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NASA Technical Memorandum 81909

Support Interference of Wind Tunnel Models - A Selective Annotated Bibliography

(NASA-TM-81909) SUPPORT INTERFERENCE OF WIND TUNNEL MODELS: A SELECTIVE ANNOTATED BIBLIOGRAPHY (NASA) 36 p HC A03/MF A01 CSCL 14B N81-20084
Unclas
G3/09 41797

Marie H. Tuttle and Blair B. Gloss

MARCH 1981

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Support Interference of Wind Tunnel Models - A Selective Annotated Bibliography

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NASA
National Aeronautics
and Space Administration

Scientific and Technical
Information Branch

1981

INTRODUCTION

The intent of this bibliography is to list publications that might be useful to persons interested in support interference of wind tunnel models. The publications included have not been limited to any particular type of model support or Mach number range. Some papers of historical interest are included.

Since sting interference effects may be discussed in publications with no mention made of this fact in the title or abstract, omissions will occur as a result of oversight. It is hoped that omissions of important papers will be called to the attention of the compilers, so that possible subsequent updated versions or supplements of this bibliography may be more nearly complete and, therefore, more useful.

The arrangement is chronological by date of publication. An author index is included for the convenience of the user.

In many cases, abstracts used are from the NASA announcement bulletins "Scientific and Technical Aerospace Reports" (STAR) and "International Aerospace Abstracts" (IAA). In other cases, authors' abstracts were used. License was taken to modify or shorten abstracts, using only parts pertinent to the subject of the bibliography. If a paper has appeared in several forms, mention is made of this fact. Accession numbers, report numbers, and other identifying information are included in the citations in order to facilitate the filling of requests for specific items.

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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 *Bacon, David L.: **Model Supports and Their Effect on the Results of Wind Tunnel Tests.** NACA-TN-130, Feb. 1923, 14 pp.

The airflow about a model while being tested is often sufficiently affected by the model support to lead to erroneous conclusions unless appropriate corrections are used. In this paper some new material on the subject is presented, together with a review of the airfoil support corrections used in several other laboratories.

*NACA, Langley Field, Virginia

2 Ferri, Antonio: **Supersonic Tests of Projectiles in Germany and Italy.** NACA Report ACR No. L5H08, Oct. 1945. NACA-Wartime Report-L-152.

Test data taken in the small supersonic tunnel at the Göttingen Laboratory and in the high-speed tunnel at Guidonia were analyzed by NACA at Langley Field. The following comments were made by A. Ferri in this report about the sting supports used in the tests:

Göttingen:

"The models each had a diameter of 0.393 inch and were supported by a sting attached to the rear face. The dimensions of the sting and the tare system adopted are not known."

Guidonia:

"The forces on each model were determined by use of a three-component balance. The model was attached to the balances by a sting on the projectile axis on the rear face of the projectile. The sting, although of small diameter, affected the experimental results somewhat since it increased the pressure on the rear face of the projectile. It was necessary, therefore, to make an accurate tare measurement by suspending the model on a faired strut attached to the side of the projectile."

3 *Perkins, Edward W.: **Experimental Investigation of the Effects of Support Interference on the Drag of Bodies of Revolution at a Mach Number of 1.5.** NACA-TN-2292, Feb. 1951, 50 pp. (Formerly NACA-RM-A8B05, Feb. 1948).

N62-54292

Tests were conducted to evaluate the effects of support interference on the drag characteristics of two bodies of revolution at zero angle of attack and at a Mach number of 1.5. The models, which varied only in their afterbody shape, were tested in the smooth condition and with roughness added to determine the support-interference effects for both laminar and turbulent flow in the boundary layer. Drag and base-pressure measurements were made for most tests over a range of Reynolds numbers, based on model length, of from 0.6 million to 5.0 millions to determine the effect of varying the length or diameter of the rear support. A side support in combination with a rear support was used to evaluate the magnitude of the interference. The schlieren method was used to determine the effect of the support on the flow over the afterbody of the models. For the body of revolution with zero boattailing and either laminar or turbulent flow in the boundary layer, the fore drag was not affected by the rear support; however, the base drag and, therefore, the total drag depended on the support configuration used. The base drag was found to depend on the diameter of the rear support over the complete range of rear-support diameters used in the investigation, but was independent of changes in support length as long as the support length was at least 5.2 body diameters. For the body of revolution with appreciable boattailing and laminar flow in the boundary layer, both the base drag and the fore drag were independent of changes in the length or diameter of the rear support as long as the length was equal to or greater than 1.7 body diameters and the diameter was equal to or less than 0.4 body diameter.

*NACA, Ames Aeronautical Laboratory, Moffett Field, Calif.

4 *Osborne, Robert S.: **High-Speed Wind-Tunnel Investigation of the Longitudinal Stability and Control Characteristics of a 1/16-Scale Model of the D-558-2 Research Airplane at High Subsonic Mach Numbers and at a Mach Number of 1.2.** NACA-RM-L9C04, April 1949, 87 pp.

A 1/16-scale model of the D-558-2 was tested (using four stings having various diameters) to determine its force, longitudinal stability, and control characteristics at Mach numbers from 0.6 to 0.95 and at a Mach number of 1.2. Much data is given. The effects of chordwise fences on the force and moment characteristics of the model are also presented.

*NACA, Langley Aeronautical Laboratory, Langley Field, Virginia

5 *Chapman, Dean R.: **An Analysis of Base Pressure at Supersonic Velocities and Comparison with Experiment.** NACA Rep. 1051, 1951, 23 pp. (Formerly NACA-TN-2137, July 1950).

An analysis is made of base pressure in an inviscid fluid, both for two-dimensional and axially symmetric flow. An approximate semi-empirical analysis for base pressure in a viscous fluid is developed. Experimental results also are presented concerning the support interference effect of a cylindrical sting.

*NACA, Ames Aeronautical Lab., Moffett Field, Calif.

6 *Bogdonoff, S. M.: **A Preliminary Study of Reynolds Number Effects on Base Pressure at M = 2.95.** Journal of the Aeronautical Sciences, vol. 19, no. 3, pp. 201 – 206, March 1952.

Chapman made a fairly complete study of the effect of support sting diameter and length at M = 2.9 in NACA Rept. 1051. For laminar flow, ratios of support diameter to body diameter below 0.6 and ratio of support length to body diameter over 2.8 gave no effect on base pressure. For turbulent flows, the ratio of support length to body diameter of over 2.8 also gave no effect. However, for ratios of support diameter to body diameter from 0.6 down to 0.3 (the smallest tested), the base pressure is still rising slightly. For the configuration used in these tests (a ratio of support diameter to body diameter of 0.25 and a length to body diameter ratio of 3.9), it seems reasonable to assume that the results obtained are, at most only slightly affected by the support system.

*Princeton Univ., Princeton, N.J.

7 *Reller, John O., Jr.; and *Hamaker, Frank M.: **An Experimental Investigation of the Base Pressure Characteristics of Nonlifting Bodies of Revolution at Mach Numbers from 2.73 to 4.98.** NACA-TN-3393, March 1955, 45 pp. (Formerly NACA-RM-A52E20, May 1952).

Base pressure characteristics of related nonlifting bodies of revolution were investigated at free-stream Mach numbers from 2.73 to 4.98 and Reynolds numbers from 0.6×10^6 to 8.8×10^6. The basic body shape was a 10-caliber tangent ogive with a cylindrical afterbody. The variation of base pressure coefficient with free-stream Mach number and Reynolds number was determined for laminar-, transitional-, and turbulent-boundary-layer flow. Some effects of body fineness ratio, nose-profile shape, and afterbody shape (boattail) were also included in the investigation. Model number 2 ($l/d = 5$) was used with supports of various lengths and diameters to evaluate the effect of support interference on measured base pressure.

(Appendix A, pp. 17 – 18, discusses support interference.)

*NACA, Ames Aeronautical Laboratory, Moffett Field, Calif.

8 *Osborne, Robert S.; and *Mugler, John P., Jr.: **Aerodynamic Characteristics of a 45° Sweptback Wing-Fuselage Combination and the Fuselage Alone Obtained in the Langley 8-Foot Transonic Tunnel.** NACA-RM-L52E14, Sept. 1952, 71 pp.

A fuselage and a wing-fuselage combination employing a wing with 45° sweepback of the 0.25-chord line, aspect ratio 4, taper ratio 0.6, and NACA 65A006 airfoil sections have been investigated in the slotted test section of the Langley 8-foot transonic tunnel at Mach numbers from 0.6 to 1.13 for angles of attack up to 36°. Maximum lift was reached at Mach numbers from 0.6 to 0.92.

(See page 7 for discussion of sting interference. No data is given but some sting interference effects were used to correct drag results.)

*NACA, Langley Aeronautical Laboratory, Langley Field, Virginia

9 *Hart, Roger G.: **Effects of Stabilizing Fins and a Rear-Support Sting on the Base Pressures of a Body of Revolution in Free Flight at Mach Numbers from 0.7 to 1.3.** NACA-RM-L52E06, Sept. 1952, 19 pp.

Isolated fuselages were flight-tested at Mach numbers from 0.7 to 1.3 in order to determine the contributions of the body and the fin-body interference to the total drag of previously tested combinations. A rear-support sting similar to those used in wind tunnels was tested with one of the fuselages.

*NACA, Langley Aeronautical Laboratory, Langley Field, Virginia

10 *Coletti, Donald E.: **Investigation of the Aerodynamic Characteristics of the NACA RM-10 Missile (with Fins) at a Mach Number of 1.62 in the Langley 9-Inch Supersonic Tunnel.** NACA-RM-L52J23a, Dec. 1952, 21 pp.

An investigation was made of a 0.050-scale model of the RM-10 missile at a Mach number of 1.62 and a Reynolds number of 2.66×10^6. Measurements were made of lift, drag, and pitching moment over an angle-of-attack range of ±5°. The effects of the ratio of sting-shield diameter to base diameter were also investigated. Comparisons are made with results of tests in other facilities at widely different Reynolds numbers.

*Langley Aeronautical Laboratory, Langley Field, Virginia

11 *Love, Eugene S.; and *O'Donnell, Robert M.: **Investigations at Supersonic Speeds of the Base Pressure of Bodies of Revolution With and Without Sweptback Stabilizing Fins.** NACA-RM-L52J21a, Dec. 1952, 66 pp.

Results are presented from an investigation at Mach numbers of 1.62, 1.93, and 2.41 of the variation with Reynolds number of the base pressure on bodies of revolution at zero lift, with and without sweptback stabilizing fins. Included are the effects of varying nose and base shapes and cut-off length, the effects of the presence of sting supports of varying diameter, and the effects of disturbances entering the wake. The over-all Reynolds number range was approximately from 1×10^6 to 10×10^6.

*NACA, Langley Aeronautical Laboratory, Langley Field, Virginia

12 *Baughman, L. Eugene; and *Jack, John R.: **Experimental Investigation of the Effects of Support Interference on the Pressure Distribution of a Body of Revolution at a Mach Number of 3.12 and Reynolds Numbers from 2×10^6 to 14×10^6.** NACA-RM-E53E28, Aug. 1953, 18 pp.

N62-62091

An experimental investigation was performed to determine the effect on base and forebody pressures of using a sting modified with varying length splitter plates and fins instead of a conventional sting to support a cone-cylinder body of revolution. The investigation was conducted at a Mach number of 3.12 for a Reynolds number range of 2×10^6 to 14×10^6 and for an angle of attack range of 0° to 9°. For Reynolds numbers of 8×10^6 and 14×10^6 there was a negligible effect of the splitter plate modification on the base pressure, and at a Reynolds number of 2×10^6 there was a small effect. Positioning the leading edge of the splitter plate at or ahead of the base made no appreciable change in the influence of the modifications on base pressure at a Reynolds number of 14×10^6. With the fin-type modification there was a small increase in base pressure.

*NACA, Langley Aeronautical Laboratory, Langley Field, Virginia

13 *Kavanau, L. L.: **Results of Some Base Pressure Experiments at Intermediate Reynolds Numbers with M = 2.84.** Univ. of Calif. Rept. HE-150-117, Oct. 22, 1953, 14 pp. Also "Journal of the Aeronautical Sciences," vol. 21, no. 4, April 1954, pp. 257 – 260, 274.

Base pressure data are presented for a cone-cylinder model at Mach Number 2.84 and Reynolds Numbers from 45,000 to 400,000. These data verify the maximum in base pressure coefficient (p_b/p) predicted by Crocco and Lees which occurs between the completely laminar and turbulent flow regimes. Sting length requirements for this model are summarized reflecting the growth of the critical wake region with decreasing Reynolds number. Results from varying the base pressure orifice location and sting diameter are also given.

*Univ. of California, Berkeley, California

Research supported by Office of Naval Research (USN) and the Office of Scientific Research (USAF).

14 *Love, Eugene S.: **A Summary of Information on Support Interference at Transonic and Supersonic Speeds.** NACA-RM-L53K12, Jan. 1954, 26 pp.

This document is a compilation of available information on the problem of support interference at transonic and supersonic speeds.

*NACA, Langley Aeronautical Laboratory, Langley Field, Virginia

15 *Harkins, W. D.: **Base Pressure and Static Pressure for a Cone-Cylinder at a Nominal Mach Number of 5.8.** CIT, Guggenheim Aeronautical Lab. Memorandum No. 19, July 20, 1954, 28 pp.

