the stagnation point. From the initial conditions, the equations are integrated by marching in the flow direction. This integration is performed in an axis-system the pole of which coincides with the stagnation point. Such an axis-system can also be of use in boundary layer calculations.

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

A21. *AGARD (Advisory Group for Aerospace Research and Development), NATO: **Experimental Data Base for Computers Program Assessment.** AGARD-AR-138 Addendum, July 1984, 148 pp.

ISBN 92-835-1475-0 N85-10020

The data collected in this Addendum complement those included in the AGARD Advisory Report No. AR-138 issued in May 1979 (see no. A11 in this bibliography). In that report certain recommendations were made with regard to further, more rigorous, test cases. A number of 3-D test cases that closely match these recommendations have since then appeared. Regarding further 2-D test cases, no test has as yet appeared that matches the recommendations for the "ideal" test case given in AR-138. However, considerable effort is still being expended in many NATO countries towards the perfection of the 2-D test methodology (e.g., U.S., Canada and the Garteur group in Europe.) Concerning body-alone configurations, it was recommended in AR-138 that the data given for the ONERA calibration body C5 (case C4 in AR-138) should be complemented with boundary layer survey data. This would result in virtually the ideal test case for bodies of revolution at zero angle of attack. However no such data have so far been produced.

*AGARD (Advisory Group for Aerospace R&D, NATO) 7 rue Ancelle, 92200 Neuilly sur Seine, France

A22. *Steinle, F.W., Jr.; and **Mabey, D.G.: **Computer Studies of Hybrid-Slotted Working Sections With Minimum Interference at Subsonic Speeds.** NASA TM-86002, Aug. 1984, 20 pp. Also, The Aeronautical Journal, Apr. 1985, pp. 135-148 (no. A28 in this bibliography).

N84-32379#

A series of computations on tunnel boundary interference effects for hybrid-slotted working sections was performed using the WALINT code. The slots were modeled as lines of porosity with linear crossflow characteristics. The basic shape evaluated was for a rectangular section with height-to-width ratio = 0.835 and its companion in the duplex mode (half model testing) with height-to-width ratio = 0.6. A best overall basic configuration was determined with seven slots on each wall with open area ratio on each wall of 17.5%. For both full-span and half-model testing, the optimum solution required closing all but two slots on each of the half-walls parallel to the plane of the wing (equivalent to four slots on the full floor and ceiling). The results are presented here for the best configurations and are shown to be within the figure-of-merit range of + or -0.04 in upwash, and + or -0.1 in curvature for the Mach number range 0.6 to 0.85. Blockage effects are shown to be small. The results should serve to heighten the interest of those contemplating incorporating active wall technology to existing test sections.

*NASA Ames Research Center, Moffett Field, CA 94035
**Royal Aircraft Establishment, Bedford MK41, 6AE, U.K.

A23. *Labrujere, Th.E.; *Maarsingh, R.A.; and *Smith, J.: **Wind Tunnel Wall Influence Considering 2D High Lift Configurations.** Presented at the 14th Congress of the International Council of the Aeronautical Sciences; Toulouse, France, Sept. 9-14, 1984. In: Proceedings, Vol. 1 (A84-44926), AIAA 1984, pp. 76-84.

A84-44935#

The present paper describes two alternative correction methods for wall interference based on measured boundary conditions. In both methods it is assumed that at or near the tunnel boundary the flow velocity will be measured in magnitude and direction and that the main part of the flow field may be considered irrotational and subsonic. One method aims at a correction in terms of changes in free stream velocity and angle of attack. The other method aims at corrections of the velocity distribution along the model. The application of both methods is demonstrated numerically for the case of a single and a multiple airfoil in a solid wall test section.

*National Aerospace Lab. (NLR), Anthony Fokkerweg 2, 1059 CM, Amsterdam, The Netherlands

A24. *Rae, W.H., Jr.; and **Pope, A.: **Low-Speed Wind Tunnel Testing.** Second Edition published by John Wiley & Sons, Inc., 1984. 534 pp. ref., index.

ISBN-0-471-87402-7 TL 567.W5 P694, 1984

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*Univ. of Washington, Aeronautical Lab., Seattle, WA 98195
**Sandia National Laboratory, NM 87047

A25. *Chan, Y.Y.: **An Asymptotic Analysis of Transonic Wind-Tunnel Interference Based on the Full Potential Theory.** Journal of Applied Mathematics and Physics (ZAMP), Vol. 36, Jan. 1985, pp. 89-104.