AD-42331 N-32953

An experimental investigation was made in the GALCIT Hypersonic Wind Tunnel to determine the base pressure and static pressure on a cone-cylinder at a nominal Mach number of 5.8 in both one-phase and two-phase flow. The scope of the investigation was a determination of interference data necessary for proper evaluation of base pressure results, investigation of the effect of Reynolds number on base pressure, and a comparison of experimental and theoretical static pressure distribution on a cone-cylinder. As has been noted by other investigators, viscous effects in hypersonic flow were quite pronounced and demonstrated the increased non-linearity of the problems in hypersonic flow. Before any base pressure determination could be made, it was necessary to obtain interference data at the test Mach number of 5.8. Chapman has specifically stated the need for such interference data at the higher Mach numbers. Briefly, the data was obtained by various combinations of sting and side support of the models. The critical length of the sting was determined. Sting diameter was varied to study the effect of this modification.

*Guggenheim Aeronautical Laboratory, California Institute of Technology, Pasadena, California.

Contract No. DA-04-495-Ord-19

16 Kavanau, L. L.: **Fluid Flow and Heat Transfer at Low Pressures and Temperature-Base Pressure Studies in Rarefied Supersonic Flows.** Univ. of Calif. Berkeley Institute of Engineering Research Rept. HE-150-125 (Series 20), Nov. 1, 1954, 119 pp. (Condensed from a Ph.D. Thesis.)

N-33862

Base pressures were measured on a simple cone-cylinder configuration over a range of Mach number M and Reynolds number Re_L (based on model length): $159 < Re_L < 800$ for $M \approx 2$ and $920 < Re_L < 7400$ for $M \approx 4$. Preliminary tests showed a considerable variation of pressure existing over the base area, thus requiring an area-mean determination of the base pressure for every flow condition. Investigations were made of support interference effects arising from the relative size of both the sting diameter and the sting length as compared to the model diameter. Some effects due to heat transfer were also studied. Supplementary pressure distributions were taken on the model surface upstream of the base and in the wake at one Mach and Reynolds number which was characteristic of this flow regime. The base pressure coefficient in free molecule flow is calculated for comparison purposes. A discussion is presented of these results together with experimental and theoretical works of other investigators.

(See no. 24 in this compilation for a journal article by this author on the same topic.)

Contract N7-onr-295-Task 3

17 *Tunnell, Phillips J.: **An Investigation of Sting-Support Interference on Base Pressure and Forebody Chord Force at Mach Numbers from 0.60 to 1.30.** NACA-RM-A54K16a, Jan. 1955, 19 pp.

Various configurations of rear sting supports were tested on one wing-body model with a turbulent boundary layer over the aft portion of the fuselage to determine the interference effects on the base pressure and foredrag characteristics. The tests were made at a Reynolds number of 5.4×10^6 based on fuselage length and over a Mach number range of 0.60 to 1.30.

*NACA, Ames Aeronautical Laboratory, Moffett Field, Calif.

18 *Donaldson, I. S.: **The Effect of Sting Supports on the Base Pressure of a Blunt-Based Body in a Supersonic Stream.** The Aeronautical Quarterly, vol. 6, Aug. 1955, pp. 221 – 229.

Experiments have been made to find the effect of the ratio of sting to base diameter on the base pressure of an axially symmetric body at zero incidence in a supersonic stream. The Mach number of the flow was 1.994 and the model boundary layer was turbulent. The model used was a one inch diameter circular cylinder without boat-tailing. It passed through and was supported upstream of the nozzle throat. This method of support allowed measurements to be made in the important (and hitherto unexplored) case of zero sting diameter. As the sting to base diameter ratio was increased from 0 to 0.85, the base pressure decreased. The minimum value reached was approximately 0.8 of the value it would have at the base of a two-dimensional body with a similar ratio of boundary layer thickness to base height. The base pressure coefficient rose rapidly to zero as the ratio was further increased to unity. Under the conditions of the experiments, with a sting to base diameter ratio of 0.4 the base pressure coefficient differed from that without a sting by approximately ten per cent. With the more modest ratio of 0.2, the difference was approximately three per cent.

*Fluid Motion Lab., Univ. of Manchester, England

19 *Estabrooks, Bruce B.: **Tests on Sting-Support Interference Conducted in the Transonic Model Tunnel — Phase I.** AEDC-TN-54-28, Jan. 1955, 62 pp.

N-35203

Tests in the Transonic Model Tunnel with both porous and solid wall test sections indicated that an outward bulge in the tunnel wall in the vicinity of the sting support strut prevented premature choking in the support strut area, and provided a favorable centerline Mach number distribution, and auxiliary mass-flow characteristics.

*ARO, Inc., Arnold Engineering Development Center, Tullahoma, Tenn.

Contract AF18(600)-1233.

20 *Estabrooks, Bruce B.: **Tests on Sting-Support Interference Conducted in the Transonic Model Tunnel — Phase II.** AEDC-TN-55-13, Oct. 1955, 51 pp.

N-39653

This report presents the results of the investigation of the sting-support system for the PWT Transonic Model Tunnel with several different types of test-section walls, wall modifications, blockage models, and with a model representing the upstream portion of the scavenging scoop. Results, obtained for the Mach number range from 0.80 to 1.20, are presented in the form of Mach number distributions along the tunnel centerline, tunnel pressure-ratio requirements, and auxiliary mass-flow requirements.

*ARO, Inc., Arnold Engineering Development Center, Tullahoma, Tenn.

Contract AF40(600)-620

21 *Estabrooks, Bruce B.: **Tests on Sting-Support Interference Conducted in the Transonic Model Tunnel — Phase III.** AEDC-TN-55-29, Oct. 1955, 39 pp.

N-39654

The results of the third phase of the experimental development program conducted in the Transonic Model Tunnel on a 1/16-scale model of the sting-support system for the transonic circuit of the Propulsion Wind Tunnel are presented. A means of decreasing the interference effects of exposed longitudinal stringers on the tunnel characteristics in the Mach number range from 0.80 through 1.20 was determined. The results include Mach number distributions, tunnel pressure-ratio requirements, and auxiliary mass-flow requirements.

*ARO, Inc., Arnold Engineering Development Center, Tullahoma, Tenn.

Contract AF40(600)-620

22 *Sivier, Kenneth R.; and *Bogdonoff, Seymour M.: **The Effect of Support Interference on the Base Pressure of a Body of Revolution at High Reynolds Numbers.** Princeton Univ. AED No. 332; AFOSR-TN-55-301, Oct. 1955, 40 pp., 21 refs.

N-39957

An experimental investigation has been made of the effect of a rear support sting on the base pressure of an ogive-cylinder body at a Mach number of 2.97 and at Reynolds numbers from 10×10^6 to 40×10^6. The body was mounted on wings to permit the measurement of a free base pressure. Stings having diameters from 0.6 to 0.0625 times the body's base diameter were employed to check the sting effect. Checks were made to assure that the present results were not affected by finite sting length. A second ogive-clyinder body, without mounting-wings, was supported on a rear sting to check the effect of the wing on the base pressure. For the range of Reynolds numbers considered in this investigation, no critical sting diameter was found to exist. In fact, the variation of base pressure with sting diameter was greatest for the smallest diameters. The error in base pressure introduced by a sting of any given diameter was found to be a function of Reynolds number. Although the curves of base pressure versus sting size showed a tendency to level off at the lower sting diameters, the assumption by several investigators that this indicated a critical sting size was found to be in error.

*Princeton Univ., Dept. of Aeronautical Engineering

Contracts — N6-onr-270 and AF18(600)-498

23 *Schueler, C. J.; and *Strike, W. T.: **An Investigation of the Lift, Drag, and Pitching Moment Characteristics of AGARD Calibration Models A and B.** Rep. No. AEDC-TN-55-34, Feb. 1956, 49 pp.

AD-81581

An investigation of the lift, drag, and pitching moment characteristics of AGARD Calibration Models A and B has been made in Tunnel E-1 of the Gas Dynamics Facility, Arnold Engineering Development Center. The tests on Calibration Model A covered a Mach number range of 2.0 to 4.0 and a Reynolds number range of 1.5×10^6 to 27×10^6. Calibration Model B was tested over a Mach number range of 1.7 to 4.0 and a Reynolds number range of 3×10^6 to 22×10^6. Included in the investigation, but limited in scope, were tests to determine the effects of model sting size on base pressure measurements.

*Arnold Engineering Development Center, ARO, Inc., Tullahoma, Tenn.

Contract AF40(600)-620

24 *Kavanau, L. L.: **Base Pressure Studies in Rarefied Supersonic Flows.** Journal of the Aeronautical Sciences, vol. 23, no. 3, March 1956, pp. 193 – 207, 230. (Also presented at the 23rd Annual Meeting of IAS, New York, Jan. 1955.)

X65-83405

(Number 16 in this compilation has the same abstract and author.)

*Lockheed Aircraft Corp., Missile Systems Division, Sunnyvale, CA

Supported by Office of Naval Research (USN) and Office of Air Research (USAF)

25 Patterson, R. T.: **The Axial-Tube Testing Technique in Supersonic Wind Tunnels.** David W. Taylor Model Basin Aero Rept. 895, April 1956, 23 pp.

N-45426

This report describes the axial-tube testing technique in supersonic wind tunnels, the advantages of this technique, the effect of an axial tube on test-section flow, and the axial-tube boundary-layer characteristics. The axial tube, located on the longitudinal axis of the channel, begins in the stilling chamber, extends downstream through the contractor and nozzle, and ends with its base in the testing region. A drag balance is installed in the tube near the base and models are mounted on the balance concentric with the tube.

26 *Klann, John L.; and *Huff, Ronald G.: **Experimental Investigation of Interference Effects of Lateral-Support Struts on Afterbody Pressures at Mach 1.9.** NACA-RM-E56C16, May 1956, 13 pp.

A series of single and double unswept, lateral-support struts were tested at Mach 1.9 and RN = 3.2×10^6 per foot on a cone-cylinder body at zero angle of attack. All strut-body interference effects were small beyond a length of eight body diameters. However, a nonreflected shock wave due to the presence of the support struts at the tunnel walls did affect afterbody pressures. Reduction of the leading-edge strut angle alleviated this disturbance.

*NACA, Lewis Flight Propulsion Laboratory, Cleveland, Ohio

27 *Cahn, Maurice S.: **An Experimental Investigation of Sting-Support Effects on Drag and a Comparison with Jet Effects at Transonic Speeds.** NACA Rept. 1353, 1958. 32 pp. (Formerly NACA RM-L56F18a, July 1956.)

Various dummy stings were tested on the rear of a related series of afterbody shapes for Mach numbers from 0.80 to 1.10 and Reynolds numbers based on body length from 15.0×10^6 to 17.4×10^6. A method is presented whereby approximate sting interference corrections can be made to models having afterbody shapes and sting supports similar to those of these tests if the Reynolds numbers are of the same order of magnitude and a turbulent boundary layer exists at the model base. Also presented is an analysis of jet duplication by use of a sting.

*NACA, Langley Aeronautical Laboratory, Langley Field, Virginia

28 *Covert, Eugene E.: **Supersonic Wind Tunnel Investigations to Determine the Interference Effects of the Sting Used to Support the Model in the Tunnel.** WADC-TR-55-214, Sept. 1956, 110 pp.

(U.S. Gov't Agencies Only)

AD-130778 N-52790

*Naval Supersonic Lab., Massachusetts Institute of Technology, Cambridge, Mass.

Contract AF-33(616)-2828

29 *Tournier, Marcel; and *Laurenceau, P.: **Suspension Magnetique d'une Maquette en Soufflerie. (Magnetic Suspension of a Model in a Wind Tunnel.)** La Recherche Aeronautique, no. 59, July – Aug. 1957, pp. 21 – 27.

(For English translation see N80-71571#.)

A new method of suspending models has been worked out and has been subjected to varying conditions of speed of flow in tests demonstrating the future use for which it was conceived. This paper provides a rapid review of methods utilized up to now to "support" the body in wind-tunnel tests which shows that no real material supports possess all the qualities which are required of them. These considerations led the O.N.E.R.A. (National Office of Aeronautical Studies and Research) to seek a means of supporting a model in a position determined by immaterial bonds in order that the fluid flow around the body be disturbed by neither the sides of the test cell (the consequences of whose perturbation creates the object of particular studies) nor by the supports. Several solutions have been imagined: the first consists of suspending a permanent magnet intended to support the model and to balance the resultant aerodynamical forces. The other utilize one or more iron electromagnets acting astride a bar of soft iron which constitutes the body of the model.

*ONERA, 92320, Châtillon, France

30 *Lee, George; and *Summers, James L.: **Effects of Sting-Support Interference on the Drag of an Ogive-Cylinder Body With and Without a Boattail at 0.6 to 1.4 Mach Number.** NACA-RM-A57I09, Dec. 1957, 28 pp.

Various sting-support configurations were tested on two bodies of revolution to determine the interference effects on the foredrag and base drag. The tests were made at a Reynolds number of 8×10^6 based on model length and over a Mach number range of 0.6 to 1.4.

*NACA, Ames Aeronautical Laboratory, Moffett Field, Calif.

31 *Whitfield, Jack D.: **Critical Discussion of Experiments on Support Interference at Supersonic Speeds.** AEDC-TN-58-30, August 1958, 49 pp.

AD-201108

An experimental investigation of the effect of the sting support length on the drag of slender ogive-cylinder models, with and without afterbody boat-tailing, has been conducted. These tests were made at Mach numbers 3.00 and 3.98 over a unit Reynolds number range from 10^5 to 10^6 per inch. The critical sting length as well as the base pressure is shown to be strongly dependent on the transition location and the length Reynolds number. The often quoted rule-of-thumb geometry ratio of three base diameters for an allowable sting length was inadequate for this investigation. The range of critical sting lengths encountered during this study was from approximately 5.5 for $Re_L = 1 \times 10^6$ and $M = 4.0$ to approximately 1.0 for $Re_L = 7 \times 10^6$ and $M = 3.0$.

*Arnold Engineering Development Center, ARO, Inc., Tullahoma, Tennessee

Contract No. AF 40(600)-700 S/A 13(59-1)

32 *Rogers, E. W. E.: **A Background to the Problems of Wind-Tunnel Interference.** National Physical Laboratory Rep. NPL/Aero/370, Jan. 1959, 26 pp., 59 refs. Prepared for AGARD Meeting on Interference Effects in Aerodynamic Test Facilities, Brussels, March 2 – 5, 1959.

N-70223

The progress that has been made in the field of wind-tunnel interference is briefly surveyed and some of the present-day difficulties are pointed out. In the concluding section an attempt is made to assess the direction in which future work is required.

*National Physical Laboratory, Aerodynamics Division, Great Britain

33 *Whitfield, J. D.: **Support Interference at Supersonic Speeds.** AGARD Rep. 300, March 1959, 26 pp. Presented at Interference Effects Meeting of AGARD Fluid Dynamics Panel, Rhode St. Genese, March 2 – 5, 1959.

N-108,671

The effect of sting-length interference on the base and afterbody drag of models with cylindrical and boat-tailed afterbodies are discussed. Results of tests with bluff-shape models supported by fine wires are presented and compared with results obtained with conventional sting-type supports. Effects of Mach number, length, Reynolds number, and unit Reynolds number on support interference are discussed. Results of experimental studies at the United States Air Force's Arnold Engineering Development Center, Gas Dynamics Facility (AEDC-GDF) are presented. The effects of sting-length interference are shown to be strongly dependent on the transition location as well as the length Reynolds number for the case with transitional wake flow.

*Arnold Engineering Development Center, Tullahoma, Tennessee

34 *Zonars, D.: **Large Angle of Attack Model-Sting Interference Effects at Transonic Speeds.** (Presented at AGARD Fluid Dynamics Panel, Rhode St. Genese, Belgium, Mar. 2 – 5, 1959.) AGARD Rep. 301, March 1959, 39 pp.

N80-73598

An experimental investigation has been conducted in the WADC 10-ft Transonic Wind Tunnel for the purpose of determining sting interference characteristics of a cylindrical body of revolution with an ogive nose. The sting-support system consisted of three different sting sizes which were attachable to either the body base, nose, or model side. This model-support system provided a method for obtaining angle of attack data through a range 0° to 180° with resulting sting effects throughout the angle range. Six-component internal strain gage balance tests were conducted throughout the Mach number range 0.6 to 1.2. The majority of the test was conducted at a stagnation pressure of 1200 lb/ft^2 abs. with resulting Reynolds number variations from 0.225×10^6 to 0.297×10^6 based on the model body diameter.

*Wright Air Development Center, Flight Dynamics Lab. (FDX), Wright-Patterson AFB, Ohio

35 *Rebuffet, Pierre: **Effets de Supports sur l'Ecoulement a l'Arriere d'un Corps. (Effects of Supports on the Flow at the Rear of a Body).** Presented at AGARD Wind Tunnel Tests and Models Working Group, March 1959, AGARD Rep. 302, 39 pp. (French text, English summary).

N80-71569#

With a view to determining the effects of supports on models with a flat base, two cases are examined, in a supersonic flow with a turbulent boundary layer. The first concerns the effect of various obstacles situated upstream of the two-dimensional base, at Mach 2. The second relates to a body of revolution passing through the throat of the jet from upstream to downstream. The interference of obstacles simulating supporting masts is examined for the base, both bare and with a sting, at Mach 1.94. Without any support, the drag of a conical-cylindrical body of revolution was measured by means of the ONERA magnetic suspension. The interference of various stings was studied at Mach 2.4, with a laminar boundary layer and with a separated turbulent boundary layer. The mechanism of the interference of a sting, progressively approached axially to the base, was determined.

*Directeur Scientifique Adjoint de l'Aerodynamique à l'O.N.E.R.A., 92320 Châtillon, France

36 *Reid, J.; and *Hastings, R. C.: **Experiments on the Axisymmetric Flow Over Afterbodies and Bases at M = 2.0.** R.A.E. Aero 2628, Oct. 1959, 67 pp.

N-79928

The effects of profile shape and boundary-layer growth on the side and base pressures of an axisymmetric afterbody are investigated. The tests were made at M = 2 with a turbulent boundary-layer on a cylinder, three truncated cones and three truncated parabolae. Firstly, the boundary-layer profile was measured at the shoulder and base of each of the conical and parabolic afterbodies, and the growth of the layer was traced along the cylinder and the shortest parabola. Secondly, the pressure was measured along each of the conical and parabolic afterbodies. Thirdly, the effect of boundary-layer thickness on the base pressure of the cylinder, and afterbody angle on the base pressure of the cones and parabolae were investigated. Supplementary tests with the cylinder show the axial pressure distribution behind the base, and also the effect of a sting or an external disturbance on the base pressure. The boundary-layer data are compared with two theoretical methods of calculating boundary-layer growth; the afterbody pressures are compared with the theoretical distributions in inviscid flow, and the effect of afterbody angle on the base pressure is compared with two semiempirical methods of correlation.

*Royal Aircraft Establishment, Farnborough, England

37 *Reese, David E., Jr.; and *Wehrend, William R., Jr.: **Effects of Sting-Support Interference on the Base Pressures of a Model Having a Blunted Cylinder Body and a Conical Flare at Mach Numbers of 0.65 to 2.20.** NASA-TM-X-161, Feb. 1960, 23 pp.

N71-75826

Various sting-support configurations were investigated with a model incorporating a conically flared afterbody to determine the interference effects on the pressure at the model base. The tests were made at Mach numbers from 0.65 to 2.20 at angles of attack up to 18° at a Reynolds number (based on the model body diameter) varying from a maximum of 1.1×10^6 to a minimum of 0.5×10^6.

*NASA, Ames Research Center, Moffett Field, CA

38 *Schueler, C. J.: **An Investigation of Support Interference on AGARD Calibration Model B.** AEDC-TN-60-35, Feb. 1960, 28 pp.

N-79995

Tests were conducted in the 12-inch supersonic wind tunnel (Tunnel E-1) of the von Karman Gas Dynamics Facility, Arnold Engineering Development Center (VKF-AEDC) to determine the critical sting length for AGARD Calibration Model B with a sting-to-body diameter ratio of 0.3. The tests were made at Mach numbers 2, 3, and 4 and covered a Reynolds number range of 3.5×10^6 to 13.5×10^6 based on the body length. The results indicate that the sting had no significant influence on the model surface pressure even when interference on base pressure was maximum. Over the Mach number and Reynolds number range of the tests, negligible interference was introduced by the windshield for sting length to model diameter ratios greater than 2.5.

*Arnold Engineering Development Center, ARO, Inc., Arnold Air Force Station, Tennessee

Contract No. AF 40(600)-800

39 *Peckham, D. H.: **Exploratory Tests on Sting Interference at a Mach Number of 6.8.** ARC-CP-566, Oct. 1960, 17 pp. (Previously issued as RAE-TN-AERO-2721.)

N63-84979

Tests with slender models at zero incidence showed that if the length of a supporting sting has to be kept short, it is desirable for transition to occur upstream of the base of the model, if interference effects are to be avoided. This type of flow corresponds to full-scale hypersonic vehicles operating at moderate altitudes. In addition, it was found that there was no advantage to be gained in using a small diameter sting. If the case of complete laminar flow over a hypersonic vehicle becomes of interest, which may happen if extreme altitudes are considered, greater interference problems would arise, and longer stings would be needed.

*Royal Aircraft Establishment, Farnborough, England

40 *Stanbrook, A.; and *Secomb, D. A.: **The Flow Around a Rod Passing Longitudinally Through an Asymmetric Supersonic Nozzle.** RAE-TN-Aero 2729, Nov. 1960, 7 pp.

N-95056

Results are given of some experimental measurements and observations of the effect on the flow of the presence of a rod held longitudinally in an asymmetric supersonic nozzle (to represent a possible upstream support system) at Mach numbers from 1.4 to 2.0. Although the static pressures along the flat bottom wall were found to be little affected by the introduction of the rod, evidence of extensive flow separation from the rod was obtained at Mach numbers of 1.8 and 2.0. The occurrence of these separations implies the existence of poor distributions of total and static pressure in the working section.

*Royal Aircraft Establishment, Farnborough, England

41 *Greenwood, G. H.: **Free-Flight Measurements of the Zero-Lift Drag and Base Pressure on a Wind Tunnel Interference Model ($M \approx 0.8 - 1.5$).** (Previously issued as RAE-TN-Aero 2725, Nov. 1960.) Now ARC-CP-553, 1961, 10 pp.

N-94483X

Five free-flight models were flown. Roughness bands on the wings and body of the model are shown to produce a small but definite increase in the zero-lift drag at all Mach numbers. The measured drag is in fair agreement with corresponding measurements made in various transonic tunnels with differences that could plausibly be explained as the effects of tunnel interference. The effect of a simulated wind tunnel support sting is shown to increase the base pressure. The discrepancy between models with and without a sting is greatest at subsonic speeds and progressively decreases with increasing Mach number until at M = 1.4 the sting has no effect on base pressure.

*Royal Aircraft Establishment, Farnborough, England

42 *Savitsky, Daniel; and *Prowse, Robert E.: **Added-Mass and Drag Coefficients of Basic Finner Missile.** Davidson Lab., Stevens Inst. of Tech. Rep. no. R-824, Dec. 1960, 28 pp.

N-91490

To determine the drag and added mass for axial motions of the Basic Finner Missile during constant, accelerated, and decelerated velocities, a four-inch model was used; rear-support stings (0.47 and 0.61 times the model diameter) were successively used to support the model. Constant speed drag coefficients obtained with the small and large sting struts were about 0.40 and 0.46, respectively, at Reynolds numbers larger than 3.5×10^6. At a Reynolds number of about 3×10^6, there was a significant peak in drag coefficient. The added-mass coefficient was 0.15 at Reynolds numbers larger than 3.4×10^6. The sting-support strut appeared to have a significant effect on the drag and added-mass coefficients. Therefore, in future studies, tests should be made with side-support struts.

*Davidson Lab., Stevens Institute of Technology, Castle Point, Hoboken, N.J.

Contract NOrd-16193

43 *Dubois, George; and *Rougé, Charles: **Sur une Méthode de Mesure de la Pression de Culot-Mesure et Visualisation sur une Maquette Cylindro-Conique Suspendue Magnétiquement à $M_o \simeq 7.6$.** La Recherche Aéronautique, no. 79, pp. 35 – 44, Nov. – Dec. 1960. (In French).

N80-71567#

English translation by **R. N. Zapata, **On a Method for Measuring the Base Pressure: Measurement and Visualization on a Cone Cylinder Magnetically Suspended at $M_o \cong 7.6$.** Rep. AFOSR-1020; AST-4443-102-61U, May 1961, 38 pp.

N80-71541#

The present paper is concerned with a method for measuring the base pressure of an axially symmetrical body. This method avoids material supports through the use of the O.N.E.R.A. magnetic suspension for keeping the model on the axis of the stream at the test section. Thus, the base pressure is measured, with no interactions, by means of an optical manometer located inside the model. At the same time, the flow can be visualized by a schlieren system. This paper specifies the conditions required for the applicability of the method, analyzes the precision of the measurements, discusses the results obtained with and without sting, and compares them to those previously obtained at lower Mach numbers.

*ONERA, 92320 Châtillon, France
**Univ. of Virginia, Charlottesville, Virginia

44 *Stivers, Louis S., Jr.; and *Levy, Lionel L., Jr.: **Effects of Sting-Support Diameter on the Base Pressures of an Elliptic Cone at Mach Numbers from 0.60 to 1.40.** NASA-TN-D-354, Feb. 1961, 30 pp.

N62-70928

Measurements were made to determine the effects of sting-support diameter on the base pressures of an elliptic cone with ratio of cross-section thickness to width of 1/3 and a plan-form semiapex angle of 15°. The investigation was made for model angles of attack from -2° to +20°, at Mach numbers from 0.60 to 1.40, and for a constant Reynolds number of 1.4 million, based on the length of the model. The results indicated that the sting interference decreased the base axial-force coefficients by substantial amounts up to a maximum of about one-third the value of the coefficient for no sting interference. There was no practical diameter of the sting for which the effects of the sting on the base pressures would be negligible throughout the Mach number and angle-of-attack ranges of the investigation.

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

45 *Gray, J. Don: **Base-Pressure Measurements with Wire-Supported Models at Supersonic Speeds.** AEDC-TN-61-23, March 1961, 24 pp.

N-94336

Base pressure measurements were made with an ogive cylinder and a blunt, boat-tailed cone at $M_\infty = 4$ to appraise the effects of small wire supports. Some measurements with a much larger blunted cone were made at $M_\infty = 3.5$ and 5. The tests covered a Reynolds number range from about 0.06 to 0.48×10^6 per inch. It was found that the small wire supports generally reduced the base pressure ratio below that obtained with a small sting support. The results for the ogive-cylinder model indicated that when transition was situated on the model the addition of wires introduced negligible interference.

*Arnold Engineering Development Center, ARO, Inc., Arnold Air Force Station, Tennessee

Contract No. AF 40(600)-800 S/A 11(60-110).

46 Turner, K. J.: **Measurements of Dynamic Stability from Three Simplified Free-Flight Models of a Supersonic Research Aircraft (Bristol ER. 134) over the Mach Number Range 1.2 – 2.6.** Rept. AGARD-378, July 1961, 62 pp.

N62-17200#

Values of the lateral stability derivatives y_v, n_v, l_v and l_p have been measured on free-flight models of the Bristol ER. 134 for Mach numbers between 1.2 and 2.6. These show that the aircraft should be laterally stable up to M = 2.6, at least, although the free-flight results indicate a somewhat smaller stability margin than estimates or wind-tunnel measurements. Some additional data on z_w and m_w have been derived from the longitudinal motion. (Effects of sting support are discussed.)