ISSN 0044-2275 A85-30171

The transonic flow over an airfoil in a wind tunnel with perforated walls has been analyzed asymptotically based on the full potential equation. By matching the flow regions about the airfoil and near the wall, the analysis yields explicitly the effects of wall constraints and transonic nonlinearity on the flow in the tunnel. The analysis indicates that in general the wall interference is uncorrectable. However, it is also shown that if a limit wall control is applied, the interference becomes correctable and the resulting corrections are given implicitly.

*National Aeronautical Establishment, National Research Council of Canada, Montreal Road, Ottawa, Ontario K1A OR6, Canada.

A26. *Ojha, S.K.; and *Shevare, G.R.: **Exact Solutions for Wind Tunnel Interference Using the Panel Method.** Computers and Fluids, vol. 13, no. 1, Jan. 1985, pp. 1-14.

ISSN 0045-7930 A85-34734

It is pointed out that the effect of wind tunnel wall constraints can be theoretically predicted only by solving the Navier-Stokes equations with the wall contraints as boundary conditions and comparing the solution with that having no wall constraints. In the absence of any such solution, the problem is generally studied by making use of the potential flow theory. The basic equation involved is the Laplace equation which is now generally solved by the method of surface singularities, also commonly known as the panel method. The existing wind tunnel interference theories are based on highly simplified assumptions, and fail to provide accurate results for large blockage ratios and incidences. The present investigation is concerned with the employment of the panel method, taking into account an extension of the method to account for wall constraints. The considered method brings out the nonlinear effect of the wall interference.

*Indian Inst. of Technology, Bombay, India

A27. *Rowe, W.S.; and *Ehlers, F.E.: **Coupling Linear Far-Field Boundary Conditions With Non-Linear Near-Field Solutions in Transonic Flow.** Presented at the AIAA 26th Structures, Structural Dynamics, and Materials Conference, Orlando, Fla., Apr. 15-17, 1985. In: Technical Papers, Part 2 (A85-30226), 1985, pp. 72-82.

AIAA Paper 85-0599 A85-30328#

A research investigation has been conducted to evaluate the feasibility of coupling linearized far-field solutions with near-field finite differencing equations to reduce the size of grid networks required in present transonic flow calculations. Procedural changes made to an existing finite differencing program involves distributing sources on the solution interface boundary in order to develop the proper far-field outgoing wave boundary condition on a reduced size grid network. Validation of the modification procedure is established for zero-thickness airfoils by comparing predicted two-dimensional results with results obtained from an exact procedure. A criterion based on the gradient of the flow field Mach number was developed for use in establishing the minimum size grid network necessary for accurate finite thickness unsteady loading predictions. Acceptable loading predictions may be achieved for a nominal 5:1 grid size reduction ratio and a 40 percent reduction in computer usage costs.

*Boeing Commercial Airplane Co., P.O. Box 3707, Renton, WA 98124
Contract F49620-83-C-0118

A28. *Mabey, D.G.; and **Steinle, F.W.: **Computer Studies of Hybrid Slotted Working Sections With Minimum Steady Interference at Subsonic Speeds.** Aeronautical Journal, vol. 89, Apr. 1985, pp. 135-148.

Note: For an earlier form of this article see no. A22 in this bibliography.

A85-39241

Currently there is renewed interest in the evaluation and reduction of steady wind tunnel wall interference, especially for large models. Evaluation of previous predictions for perforated and slotted tunnels suggests that a hybrid slotted tunnel, (i.e., a slotted tunnel with closed slats and perforated slots) should offer minimum corrections for upwash, flow curvature and solid blockage. This suggestion is confirmed by the present computer studies of a range of rectangular hybrid slotted tunnels. The computer studies are for tunnel working section height to breadth ratios of 0.835 and 0.600 over the Mach number range from 0 to 0.85. Wings swept at 28° and 50°, with ratios of model span to tunnel breadth varying from 0 to 0.7, are considered. An idealised fuselage shape is used to predict solid and wake blockage corrections for the wall configurations selected on the basis of minimum upwash and curvature interference.

*Royal Aircraft Establishment, Bedford MK41 6AE, U.K.
**NASA Ames Research Center, Moffett Field, CA 94035

A29. *Om, D.; **Viegas, J.R.; and *Childs, M.E.: **Transonic Shock-Wave/Turbulent Boundary-Layer Interaction in a Circular Duct.** AIAA Journal, vol. 23, May 1985, pp. 707-714, 27 refs.

AIAA Paper 82-0990 A85-32610#

For an earlier form of this paper and an abstract, see no. A15 in this bibliography.

*Univ. of Washington, Seattle, WA 98195
**NASA Ames Research Center, Moffett Field, CA 94035

A30. *Yoshihara, H.; and **Sacher, P., (chairmen): **Test Cases for Inviscid Flow Field Methods.** AGARD-AR-211, May 1985, 336 pp.