47 *Valk, H.; and *van der Zwaan, J. H.: **A Review of Measurements on AGARD Calibration Model B in the Transonic Speed Range.** In A Review of Measurements on AGARD Calibration Models, Nov. 1961, pp. 35 – 94 in N63-13508, 15 refs.

N63-13510

A survey and a comparison are presented of the results from tests with AGARD Calibration Model B at Mach numbers between 0.7 and 1.3. The available data include tests in different wind tunnels, at different Reynolds numbers and blockage percentages for models with and without fixed transition. The results from different sources show many discrepancies. A first effort is made to establish reference curves, to facilitate further comparison.

*National Aero- and Astronautical Research Inst., Amsterdam (Netherlands)

48 *Hartzuiker, J. P.: **A Review of Measurements on AGARD Calibration Model B in the Mach Number Range from 1.4 to 8.** In A Review of Measurements on AGARD Calibration Models, Nov. 1961, pp. 95–136 in N63-13508, 33 refs.

N63-13511

This report contains a survey and a comparison of the results from tests with AGARD Calibration Model B at Mach numbers between 1.4 and 8. The data include tests from various wind tunnels and in free flight, for a range of Reynolds numbers between 10^6 and 98×10^6. Models with and without fixed transition of the boundary layer have been considered. Good agreement between the various measurements of the lift, the pitching moment, and the neutral point location has been found. With respect to drag, many differences exist.

*National Aero- and Astronautical Research Inst., Amsterdam (Netherlands)

49 *Valk, H.: **A Review of Measurements on AGARD Calibration Model C in the Transonic Speed Range.** In A Review of Measurements on AGARD Calibration Models, Nov. 1961, pp. 137 – 211 in N63-13508, 14 refs.

N63-13512

This report contains a survey and a comparison of the results from tests with AGARD Calibration Model C at Mach numbers between 0.7 and 1.3. The available data include tests in different wind tunnels, at different Reynolds numbers on blockage percentages, on models with and without fixed transition of the boundary layer. The correspondence between the results of the various tests is not very satisfactory. There are many differences and the pitching moment, especially, shows large discrepancies in value and in trend. Some indications are given of the probable origins of the discrepancies.

*National Aero- and Astronautical Research Inst., Amsterdam (Netherlands)

50 *Allen, H. Julian: **Methods of Model Support.** Chapter 2 (pp. 683 – 691) of "High-Speed Problems of Aircraft and Experimental Methods," Edited by A. F. Donovan, et al., Princeton, N.J., Princeton Univ. Press, 1961. (Vol. 8 of "High-Speed Aerodynamics and Jet Propulsion.")

N-68576

Discussed are wall support methods, strut and sting support methods, and sting-flare interference. The principal difficulty with the strut or sting supports is that their presence alters the flow about the model from what it would be in free flight. The problem is then to provide a support which gives a minimum and, if possible, a known influence on the flow about the model.

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

51 *Squire, L. C.: **The Characteristics of Some Slender Cambered Gothic Wings at Mach Numbers from 0.4 to 2.0.** A.R.C. R. & M. 3370, May 1962, 50 pp. (Formerly R.A.E. Rep. no. Aero. 2663).

N64-28083

Wind tunnel tests have been made on a series of cambered slender wings of modified gothic planform. The main purpose of these tests was to investigate camber designs which have low lift-dependent drag and a given centre of pressure position ahead of the aerodynamic centre. An appendix is included on the effect of sting shields.

*Royal Aeronautical Establishment, England

52 Dayman, Bain, Jr.: **Simplified Free-Flight Testing in a Conventional Wind Tunnel.** JPL-TR-32-346, Oct. 1, 1962, 27 pp.

N62-16382

In order to incorporate the advantages of ballistic-range testing with the convenience of wind-tunnel testing, simplified techniques have been developed at the Jet Propulsion Laboratory (JPL) for free-flight testing of models in a conventional wind tunnel. So far, only a small number of the many possibilities have been investigated, but the preliminary results indicate that such techniques are both practical and useful. The model to be investigated is suspended on a single traverse wire at the upstream end of the test section window, then is released from this position by causing the wire to break within the model. High speed motion pictures taken of the model oscillating during its travel across the viewing area make it possible to determine various aerodynamic parameters such as drag, lift, pitching moment, and pitch damping in much the same manner as is done in ballistic-range testing. Also, a spark schlieren photograph can be taken of the model in flight in order to observe details of an undisturbed (from support interference) wake. (This is an example referred to in AGARDograph 113, no. 68 in this bibliography.)

*Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena, CA

Contract NAS7-100

53 *Runckel, Jack F.; *Lee, Edwin E., Jr.; and *Simonson, Albert J.: **Sting and Jet Interference Effects on the Afterbody Drag of a Twin-Engine Variable-Sweep Fighter Model at Transonic Speeds.** NASA-TM-X-755, Jan. 1963, 69 pp.

N72-73506

A front-supported model with a removable and instrumented afterbody has been used to compare the drag level of a model simulating a variable-sweep airplane configuration with that of wind-tunnel models simulating the same configuration, but with rear-mounted dummy support stings. The dummy-sting models also required modifications to the airplane contour to accommodate the stings and are shown to have had higher drag than the airplane model.

*NASA, Langley Research Center, Hampton, Virginia

54 *Wehrend, William R., Jr.: **An Experimental Evaluation of Aerodynamic Damping Moments of Cones with Different Centers of Rotation.** NASA-TN-D-1768, March 1963, 52 pp.

N63-14029

The static and dynamic stability characteristics of a 12½$^{\circ}$ semivertex angle cone were studied. The cone was tested with both sharp and blunt tips and with a flat base and spherical segment afterbodies, at M = 0.25 to 2.20; α = -13° to +18°; and R.N. from 0.68 to 1.54 × 10^6 based on model base diameter. Tests with different sting diameters and lengths showed that, in general, the damping in pitch moment was not sensitive to variations of sting geometry. See page 9 and figure 8 for sting interference effects which were evaluated at M = 0.65, 1.00 and 1.60 for the round nose cone with either flat or spherical segment bases. Tests were made using three sting diameters and three lengths of the 2" diameter sting.

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

55 *Fuller, Dennis E.; and *Langhans, Victor E.: **Effect of Afterbody Geometry and Sting Diameter on the Aerodynamic Characteristics of Slender Bodies at Mach Numbers from 1.57 to 2.86.** NASA-TN-D-2042, Nov. 1963, 29 pp.

N64-10335#

An investigation has been made in the low Mach number test section of the Langley Unitary Plan wind tunnel to determine the effects of afterbody boattail, camber, and length, and of variations in sting diameter on the aerodynamic characteristics of slender bodies. A common forebody was utilized for all configurations tested. Tests were performed at Mach numbers from 1.57 to 2.86 and at a Reynolds number per foot of 3.0 × 10^6, and α from -4° to +4°. Results indicate that wind-tunnel models of airplanes with afterbodies which are appreciably altered to accommodate a rear-mounted sting-support system will produce different drag characteristics than those which would be obtained from true representations of the aircraft with closed afterbodies. It is further indicated that negative afterbody camber may be beneficial in minimizing the trim performance penalty of airplanes. There is little effect of sting diameter on the aerodynamic characteristics in pitch of the wind-tunnel models that have turbulent flow over their length. There is, in general, little variation in the base-pressure coefficients with angles of attack from -4° to 4°.

*NASA, Langley Research Center, Hampton, Virginia

56 *Chrisinger, J. E.; *Tilton, E. L., III; *Parkin, W. J.; *Coffin, J. B.; and *Covert, E. E.: **Magnetic Suspension and Balance System for Wind Tunnel Application.** Journal of the Royal Aeronautical Society (London), vol. 67, no. 635, Nov. 1963, pp. 717 – 724.

A64-11303#

It is probably no exaggeration to state that every engineer who has been engaged in wind tunnel testing has encountered support interferences and has thought of the advantages of supporting the model with magnetic fields. NACA Ames engineers took the initial steps to fabricate a magnetic balance system for wind tunnel use, but the work was never completed. The first successful magnetic suspension to be used for a wind tunnel was constructed in France by O.N.E.R.A. and was reported by Tournier and Laurenceau in 1957. The report of the success that the French had achieved served to initiate preliminary studies of the possibility of building such a system at the Massachusetts Institute of Technology. The initial studies were made on the basis of an exact copy of the French system, and permission was given by O.N.E.R.A. to fabricate this copy. Further studies indicated that an exact copy would not be adequate. In this article a magnetic suspension and balance system designed by M.I.T. and suitable for wind tunnel application is discussed. General considerations are presented that illustrate the nature of the problems to be solved as well as one solution of these problems. Some initial wind tunnel data are presented.

*Mass. Inst. of Technology, Cambridge, Mass.

Contract No. AF 33(616)-7023

57 *Hensel, Rudolph W.: **A Survey of Recent Developments in Wind Tunnel Testing Techniques at Transonic and Supersonic Speeds.** Presented at the AIAA Aerodynamic Testing Conference held at Arnold Air Force Station, Tenn., March 9 – 10, 1964, Proceedings, pp. 69 – 103; 89 refs. (A64-14530#). Also, Journal of Spacecraft and Rockets, vol. 1, Sept. – Oct. 1964, pp. 449 – 463.

A64-26570#

Support interference with respect to dynamic stability investigations is discussed beginning on page 85 and the basic principles of a magnetic model suspension system are considered on pages 88 – 91.

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

58 *Uselton, B. L.: **Investigation of Sting Support Interference Effects on the Dynamic and Static Stability Characteristics of a 10-Deg. Cone at Mach Numbers 2.6, 3.0, and 4.0.** AEDC-TDR-64-226, Nov. 1964, 23 pp.

AD-450660 N65-14661#

A free oscillation, cross-flexure pivot balance system was used. Data were obtained at Mach numbers of 2.5, 3.0, and 4.0 at Reynolds numbers ranging from 0.45×10^6 to 10.2×10^6. Selected test results are presented and comparisons are made with first- and second-order potential flow theory and conical flow theory.

*ARO, Inc., Arnold Air Force Station, Tennessee

Contract AF 40(600)-1000

59 *Agnone, A.; *Martellucci, A.; and *Trucco, H.: **Measurements of the Turbulent Near Wake of a Cone at Mach 6.** GASL-TR-482, Dec. 1964, 85 pp.

AD-456869 N66-15537#

Flow properties in the subsonic and supersonic regions of the turbulent near wake of a 10-degree half angle circular cone at zero angle of attack in a Mach 6 flow were measured. Tests were conducted at a stagnation pressure of 800 psia with a corresponding Reynolds number of 14.4×10^6/ft. The boundary layer flow on the cone surface was turbulent for the entire test series. To optimize the method of support for a minimum of flow interference, several model support schemes were investigated. The system that provided a minimum of support interference consists of a slender axial sting attached to the model nose and also extended upstream through the nozzle throat. The model was supported at the base by three bands 0.010-in. thick and 0.250-in. wide, with a 60-degree sweep back. The total temperature, total and static pressure distributions in the supersonic part of the wake were recorded at various axial stations and radial distances from the model axis. The radial base pressure distribution, the $u = 0$ line; that is, the locus of all points in the recirculation zone where there is only a component of velocity normal to the cone axis, the pitot and static pressures on the model axis in the subsonic region, and various properties in the recirculation zone are presented. Some effects of support interference on the wake properties are also presented.

*General Applied Science Labs., Inc., Westbury, N.Y.

Contract ARPA SD-149; ARPA Order 396

60 *Stivers, Louis S., Jr.: **Effects of a Sting Support on the Supersonic Force and Moment Characteristics of an Apollo Model at Angles from -30° to +185°.** NASA-TM-X-1081, March 1965, 50 pp.

N70-77996

Wind-tunnel tests of an early configuration of the Apollo Command Module were made for Mach numbers of 5.45 and 3.29 with corresponding Reynolds numbers of 0.68 million and 1.07 million, respectively, to provide data for determining the effects of the sting-support inclination. A number of models were used, each having different mounting attitudes so that the sting inclination would not need to exceed ±30°. Secondary tests were made for a Mach number of 3.29 to determine the effects on the measured data of changing Reynolds number from about 0.25 million to 1.0 million and to determine some of the flow characteristics on the surface of the models.

*NASA, Ames Research Center, Moffett Field, CA

61 *Miller, Charles G., III: **An Experimental Investigation of Support Interference on a Blunt Body of Revolution at a Mach Number of Approximately 20.** NASA-TN-D-2742, April 1965, 27 pp.

N65-19922#

An investigation of support interference on the base pressure of a hemisphere cylinder model at zero angle of attack was conducted in the Langley hotshot tunnel at a free-stream Mach number of approximately 20 over a range of free-stream Reynolds numbers per foot from 3.00×10^5 to 4.65×10^5. The effect of sting length, sting diameter, and shroud semiapex angle on the base pressure coefficient and afterbody-pressure coefficient was examined. Flow over the model base region was investigated by performing an axial pressure distribution study along the sting.

*NASA, Langley Research Center, Hampton, Virginia

62 *McDonald, H.: **An Analysis of the Turbulent Base Pressure Problem in Supersonic Axisymmetric Flow.** The Aeronautical Quarterly, vol. 16, May 1965, pp. 97 – 121.

A65-26323

The problem of predicting the turbulent supersonic base pressure in axisymmetric flow is treated by an extension of a method of solution to the two-dimensional problem given in Ref. 1. The solution consists principally in tracing the boundary-layer development from upstream of the base to downstream of the recompression region for a given base pressure. A unique solution is obtained by specifying the shape of the rehabilitated boundary-layer velocity profile. A comparison with experiment in the case of the step-down cylinder problem (the sting-support problem) yields some very favourable results. It is pointed out that, while it has not been found possible to obtain a solution to the problem of a vanishingly small sting, the base pressure does not vary appreciably while the sting is decreased from about 0.3 of the base diameter down to zero. It would appear that the present analysis is capable of giving accurate results down to sting/diameter ratios of the order of 0.3.

*British Aircraft Corp., Ltd., Preston Division, Lancashire, England

63 *McDonald, H.; and *Hughes, P. F.: **A Correlation of High Subsonic Afterbody Drag in the Presence of a Propulsive Jet or Support Sting.** Journal of Aircraft, vol. 2, May – June 1965, pp. 202-207.

A65-26014#

The problem of predicting the afterbody contribution to the fuselage form drag at subsonic speeds in the presence of a propulsive jet, support sting, or blunt base is treated by a correlation method. The method includes both curved and conical bodies of revolution below the drag rise Mach number, provided separation of the boundary layer over the body is avoided. In the jet-flow case, at present, the method is restricted to convergent propulsive nozzles but the effect of jet-pressure ratio and temperature is accounted for. From the results it can be seen that afterbody drag can account for as much as 30% of the subsonic profile drag of a typical fighter-type aircraft.

*British Aircraft Corp., Ltd., Preston Division, Propulsion Group, Lancashire, England

64 *Carter, E. C.: **The Use of a Twin-Sting Model Support System to Determine the Effects of Rear Fuselage Distortion.** Presented at the 24th Meeting of the Supersonic Tunnel Assoc., Northrop Norair, Los Angeles, CA, Nov. 1 – 2, 1965, 15 pp., Wind Tunnel Note no. 56.

N66-18049#

The conventional single-sting support system for wind tunnel models often introduces large errors in measured forces. These errors can arise from the forward influence of the sting or from the body distortions necessary to house the sting. The first of these items has been fully studied in supersonic flow and to a lesser extent in subsonic flow, and some basic sting design rules have been established. The body distortion effects, however, cannot be treated in any straightforward analytical manner, each case requiring to be treated on its own merits. This note briefly describes a method of experimental solution whereby the model is supported on a pair of slender stings on the wings and the effect of distortion is measured by an internal balance. Problems of model gap sealing and the forward influence of the support struts at transonic speeds are discussed. Some results of the effects of severe fuselage distortion are illustrated for one particular application.

See no. 74 in this bibliography for more on "twin-stings."

*Aircraft Research Association, Ltd., Bedford, England

65 *Saltzman, Edwin J.; and *Garringer, Darwin J.: **Summary of Full-Scale Lift and Drag Characteristics of the X-15 Airplane.** NASA-TN-D-3343, March 1966, 47 pp.

N66-19345#

Power-off flight lift and drag characteristics of the full-scale X-15 are summarized for Mach numbers from 0.65 to 6.0 and for free-stream Reynolds numbers from 10×10^6 to 140×10^6, based on the fuselage length. Some of these data are compared with wind-tunnel-model results. The X-15 drag characteristics are strongly influenced by relatively large components of base drag and drag-due-to-lift, with a significant part of the drag-due-to-lift resulting from trim drag. When compared with wind tunnel data the results show that at M = 2.5 and 3.5 from 8% to 15% of the base drag measured in the wind tunnel may be due to sting interference after other factors are taken into account. The data shows that sting-interference effect is not just a "transonic problem" but also exists at Mach numbers between 2.5 and 3.5.

*NASA, Flight Research Center, Edwards AFB, CA

66 *Kurn, A. G.: **Drag Measurements on a Series of Afterbodies at Transonic Speeds Showing the Effect of Sting Interference.** ARC-CP-984, 1968, 47 pp. (Supersedes RAE-TR-66298, Sept. 1966.)

N69-13412#

A number of axisymmetric afterbodies consisting of the basic profile, a tangent ogive with a fineness ratio of 3.33, and progressively truncated versions of this shape were tested at zero incidence over a Mach number range from 0.8 to 1.3. Measurements were made of the afterbody pressure distribution, the base pressure and the total drag with and without the presence of various rear stings. In general, the drag, in the absence of a sting, was increased by truncating the ogive, but at supersonic speeds small truncations had little effect. The results at a given free stream Mach number show that, for the different stings fitted to each afterbody, there is an approximately linear relationship between afterbody drag and base pressure. Curves are presented whereby the measured total drag of the sting-mounted afterbody model may be corrected to obtain the true total drag in the absence of the sting.

*Royal Aircraft Establishment, Farnborough, England

67 *Wiley, Harleth G.: **The Significance of Nonlinear Damping Trends Determined for Current Aircraft Configurations.** NASA-TM-X-59114, 1966, 27 pp. Presented at the AGARD Flight Mechanic's Panel's Specialists' Meeting on Stability and Control, Cambridge, England, Sept. 20 – 23, 1966. (N68-27535#) This paper is also in "AGARD Stability and Control, Pt. 1" Sept. 1966, pp. 393 – 408.

N68-17455#

The basic features and accuracy of the rigidly forced dynamic-stability technique used in wind tunnels at the Langley Research Center of the National Aeronautics and Space Administration for measuring pitch- and yaw-damping derivatives at subsonic, transonic, and supersonic speeds are reviewed. The ability of the equipment to permit investigations at high angles of attack where separated flow may be present and in regions of large aerodynamic instabilities is discussed. The effects of sting mounting on the measured derivatives are included. Representative results of experimental research performed for several current and proposed aircraft configurations are presented.

*NASA, Langley Research Center, Hampton, Virginia

68 *Dayman, Bain, Jr.: **Free-Flight Testing in High-Speed Wind Tunnels.** AGARDograph 113, 1966, 87 pp., 64 refs.

N67-23241

The adaptation of free-flight techniques to testing in a conventional wind tunnel was made operational recently at the California Institute of Technology, Jet Propulsion Laboratory. This AGARDograph describes this technique in enough detail that it can be applied to other facilities with a minimum amount of development. Examples and results of many applications are included in order to demonstrate the need and advantages for using this free-flight technique. (One of these examples is no. 52 in this bibliography.)

*Jet Propulsion Lab., Calif. Inst. of Tech., Pasadena, CA

69 *Sirieix, Maurice; and *Delery, Jean: **Analyse Experimentale du Proche Sillage d'un Corps Elance Libre de Tout Support Lateral. (Experimental Analysis of the Near-Wake of a Slender Body with no Lateral Support).** Presented at the AGARD meeting on Plasmas Occurring in Wakes, Fort Collins, Colo., May 10 – 12, 1967, 45 pp. (In French). ONERA-TP-454, A67-29379#, N67-33336#. This report is also in AGARD "Fluid Physics of Hypersonic Wakes," Vol. 1, May 1967.

N67-37605#

Testing conditions without any parasite interaction for studying experimentally the near-wake of axisymmetric bodies were studied. Hence, either streamlined supports fixed upstream of the throat of Mach 1.92 and Mach 4 nozzles designed to study cylindrical afterbodies in turbulent flow were used or a magnetic suspension for the blunt and slender model (HB1) which was tested at Mach 5 in laminar flow. The results obtained include a detailed analysis of the flow at the base and are compared with some existing theoretical elements. At the same time, a hot-wire transition investigation, in the case of wake of a cylinder normal to the flow, was carried out at Mach 2.3 and provided an experimental criterion for transition.

*ONERA, 92320 Châtillon, France

70 Re, R. J.; Wilmoth, R. G.; and Runckel, J. F.: **Investigation of Effects of Afterbody Closure and Jet Interference on the Drag of a Twin-Engine Tactical Fighter.** NASA-TM-X-1382, June 1967, 100 pp.

(U.S. Gov't Agencies and Their Contractors Only)

X75-75152

71 *Loving, Donald L.; and *Luoma, Arvo A.: **Sting-Support Interference on Longitudinal Aerodynamic Characteristics of Cargo-Type Airplane Models at Mach 0.70 to 0.84.** NASA-TN-D-4021, July 1967, 59 pp.

N67-31054#

Wind-tunnel tests at angles of attack from -2° to 4° were conducted on three different cargo-type airplane models. The effects on the longitudinal aerodynamic characteristics of sting-support interference for each model were evaluated. The results show that the sting tares for constant angles of attack were small; and when applied to the lift-drag polar, the combination of the sting lift and drag tares tended to cancel each other at a given lift in the design-cruise lift range.

*NASA, Langley Research Center, Hampton, Virginia

72 Sukhnev, V. A.: **Experimental Determination of Drag Factor for a Sphere in a Supersonic Rarefied Gas Flow.** Foreign Technology Division (AFSC) Wright-Patterson AFB, FTD-HT-67-174. Translation into English from IZV. Akad. Nauk SSSR, Mekh. (USSR), no. 3, 1965, pp. 172 – 175.

AD-671585 N68-33468#

A large number of experiments were conducted in a low density wind tunnel to determine the drag coefficient of a sphere in the Mach and Reynolds number range $3.6 < M < 6.0$ and $2 < R < 500$. The sphere surfaces were highly polished; the diameters varied between 1 and 14 mm. A special effort was made to determine the effect of model support (sting) on the total sphere drag. This was done by two sets of experiments. First, the total moment on the sphere was measured including the support and secondly, the drag was measured with the support flush with, and separated from the model. The experimental data obtained in this manner showed that the effect of the sting on the drag C_x was of order 3 – 5% for a sting-to-sphere diameter ratio of 0.1. The effect of surface roughness on C_x was tested by scratching the sphere surface. Within the experimental accuracy no effect could be observed on the sphere drag coefficient due to such surface roughness.

73 Baryshev, Yu. V.; and Morozov, M. G.: **Supersonic Flow Past Bodies of Revolution With Annular Recesses.** Johns Hopkins Univ. Applied Physics Lab. TG-230-T534. Translation into English from Vestn. Mosk. Univ., Ser. 1 – Mat. I Mekhan (Moscow), no. 6, 1966, pp. 108 – 113.

AD-663077 N68-15489#

Discussed are experiments on supersonic flow past a cone-cylinder type body with an annular recess of rectangular section for different M and RE numbers, particular attention is devoted to a determination of the ratio of critical length to depth of the recess in order to clarify the best arrangement for sting supports.

Contract NOw-62-0604-c

74 *Carter, E. C.: **Some Measurements of the Interference of a Sting Support on the Pressure Distribution on a Rear Fuselage and Tailplane at Subsonic Speeds.** Aircraft Research Association, Ltd., Wind Tunnel Note no. 67, 1967, 27 pp. Presented at the 28th Meeting of the Supersonic Tunnel Association, Martin Corp., Denver, Colo., Oct. 30 – 31, 1967.

N68-13511

This note illustrates the way in which the presence of a parallel sting in the rear of a model is likely to change the pressure distribution on the tailplane and fuselage. It is shown that the major influence is on the lower surface of the tail and that the interference can give incorrect values of tail-on C_{m_0}, tail power, and at higher Mach numbers $\delta C_m/\delta C_L$. The interference on the fuselage is shown to be very small if account is taken of the missing areas of fuselage. The interference of the twin stings is also shown to be very small, affecting only the upper surface of the tail with no influence at all on the fuselage. These results not only quantitatively confirm previous measurements made on twin stings with a rear fuselage balance, but also show the errors which can occur in single sting results and the need for supplementary twin sting tests. It is also shown that, if drag is of major importance, the fuselage split position for twin sting balance tests should be chosen bearing in mind the circumferential pressure distribution in the region. It is desirable to seal the gap if possible to eliminate cross flow.

See no. 64 in this bibliography for another paper on twin stings.

*Aircraft Research Association, Ltd., Bedford, England

75 *Cassanto, John M.: **Base Pressure Results at M = 4 Using Free-Flight and Sting-Supported Models.** AIAA Journal, vol. 6, July 1968, pp. 1411 – 1414.

A68-36705#

Study of some recent free-flight base-pressure data obtained using telemetry techniques, and comparison of these data with sting-supported data from the same facility. The data were obtained in a wind tunnel under the conditions $M_\infty = 4$ and $\alpha = 0$, for Reynolds numbers between 4×10^5 and 1×10^7, and pertain to three 10^o sphere cone model configurations having nose bluntness ratios of 0, 0.3, and 0.6. The turbulent-flow free-flight data are correlated, as a function of the ratio of base to local cone pressure, with the local Mach number at the edge of the boundary layer preceding the base.

*General Electric Co., Aerospace Group, Aerodynamics Lab., King of Prussia, PA

76 *Sieling, Walter R.: **The Effect of Sting Diameter and Length on Base Pressure at M = 3.88.** The Aeronautical Quarterly, vol. 19, Part 4, Nov. 1968, pp. 368 – 374.

A69-15712

The effects of sting diameter and cylindrical protuberance length on the base pressure of an axisymmetric body in a turbulent supersonic flow are experimentally determined. It is found that the change in base pressure due to the presence of the sting is greater than 4 per cent when the ratio of sting diameter to base diameter is 0.150 or greater. When the ratio of cylindrical protuberance length to base diameter is greater than 1.3 there is no apparent change in base pressure with a change in length. However, when this ratio is less than 1.3, the base pressure varies greatly with length.

*Rutgers Univ., New Brunswick, NJ

National Science Foundation GY-3068
Contract AF 44(620)-68-C-0018

77 *Adcock, Jerry B.: **Some Experimental Relations between the Static and Dynamic-Stability Characteristics of Sting-Mounted Cones with Bulbous Bases.** 24 pp., 32 refs. In Transactions of the 3rd Technical Workshop on Dynamic Stability Problems, vol. 2, held at Moffett Field, Calif., on Nov. 4 – 7, 1968.