ISBN 92-835-1497-1 N86-15256#

The escalating costs and the continuing limitations of wind tunnel testing together with the growing imperative to achieve the "optimal" design have rapidly increased the importance of computational fluid dynamics in the design of military aircraft. At relevant Reynolds numbers, inviscid flow methods continue to play an essential role in this design process. In recognition of this, the AGARD Fluid Dynamics Panel established Working Group 07 to specify relevant reference test cases to serve as validation bases for those developing new methods with improved accuracy and cost-effectiveness. These cases further serve as check cases for those learning to use existing production codes.

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**Messerschmitt-Bolkow-Blohm GmbH, UF, Postfach 80 11 60, D-8000 Munchen 80, West Germany (FRG)

A31. *Heyson, H.H.: **Variable Geometry Wind Tunnels—Patent Application.** H.H. Heyson, inventor (to NASA) Filed 20 Oct. 1969, 12 p. (NASA-Case-XLA-7430; US-Patent-Appl-SN-867841.)

N70-35678#

A variable geometry wind tunnel is described for testing aircraft models in subsonic tests representing the low speed phases of flight. The system provides for variation of the test section of the tunnel during a test and reduces the corrections needed in data obtained in subsonic wind tunnel tests. The system is computerized to attain optimum test conditions.

*NASA Langley Research Center, Hampton, VA, 23665

A32. *Stanewsky, E.; **Puffert-Meissner, W.; **Muller, R.; and **Hoheisel, H.: **The Transonic Windtunnel Braunschweig of DFVLR.** (Der Transsonische Windkanal Braunschweig der DFVLR). Z. Flugwiss. Weltraumforsch. 6 (1982), Heft 6; Nov.-Dec, 1982, pp. 398—408, (in German).

A 83-19663

This paper describes the German "Transonic Wind Tunnel Braunschweig" (TWB) of DFVLR. Topics of the discussion are the test set-up and the data acquisition system as well as a detailed description of a method for optimizing the test section wall geometry leading to a strong reduction in wall interference. To demonstrate the test quality and capacity of the TWB, the results obtained in this tunnel are compared to those of similar test facilities; furthermore, within the given possibilities, the influence of the Reynolds number on the flow about a specific transonic airfoil is outlined.

*DFVLR, AVA, Bunsenstrasse 10, D-3400 Goettingen, West Germany (FRG)
**DFVLR, Flughafen, D-3300 Braunschweig, West Germany (FRG)

A33. *Archambaud, J.P.; *Dor, J.B.; *Mignosi, A.; and *Lamarche, L.: **First Tests of the Two-Dimensional Automatic Wall Adaptation of the T2 Windtunnel Using Three-Dimensional Models.** (Premiers essais d'adaptation des parois auto-adaptables bidimensionnelles de la soufflerie T2 autour d'obstacles tridimensionnelles.) DERAT 11/5015 DN; R.T. OA no. 33/3075 AND; Sept. 1985, 49 pp. (in French).

*ONERA/CERT, BP 4025, 31055 Toulouse Cedex, France

A34. *Barnwell, R.W.: *Edwards, C.L.W.; *Kilgore, R.A.; and *Dress, D.A.: **Optimum Transonic Wind Tunnel.** AIAA 14th Aerodynamic Testing Conference, West Palm Beach, Fla., Mar. 5—7, 1986. Technical Papers, pp. 173-182.

AIAA Paper 86-0755

The optimum facility to complement existing high Reynolds number transonic wind tunnels is discussed. It is proposed that the facility be cryogenic, have a total pressure of five atmospheres or less, and have a test section on the order of 4- to 5-meters square. The large size is to accommodate complicated models such as those used in propulsion testing. It is suggested that magnetic suspension and wall interference minimization and correction procedures be used. Simplicity of initial design is stressed as a means of providing for future growth opportunities.

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Author Index

SUBJECT INDEX

NOTE: The following index, although in no way complete, might be useful by giving an indication of where some material on definite subject areas may be found. Generally, surveys and summaries are not indexed in depth.

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15. Supplementary Notes

Marie H. Tuttle: Vigyan Research Associates, Inc., Hampton, Virginia.
Raymond E. Mineck: Langley Research Center, Hampton, Virginia.

16. Abstract

This bibliography, with abstracts, consists of 257 citations arranged in chronological order. Selection of the citations was made for their value to researchers working to solve problems associated with reducing wall interference by the design, development, and operation of adaptive wall test sections. Author, source, and subject indexes are included.

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