(U.S. Gov't Agencies and Their Contractors Only)

X70-12303#

*NASA, Langley Research Center, Hampton, Virginia

78 *Ericsson, L. E.; and *Reding, J. P.: **Dynamic Support Interference on Bulbous-Based Configurations.** In "Transactions of the 3rd Technical Workshop on Dynamic Stability Problems," vol. 2, Paper no. 7, held at Moffett Field, Calif., on Nov. 4–7, 1968, 32 pp.

(U.S. Gov't Agencies and Their Contractors Only)

X70-12305#

*Lockheed Missiles and Space Co., Sunnyvale, CA

Contract No. NAS1-6450

79 *Ericsson, Lars E.; and *Reding, J. Peter: **Aerodynamic Effects of Bulbous Bases.** NASA-CR-1339, Aug. 1969, 116 pp. Lockheed Rep. no. LMSC-4-17-68-4.

N69-35521#

An exploratory study has been made of the effect that a bulbous base can have on the aerodynamic characteristics of blunt space capsules and slender reentry bodies. It is found that the base has a profound effect and can cause drastic loss of dynamic stability. A careful examination of available experimental data reveals that the often complex effects of bulbous bases can be explained using quasi-steady separated flow concepts. In general, a bulbous base adversely affects the vehicle dynamics but increases the static stability. Support interference is a serious problem that can prevent simulation in dynamic wind tunnel tests of full-scale vehicle dynamics. A possible means of measuring and correcting for this dynamic sting interference is outlined.

*Lockheed Missiles and Space Co., Sunnyvale, CA

Contract No. NAS1-6450

80 *Cahill, J. F.; and *Stanewsky, E.: **Wind Tunnel Tests of a Large-Chord, Swept-Panel Model to Investigate Shock-Induced Separation Phenomena.** LGR-10253; AFFDL-TR-69-78, Oct. 1969, 61 pp.

(U.S. Gov't Agencies and Their Contractors Only)

AD-861041 X70-11319#

*Lockheed-Georgia Co., Marietta, GA

Contract F33615-69-C-1256

81 *Compton, William B., III; and *Runckel, Jack F.: **Jet Effects on the Boattail Axial Force of Conical Afterbodies at Subsonic and Transonic Speeds. Appendix B — Calibration Bodies.** NASA-TM-X-1960, Feb. 1970, pp. 16–19.

N70-22634#

A parametric investigation has been conducted to determine the jet effects on the boattail axial force of nozzles having truncated conical afterbodies. The boattail axial force for nozzle configurations having boattail angles of 3°, 5°, 10°, and 15° and having ratios of boattail length to maximum diameter of 1.0, 0.8, and 0.6 was compared for the jet-off condition and for a wide range of jet pressure ratios. A nozzle configuration with a boattail angle of 7.5°, one with a boattail angle of 20°, and one with a circular-arc boattail were tested also. The tests were run at an angle of attack of 0° and through a Mach number range of 0.30 to 1.30. (An appendix is included (pp. 16 — 19) which compares strut-mounted and sting supported models.)

*NASA, Langley Research Center, Hampton, Virginia

82 *Sieling, Walter R.; and **Page, Robert H.: **A Re-Examination of Sting Interference Effects.** Presented at the AIAA 5th Aerodynamic Testing Conference, Tullahoma, Tenn., May 18 — 20, 1970, 8 pp., 29 refs., AIAA Paper 70-585.

A70-29885#

The effects of sting diameter and cylindrical protuberance length on the base pressure of an axisymmetric body in a turbulent supersonic flow, M = 3.88, are experimentally determined. A review of available sting interference data is presented. An analysis of this data shows that the percentage change in base pressure due to the presence of a sting varies significantly with Mach number. The often used assumption, that, for a sting diameter ratio of approximately 0.3, the percentage deviation in base pressure is small, is shown to be unreliable except in a very limited Mach number region near M = 2.

*Bell Telephone Laboratories, Inc., Whippany, NJ
**Rutgers Univ., New Brunswick, NJ

NSF-Grant No. GY-3068
Contract AF 44(620)-68-C-0018

83 *Ericsson, Lars E.; and *Reding, J. P.: **Boundary-Layer Transition and Dynamic Sting Interference.** AIAA Journal, vol. 8, no. 10, Oct. 1970, pp. 1886 — 1888.

A70-44581#

Discussion of boundary-layer transition and dynamic sting interference taking into consideration an investigation conducted by Wehrend (1963). Results obtained by Wehrend are examined and a study of Ericsson and Reding (1968) concerning the effect of a bulbous base is considered. Boundary-layer transition effects on sharp cone stability are shown and boundary-layer transition Reynolds numbers for cones are presented.

*Lockheed Missiles and Space Co., Sunnyvale, CA

84 *Vlajinac, M.; *Stephens, T.; *Gilliam, G.; and *Pertsas, N.: **Subsonic and Supersonic Static Aerodynamic Characteristics of a Family of Bulbous Base Cones Measured With a Magnetic Suspension and Balance System.** MIT-TR-166, Nov. 1970, NASA-CR-1932, Jan. 1972, 63 pp.

N72-14984#

Results of subsonic and supersonic wind-tunnel tests with a magnetic balance and suspension system on a family of bulbous based cone configurations are presented. At subsonic speeds the base flow and separation characteristics of these configurations are shown to have a pronounced effect on the static data. Results obtained with the presence of a dummy sting are compared with support interference free data. Support interference is shown to have a substantial effect on the measured aerodynamic coefficient.

*M.I.T., Cambridge, Mass.

Contract No. NAS1-8658

85 *Carmel, Melvin M.; and *Brown, Clarence A., Jr.: **Supersonic Aerodynamic and Wake Characteristics of Large-Angle Cones at Low Reynolds Numbers Including Effects of Model Support.** Presented at the 6th AIAA Aerodynamic Testing Conference, Albuquerque, New Mex., Mar. 10 — 12, 1971, 12 pp. Also, Journal of Aircraft, vol. 9, no. 2, Feb. 1972, pp. 99 — 100, AIAA Paper 71-264.

A71-21990#

The effects of sting diameter and Reynolds number variation in the low range on the aerodynamic characteristics of a 140° cone at M = 1.5 and 2.0 are shown from experiment. The effects of support interference on the wake of a 120° cone at M = 1.6 is also presented. The results indicate no appreciable effect of sting diameter or Reynolds number on the cone aerodynamic characteristics other than an increase in C_A with sting diameters greater than about 0.3 d/D. Also, asymmetry of the support system for blunt cones may lead to significant error in wake results.

*NASA, Langley Research Center, Hampton, Virginia

86 *Dayman, Bain, Jr.: **Comparisons Between Sting-Supported and Free-Flight Tests in the JPL Hypersonic Wind Tunnel on a Modified Saturn-Apollo Launch Configuration.** Presented at the 6th AIAA Aerodynamic Testing Conference, Albuquerque, New Mex., Mar. 10 – 12, 1971, 12 pp., AIAA Paper 71-265.

A71-21991#

Trajectories predicted from sting-supported internal-balance model tests conducted in the Jet Propulsion Laboratory (JPL) 21-inch Hypersonic Wind Tunnel (HWT) were compared with trajectories of free-flight model tests on a modified Saturn-Apollo launch configuration run in the JPL HWT. They were also compared with tests run in the U.S. Naval Ordnance Laboratory (NOL) Pressurized Ballistics Range No. 3 (PBR3). The purpose of this test program was to determine, under controlled and ideal conditions, just how closely "static" data can compare with "flight" data. In spite of the extremely complex flow field over the model (the characteristics, attached vs. separated flow, were a strong function of Mach and Reynolds numbers, ratio of model wall temperature to flow temperature, and angle of attack) the comparisons with the sting-supported model tests were generally within 5% in drag and 2% of model diameter in center-of-pressure location for the wind tunnel free-flight trajectories and were within 5% and 7%, respectively, for the ballistics range trajectories. Pitch damping determined from the wind tunnel and ballistics range free-flight trajectories also compared quite favorably.

*Jet Propulsion Laboratory, Calif. Inst. of Tech., Pasadena, Calif.

Contract No. NAS7-100

87 *Hammond, D. G.; and *Wilkerson, C., Jr.: **An Evaluation of Single and Multiple Sting Methods to Obtain Unmodified Interference-Free Wind Tunnel Data.** Presented at the 6th AIAA Aerodynamic Testing Conference, Albuquerque, New Mex., Mar. 10 – 12, 1971, 10 pp., AIAA Paper 71-267.

A71-21993#

Wind tunnel tests of a conventional force model were conducted in which the "Image Sting" method of support was used in an attempt to obtain corrections that could be applied to data to eliminate aerodynamic interference effects caused by the model single-sting support system. The tests were conducted over a Mach number range of 0.85 to 2.20 in the General Dynamics High-Speed Wind Tunnel. The test results for several single-support and multiple-support sting arrangements are compared with the Image Sting results as a means of evaluating this method of support. The Image Sting demonstrated its acceptability as a means of determining interference free wind tunnel model data. A single sting method that provides test data in close agreement with the Image Sting data levels was also determined.

*General Dynamics, Convair Aerospace Division, Fort Worth Operation, Fort Worth, Texas

88 *Orlik-Rückemann, K. J.; *Adams, P. A.; and *LaBerge, J. G.: **On Dynamic Stability Testing of Unconventional Configurations.** Presented at the 6th AIAA Aerodynamic Testing Conference, Albuquerque, New Mex., Mar. 10 – 12, 1971, 11 pp., AIAA Paper 71-276.

A71-22001#

Situations frequently occur when standard wind-tunnel test equipment, based on the concept of an all-containing rear-sting support is impractical or even impossible to use. In this paper some possible alternative test arrangements are indicated and descriptions are given of the actual experimental equipment and procedures. Full- and half-model techniques are discussed and the experimental procedures include free- and forced-oscillation methods. Examples contain cases such as cones at incidence and combinations of two models in close proximity (space shuttle), at supersonic and hypersonic speeds. Comparisons of results obtained with different methods and techniques are included.

*National Aeronautical Establishment, Ottawa, Ontario, Canada

89 *Reding, J. Peter; and *Ericsson, Lars E.: **Dynamic Support Interference – Fact or Fiction?** Presented at the 6th AIAA Aerodynamic Testing Conference held at Albuquerque, New Mex., March 10–12, 1971, 10 pp. Also see Journal of Spacecraft and Rockets, vol. 1, July 1972, pp. 547–553, AIAA Paper 71-277.

A71-22002#

Available experimental results are reviewed and organized to provide a logical explanation of aerodynamic support interference for dynamic wind tunnel testing. Configurations involving bulbous bases, mass addition, boundary layer transition near the base, and hypersonic low density flows are shown to be particularly sensitive to sting interference effects. Transverse rod support interference occurs at all Mach numbers depending on oscillation amplitude and/or trim angle of attack. The postulated flow model predicts that cylindrical and flared stings will have opposite interference effects in agreement with experimental observations. An analytical method of correcting the wind tunnel results for dynamic support interference is proposed.

*Lockheed Missiles and Space Company, Sunnyvale, CA

Contract NAS1-6450

90 *Evans, J. Y. G.; and *Taylor, C. R.: **Some Factors Relevant to the Simulation of Full-Scale Flows in Model Tests and to the Specification of New High-Reynolds-Number Transonic Tunnels.** Paper presented at the Fluid Dynamics Panel 'Specialists' Meeting at Göttingen, Germany, Apr. '71, on "Facilities and Techniques for Aerodynamic Testing at Transonic Speeds and High Reynolds Numbers." AGARD-CP-83-71, Aug. 1971, pp. 31–1 through 31–13.

N72-11881#

This paper considers some limitations and difficulties of achieving representative flow simulation in model tests. Particular attention is given to obtaining design data for swept-winged aircraft at high lift coefficients, when the flow over the wing is locally transonic and sensitive to scale. Examination of the limitations due to model strength suggests that the maximum tunnel static pressure for tests at high-lift conditions is about 5 atm, and consequently that full-scale Reynolds numbers could only be obtained in very large tunnels. In some cases, low tunnel pressures may be desirable to improve compatibility of model and aircraft distortion and to avoid gross interference from the sting support and difficulties of engine flow representation. Discussion of known causes of gross scale effects leads to the suggestion that model tests over the range of chord Reynolds numbers from 15 to 25 million should give results which are representative of flight at these and higher Reynolds numbers.

*Royal Aircraft Establishment, Bedford and Farnborough, England

91 *Vlajinac, M.: **Aerodynamic Characteristics of Axisymmetric and Winged Model Configurations Using a Magnetic Suspension and Balance System.** In the 2nd Int. Symp. on Electro-Magnetic Suspension, Proceedings, July 12–14, 1971, pp. N.1–N.12; Discussion, p. N.13.

A72-24769#

Results of subsonic and supersonic wind tunnel tests with a magnetic balance and suspension system on a family of bulbous-based cone models are presented. At subsonic speeds the base flow and separation characteristic of these models is shown to produce anomalous behavior of the static force and moment coefficients with angle of attack. Comparison of data obtained with a dummy sting is made with support interference free results. The static aerodynamic characteristics of three sharp-edged, slender wings at subsonic speeds are presented. Comparison of the present results with tests at Reynolds numbers an order of magnitude higher is considered good, thereby validating the small scale tests.

*M.I.T., Cambridge, Mass.

92 *Zapata, R. N.; *Kuhlthau, A. R.; and *Fisher, S. S.: **Research in Rarefied Gas Dynamics Using an Electromagnetic Wind-Tunnel Balance.** 2nd Int. Symp. on Electro-Magnetic Suspension, July 12 – 14, 1971, Proceedings, pp. P.1 – P.16; Discussion, pp. P.17, P.18.

A72-24771#

Aerodynamic forces on spheres and slender cones in hypersonic, low-density flows have been measured with a 3-component magnetic balance of improved capabilities. Improvements in the experimental techniques permitting measurements of increased accuracy, precision, and resolution have made possible interesting studies of slender-cone aerodynamics. Preliminary results of an investigation of sting effects are reported. Current and future research plans are discussed from the point of view of facility development.

*Univ. of Virginia, Charlottesville, Virginia

Grant No. AF-AFOSR-69-1798

93 *Maiden, Donald L.; and *Berrier, Bobby L.: **Effects of Afterbody Closure and Sting Interference on the Longitudinal Aerodynamic Characteristics of a Fixed-Wing, Twin-Jet Fighter Airplane Model.** NASA-TM-X-2415, Oct. '71, 135 pp.

(U.S. Gov't Agencies and Their Contractors Only)

X71-10815#

*NASA, Langley Research Center, Hampton, Virginia

94 *Bailey, Frank R.: **Numerical Calculation of Transonic Flow About Slender Bodies of Revolution.** NASA-TN-D-6582, Dec. 1971, 39 pp.

N72-11899#

This paper describes a relaxation method for the numerical solution of the transonic small disturbance equation for flow about a slender body of revolution. Results for parabolic arc bodies, both with and without an attached sting, are compared with wind-tunnel measurements for a free-stream Mach number range from 0.90 to 1.20. The method is also used to show the effects of wind-tunnel wall interference by including boundary conditions representing porous-wall and open-jet wind-tunnel test sections.

*NASA, Ames Research Center, Moffett Field, CA

95 *Pick, G. S.: **Sting Effects in Hypersonic Base Pressure Measurements: Test Report.** NSRDC Rep. No. AL-85, Dec. 1971, 24 pp.

AD-741888 N72-29224#

Sting interference effects were investigated at nominal Mach numbers of 6.3 and 9.9. Sting mounted and instrumented free flight sharp cone models were used at a unit Reynolds number of about 1,000,000/ft. Measurements showed that the base pressure distribution changes little below angle of attack 15 degrees but becomes highly nonuniform and sensitive to angle of attack changes at high angles of incidence. Sting interference effects are not very severe at M 6.3 when angle of attack is less than 20 degrees, but as the angle of attack increases, the flow becomes progressively more distorted. Consequently, the base pressure values of the sting mounted model deviate from the free flight interference free model measurements. Beyond about 40 degrees, due to the severe effects of sting interference, no steady base pressure value could be reached with the sting mounted model at either of the tested Mach numbers. For the free flight model at Mach number 9.9, the magnitude of the measured base pressure ratios at corresponding flow conditions and angles of attack were about 70 percent above the sting mounted model showing how serious sting interference can be.

*Naval Ship Research and Development Center, Aviation and Surface Effects Dept., Bethesda, Md.

96 *Uselton, Bob L.; and *Wallace, Arthur R.: **Damping-in-Pitch and Drag Characteristics of the Viking Configuration at Mach Numbers from 1.6 through 3.** Final Rept. 21 June – 18 Aug. 1971, ARO-VKF-TR-72-10; AEDC-TR-72-56; May 1972, 106 pp.

AD-741826 N72-29886#

Wind tunnel tests were conducted to substantiate earlier test results from another AEDC facility and to determine the dynamic stability characteristics of the Viking-Balloon Launched Decelerator Test (BLDT) configuration. The dynamic instabilities at zero angle of attack which were found during the previous tests were verified by the present tests. For angles of attack of 3 to 15 deg at all Mach numbers, the BLDT configuration was dynamically stable, and the damping derivatives were generally independent of the test variables. Free-flight drag coefficients show good agreement with coefficients obtained from tests on a similar configuration with a sting-supported model.

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

Contract F40600-72-C-0003

97 *Orlik-Rückemann, K. J.; *LaBerge, J. G.; and *Iyengar, S.: **Half- and Full-Model Experiments on Slender Cones at Angle of Attack.** Presented, under the title "Comparison of Three Oscillatory Techniques for Cones at Incidence," at the AIAA 7th Aerodynamic Testing Conference, Palo Alto, CA, Sept. 13 – 15, 1972; revised May 9, 1973. This paper was published in the "Journal of Spacecraft and Rockets," Sept. 1973, vol. 10, no. 9, pp. 575–580, AIAA Paper 72-1015.

AD-772892 A72-41595#

For some wind-tunnel experiments the presence of a sting at the rear of a model may constitute a source of significant error. Alternative techniques to the conventional sting support are therefore of interest. One such technique involves the use of half models. An evaluation has been made of the angle-of-attack range at which experiments on slender sharp cones can be performed using half models. The evaluation was based partly on a comparison of surface flow patterns over full and half models, partly on the measurement of the static side force on full models at zero yaw, and partly on a comparison of oscillatory pitching results obtained with full and half models. Most of the results were obtained at a Mach number of two in the range of angle of attack between 0° and 30°, but the static side force was also measured at Mach numbers between 0.5 and 0.8. In all cases investigated, it was found that up to an angle of attack of at least 15° no significant side force could be detected on full models, and that the pitch damping results and the surface flow patterns (with the exception of the primary attachment line) obtained on full and half models were in close agreement. The half-model technique appears therefore suitable for oscillatory experiments on slender cones (and probably on other similar geometries) at angles of attack at least up to 15°, at low supersonic speeds. Application to higher speeds, however, may very well require special corrections for tunnel-wall or reflection-plate boundary layer.

*National Aeronautical Establishment, Ottawa, Ontario, Canada

98 *Steinberg, S.; **Uselton, B. L.; ***Siemers, P. M.: **Viking Configuration Pitch Damping Derivatives as Influenced by Support Interference and Test Technique at Transonic and Supersonic Speeds.** Presented at the 7th AIAA Aerodynamic Testing Conference, Palo Alto, Calif., Sept. 13–15, 1972, 10 pp. Also see Journal of Spacecraft and Rockets, vol. 10, no. 7, July 1973, pp. 443 – 449, AIAA Paper 72-1012.

A72-41593#

Experimental studies to determine the 140-deg spherically-blunted cone configuration single degree-of-freedom damping derivative included model sting interference effects at M = 1.76 to 3.0. Minimal sting influences are noted with sting/model diameter ratios of 0.183 and effective sting lengths of 3.55 of the reference length. Increasing the ratio of sting diameter to reference length to 0.53 influences damping considerably at angles of attack from 0 to 3 deg at all Reynolds numbers but shows little or no effect at higher angles. Free-flight model wake geometries (wake neck position and size) correlate well with those from captive model tests with the small diameter sting; this adds confidence to obtaining damping derivatives through captive model testing. The damping characteristics of an early Viking configuration obtained on 11.23 and 4.35% scale models using forced and free oscillation test methods, respectively, in two different test facilities are compared. The agreement is quite good under test conditions.

*Martin Marietta Corp., Denver, Colo.
**ARO, Inc., Arnold Air Force Station, Tenn.
***NASA, Langley Research Center, Hampton, Va.

Contract No. NAS1-9000
USAF-supported research

99 *Reichenau, D. E. A.: **Sting and Strut Support Interference Effects on a Cylindrical Model With an Ogive Nose at Mach Numbers from 0.7 to 1.4: Final Report.** Rep. Nos. ARO-PWT-TR-72-165; AEDC-TR-72-175, 77 pp., Nov. 1972.

(U.S. Gov't Agencies and Their Contractors Only)

AD-905771L X73-75159#

*Arnold Engineering and Development Center, ARO, Inc., Arnold Air Force Station, Tenn.

Contract No. F40600-73-C-004, AF Proj. 668A

100 *Carter, E. C.: **Interference Effects of Model Support Systems.** 10 pp. Paper No. 3 in AGARD-R-601, "Problems in Wind Tunnel Testing Techniques," April 1973.

N73-26242

A brief discussion is given of the forms of interference occurring in subsonic and transonic wind tunnels due to the model support system. Two types of model attachment, rear sting and vertical blade sting are considered and the form and magnitude of interference terms is given for some particular examples. It is seen that apart from drag the major interference is on $(C_m)_o$ tail on due to the upwash interference at the rear fuselage. The buoyancy interference in the working section due to a typical sting joint and roll mechanism behind a model is considered and the effect on drag evaluated for two typical bodies. The effect of increase of stagnation pressure is shown to give a significant increase in buoyancy drag interference. The use of improved materials helps to reduce this term but currently known material limits do not contribute significantly. The buoyancy interference in the working section due to a vertical or horizontal incidence support strut is also considered although in practice, the term should be measured in the working section calibration. It is unlikely that any of these interferences can be eliminated and their effect will have to be allowed for in the planning of test schedules for future high Reynolds number tunnels.

*Aircraft Research Association Limited, Manton Lane, Bedford, England

101 *Mercer, Charles E.; and *Reubush, David E.: **Sting and Jet Interference Effects on Longitudinal Characteristics of a Twin-Jet, Variable-Wing-Sweep Fighter Model at Mach Numbers to 2.2.** NASA-TM-X-2825, July 1973, 149 pp.

(U.S. Gov't Agencies and Their Contractors Only)

X76-77447

*NASA, Langley Research Center, Hampton, Va.

102 *Sykes, D. M.: **Sting Interference Effects on Afterbodies at Transonic Speeds.** In AGARD "Aerodynamic Drag," N74-14709#, AGARD-CP-124, 469 pp., Oct. 1973, Proceedings of the Fluid Dyn. Panel Specialists' Meeting, Izmir, Turkey, 10 – 13 Apr. 1973, 9 pp.

N74-14737#

The pressure distribution over the surface of three axisymmetric afterbodies at zero incidence has been measured and sting interference effects determined through the Mach number range from 0.70 to 1.15 in an octagonal, slotted wall wind tunnel. The afterbodies tested were a simple cylinder and conical boat-tails 1/2 calibre long with 7 1/2 deg angle and 1 calibre long with 9 deg angle, each carrying a representative driving band. Sting diameter effects were determined using 4 calibre long cylindrical stings of diameter 1/8, 1/4, 3/8 and 1/2 calibre, and stingflare interference effects were determined for a 10 deg semi-angle cone on a 1/4 calibre sting. The tests showed that the ratio of sting to base diameter was the main parameter for interference effects, but data for diameter effect from afterbodies with other geometries was not fully correlated using this parameter. Successful correlation with other data has been achieved for the proximity of conical flares of different angles for subsonic flow conditions.

*Dept. of Aeronautics, City Univ., London, England

103 *Haldeman, Charles W.; *Coffin, James B.; *Birtwell, Edwin P.; and *Vlajinac, Milan: **Magnus Measurements With the Magnetic Balance System.** Final Tech. Rep., 6 Mar. 1972 – 30 Dec. 1973. Ballistics Research Labs. Rep. BRL-CR-153, May 1974, 57 pp.

AD-782753 N75-13236#

Recent wind tunnel tests in the Magnetic Balance System at the M.I.T. Aerophysics Laboratory are described. Improvement in the balance, which holds wind tunnel models magnetically without physical supports, were required in order to obtain measurements of the aerodynamic Magnus side force on spinning bodies of revolution at angles of attack up to 10 degrees and spinning ring airfoils at angles of attack up to 3.5°. Improvements described include a laser position system with an angular holding capability of .02 degrees, a data acquisition system, and model construction techniques using copper-iron composite structures. Typical aerodynamic data is presented for a 5-1 ogive cylinder at M = .27 (Re = 7.7 $\times$ 10^5) to .43 (Re = 1.3 $\times$ 10^6). Magnetically obtained Magnus side force data is presented which exhibits a scatter of less than 0.005 in side force coefficient. Data is also presented, which shows that in this Reynolds number range the effect of a sting can be large.

*M.I.T., Cambridge, Mass.

Contract No. DAAD05-72-C-0181

104 *MacWilkinson, D. G.; *Blackerby, W. T.; and Paterson, J. H.: **Correlation of Full-Scale Drag Predictions With Flight Measurements on the C-141A Aircraft. Phase 2: Wind Tunnel Test, Analysis, and Prediction Techniques. Volume 1: Drag Predictions, Wind Tunnel Data Analysis and Correlation: Final Report.** NASA-CR-2333, Feb. 1974, 166 pp., Lockheed-Georgia Rep. No. LG73ER0058-Vol. 1.

N74-18679#

The degree of cruise drag correlation on the C-141A aircraft is determined between predictions based on wind tunnel test data, and flight test results. An analysis of wind tunnel tests on a 0.0275 scale model at Reynolds number up to 3.05 $\times$ 1 million/MAC is reported. Model support interference corrections are evaluated through a series of tests, and fully corrected model data are analyzed to provide details on model component interference factors. It is shown that predicted minimum profile drag for the complete configuration agrees within 0.75% of flight test data, using a wind tunnel extrapolation method based on flat plate skin friction and component shape factors. An alternative method of extrapolation, based on computed profile drag from a subsonic viscous theory, results in a prediction four percent lower than flight test data.

*Lockheed-Georgia, Marietta, GA

Contract No. NAS1-10045

105 *Blaha, B. J.: **Wind Tunnel Blockage and Support Interference Effects on Winged-Body Models at Mach Numbers from 0.6 to 1.0.** NASA-TM-X-3011, March 1974, 36 pp.

N74-18656#

Three sting-mounted winged-body models with tunnel blockages of 0.1, 1.0, and 2.0 percent were tested in the Lewis Research Center's 8- by 6-Foot Supersonic Wind Tunnel. Fuselage pressures were obtained over a Mach number range of 0.6 to 1.0 at angles of attack from 0 deg to 4 deg. Two other types of model support were investigated, which included simulated wing-tip and fuselage support-strut mountings. The effects of tunnel porosity and sidewall geometry were also investigated. Model blockage effects were small up to M_o = 0.95. At higher speeds the major blockage effect observed was a displacement of the local transonic terminal shocks on the model. The effects of the wing-tip type of model support were small up to M_o = 0.95, but disturbances were observed on the fuselage at higher speeds. Changes in local tunnel porosity were effective in reducing the disturbances up to M_o = 0.975, but a change in sidewall geometry was not.

*NASA, Lewis Research Center, Cleveland, Ohio

106 *Price, E. A., Jr.: **Afterbody Aerodynamic Characteristics and Support System Interference on a Twin-Jet Fighter-Type Aircraft Model at MachNumbers from 0.6 to 1.5: Final Report, 1 Aug. – 21 Sept. 1973.** Rep. Nos. ARO-PWT-TR-73-163; AEDC-TR-74-13, April 1974, 107 pp.

(U.S. Gov't Agencies Only)

AD-918789L X75-70062#

*Arnold Engineering and Development Center, ARO, Inc., Arnold Air Force Station, Tenn.

ARO Proj. PA323

107 *Birtwell, Edwin P.: **Magnus Forces and Sting Interference on Magnetically-Suspended Ogive Cylinders.** MIT, M.S. Thesis, May 1974, 94 pp. (Available from MIT).

N80-71560#

Subsonic Magnus testing was conducted on a spinning ogive nosed cylinder suspended with a magnetic suspension and balance system. At low angles of attack and Reynolds numbers, an unanticipated reversal in Magnus coefficient was observed. Further testing was done to determine the influences of sting interference and transition to turbulence on this effect. The results showed that a considerable dependence exists on the sting and transition and suggested a possible explanation for the reversal effect.

*M.I.T., Graduate student

108 *Buckner, J. K.; and *Webb, J. B.: **Selected Results from the YF-16 Wind Tunnel Test Program.** Presented at the 8th AIAA Aerodynamic Testing Conference, Bethesda, Md., July 8 – 10, 1974, 13 pp., AIAA Paper 74-619.

A74-36046#

YF-16 force-model results from several facilities are compared, with emphasis on the drag data. Rather large initial subsonic differences between the NASA-Ames 11-ft and Calspan 8-ft tunnels are reconciled by the 'relative buoyancy' discoveries of S. L. Treon et al. (1971). Data from two model scales in these tunnels also demonstrate scale effects on profile and induced drag. The higher turbulence level of the Calspan tunnel is evident from the Reynolds number effects observed in both tunnels. It is further shown that simple force-model techniques can be used successfully to derive inlet spillage effects. It appears that nozzle-exit-diameter effects on airplane drag can also be derived by force-model testing on a single-engine fighter aircraft, but the size of the model support sting restricts the ability to simulate the small dry-power nozzle exit.

*General Dynamics Corp., Convair Aerospace Div., Fort Worth, TX

109 *Burt, G. E.; and *Uselton, J. C.: **Effect of Sting Oscillations on the Measurement of Dynamic Stability Derivatives in Pitch or Yaw.** Presented at the 8th AIAA Aerodynamic Testing Conference, held at Bethesda, Md., July 8 – 10, 1974, 10 pp. Also, Journal of Aircraft, vol. 13, no. 3, March 1976, pp. 210 – 216, AIAA Paper 74-612.

A74-36045#

Long, slender stings required to minimize support interference on dynamic stability test mechanisms are subject to oscillatory bending because of aerodynamic (particularly for aircraft configurations), structural, and inertial loads. Sting oscillations can cause large errors in dynamic stability measurements using typical data reduction techniques for both forced and free oscillation. In this paper, data reduction equations are derived from equations of motion which include the sting movement. This movement can be measured by instrumentation or calculated from static data. Bench tests and wind tunnel tests using AGARD Models B and C verify that accurate data are obtained when the correct data reduction is used.

*ARO, Inc., von Karman Gas Dynamics Facility, Arnold Air Force Station, Tenn.

110 *Trescott, Charles D., Jr.; *Brown, Clarence A., Jr.; and *Howell, Dorothy T.: **Effects of Reynolds Number and Model Support on the Supersonic Aerodynamic Characteristics of a 140°-Included-Angle Cone.** NASA-TM-X-3019, July 1974, 74 pp.

N74-28481#

An investigation has been made in the Langley Unitary Plan wind tunnel to determine the effects of Reynolds number and sting-support interference on the static aerodynamic characteristics of a 140 deg-included-angle cone. Base pressures and forces and moments of the model were measured at Mach numbers of 1.50, 2.00, 2.94, and 4.00 for ratios of sting diameter to model diameter that varied from 0.125 to 0.500 through an angle-of-attack range from about minus 4 deg to 13 deg. The Reynolds number, based on model diameter 4.80 in., was varied from 161,000 to 415,000.

*NASA, Langley Research Center, Hampton, VA

111 *Campbell, J. H., II; and *Embury, W. R.: **Aerodynamic Results of Support System Interference Effects Tests Conducted in NASA/ARC 6- by 6-Foot Supersonic Wind Tunnel Using an 0.015-Scale Model of the Configuration 140A/B SSV Orbiter (OA59).**

Vol. 1: Chrysler Corp., New Orleans, La., Rep. No. DMS-DR-2159-Vol. 1, NASA-CR-134410, Sept. 1974, 683 pp.

N75-10108#

Vol. 2: Rep. No. DMS-DR-2159-Vol. 2, NASA-CR-134412, Sept. 1974, 553 pp.

N75-10109#

The primary objective was to determine the extent aerodynamic simulation is compromised by sting base mounting with MPS nozzles removed. Both a conventional sting (through the base) and an alternate model mounting system were utilized. The alternate mounting system consisted of a non-metric blade strut, which approximated the vertical tail and entered the model through the upper aft section of its fuselage. The model was tested both in and out of the presence of a dummy sting with and without MPS nozzles when on the alternate mounting system. Data were obtained at Mach numbers from 0.6 through 2.0, a Reynolds number of 2.5 million per foot, angles of attack from -4 through 14 degrees, angles of sideslip from -15 through 15 degrees, elevon deflections of 0 and 15 degrees, and bodyflap deflections of -11.7, 0, and 16.3 degrees.

*Rockwell International Corp., Downey, Calif.

Contract NAS9-13247

112 *Rejeske, J. V.; and **Stava, D.: **A Test Technique for Inlet/Aircraft Drag Evaluation.** Presented at the 10th AIAA and SAE Propulsion Conference held at San Diego, Calif., Oct 21 – 23, 1974, 7 pp., AIAA Paper 74-1145.

A75-10306#

A new technique for evaluating inlet and inlet/airframe interaction forces is discussed. This technique features a two-balance system with thermal control and long hollow sting supports that enter the model through the exit nozzles. The two balances permit simultaneous measurement of inlet forces and moments, and aircraft forces and moments. The hollow sting tubes, in addition to supporting the model, serve as mass flow tubes, thereby providing a minimum interference support system, eliminating the effects of a flowing exhaust, and permitting remote control of inlet airflow. Results of an evaluation test at subsonic conditions, utilizing a high speed fighter aircraft configuration, are presented.

*McDonnell Aircraft Co., St. Louis, Mo.
**USAF, Flight Dynamics Lab., Wright-Patterson AFB, Ohio

113 *Campbell, J. H., II; and *Embury, W. R.: **Aerodynamic Results of a Support System Interference Effects Test Conducted at NASA/LaRC UPWT Using an 0.015-Scale Model of the Configuration 140A/B SSV Orbiter (OA208).** Chrysler Corp., DMS-DR-2163; NASA-CR-134403, 1974, 390 pp.

N74-34315#

An experimental aerodynamic investigation was conducted to determine the interference effects of a wind tunnel support system. The test article was a 0.015 scale model of the space shuttle orbiter. The primary objective of the test was to determine the extent that aerodynamic simulation of the space shuttle orbiter is affected by base mounting the model, without nozzles, on a straight sting. Two support systems were tested. The characteristics of the support systems are described. Data from the tests are presented in the form of graphs and tables.

*Rockwell International Space Division, Downy, Calif.

Contract No. NAS9-13247

114 *Jaffe, P.: **A Free Flight Investigation of Transonic Sting Interference.** NASA-CR-142084; JPL-TM-33-704, Jan. 1975, 48 pp.

N75-16544#

Transonic sting interference has been studied in a supersonic wind tunnel to obtain free flight and sting support data on identical models. The two principal configurations, representing fuselage bodies, were cigar shaped with tail fins. The others were a sharp 10-deg cone, a sphere, and a blunt entry body. Comparative data indicated that the sting had an appreciable effect on drag for the fuselage-like configurations; drag rise occurred 0.02 Mach number earlier in free flight, and drag level was 15% greater. The spheres and the blunt bodies were insensitive to the presence of stings regardless of their size. The 10-deg cones were in between, experiencing no drag difference with a minimum diameter sting, but a moderate difference with the largest diameter sting tested. All data tend to confirm the notion that for the more slender bodies the sting not only affects base flow but the forebody flow as well.

*Jet Propulsion Lab., California Inst. of Tech., Pasadena, Calif.

115 *Sammonds, R. I.; and *Kruse, R. L.: **Aerodynamic Characteristics of the Planetary Atmosphere Experiments Test Entry Probe.** "Journal of Spacecraft and Rockets," vol. 12, Jan. 1975, pp. 22 – 27.

A75-20067#

The aerodynamic characteristics of the Planetary Atmosphere Experiments Test entry probe were determined experimentally in ballistic range tests over a wide range of Mach and Reynolds numbers, and were compared with full-scale flight results. The ground facility data agreed with the full-scale data within 2 to 3% in drag coefficient, and within 5 to 10% in static stability, at the higher Mach numbers. Comparisons of the flight data with conventional wind-tunnel data indicated a significant disagreement in drag coefficient in the transonic speed range suggestive of important sting or wall interference effects. Variations in drag coefficient with Mach number were very small hypersonically, but variations with Reynolds number were of the order of 15% at a free-stream Mach number of 13 over the Reynolds number range from 10,000 to 1,000,000. Variations in the lift and static-stability curves with Mach number and Reynolds number were also defined.

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

116 *Reid, J.; *Mundell, A. R. G.; and *Crane, J. F. W.: **The Subsonic Base Drag of Clyindrical Twin-Jet and Single-Jet Afterbodies.** (In AGARD Airframe/Propulsion Interference, N75-23485). March 1975, 13 pp.

N75-23498

The effect was studied of forebody and support interference on the base drag of cylindrical twin-jet afterbodies in wind tunnel tests at subsonic speeds. Two almost identical afterbodies were tested, one in a strong interference field and the other nearly free from interference. The results illustrate the importance of the effect and also serve to test two methods of correction. Supplementary tests show that the base drag of a cylindrical twin-jet afterbody tends to be slightly greater than that of the equivalent axisymmetric configuration. Finally, a method of correlation is described whereby the base drag of both twin-jet and single-jet models may be expressed in linear form.

*Royal Aircraft Establishment, Farnborough, England

117 *Starr, R. F.; and *Varner, M. O.: **Experimental and Theoretical Observations on the Drag of Bodies of Revolution at Transonic Speeds.** Presented at the 14th AIAA Aerospace Sciences Meeting, held at Washington, D.C., Jan. 26 – 28, 1976, 13 pp., AIAA Paper 76-90.

A76-18782#

A study of the drag variation of conical bodies at transonic speeds in a wind tunnel and aeroballistic range has yielded some insight into wall interference phenomena and sting effects. The drag reduction of these conical bodies, caused by wall interference near Mach 1, is similar to those severe trends previously observed on longer slender bodies of revolution. However, a transonic test section wall which can be reduced in porosity near Mach 1 (variable porosity with Mach number) appears to measurably reduce the wall interference problem. The influence of a sting on the base drag of these bodies has been demonstrated to be important, about 5 to 10 percent, and a sophisticated mathematical model of the transonic base flow field has been developed. This model treats the base drag for various forebody cone angles and is valid for stings up to one half the body diameter in size.

*ARO, Inc., von Karman Gas Dynamics Facility, Arnold Air Force Station, Tenn.

118 *Dix, R. E.: **Influences of Sting Support on Aerodynamic Loads Acting on Captive Store Models.** Final Rept., April 1973 – June 1975. ARO-PWT-TR-75-95; AEDC-TR-76-1; AFATL-TR-76-25; March 1976, 329 pp.

AD-A022257 N76-29184#

In a series of wind tunnel tests, measurements were made of the aerodynamic loads acting on eight different store configurations mounted in the external captive position on a one-twentieth-scale model of the F-4C aircraft. Store models included blunt and contoured afterbody shapes, stable and unstable designs, and large (one per pylon) and small (rack-mounted) configurations. The tests were conducted in an effort to evaluate sting effects on captive store loads. Sting effects were considered to consist of two contributions: the effect of altering the afterbody of a store to allow insertion of a sting, and the effect of the presence of the sting. Altering the afterbody of an unstable store influenced captive loads less than altering a stable configuration. It was also determined that the presence of a sting affected most the pitching and yawing moments.

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

119 *German, R. C.: **Strut Support Interference on a Cylindrical Model with Boattail at Mach Numbers from 0.6 to 1.4.** ARO-PWT-TR-110, AEDC-TR-76-40, May 1976, 289 pp.

AD-A024473 N76-33164#

An investigation was conducted in the Aerodynamic Wind Tunnel (1T), with a sting-mounted, ogive-cylinder model and various dummy strut designs, to provide further information on sources of nozzle afterbody (NAB) interference and to determine how incremental changes in afterbody boattail and base pressures are affected by changes in support strut design and location. The investigation also included the effect of changing local wall porosity on the NAB intereference. An analysis of pressure data obtained on the model, boattail, base, and tunnel wall surfaces at Mach numbers from 0.6 to 1.4 indicates that interference occurs above Mach 0.99 as the result of disturbances generated by the strut leading edge which are reflected from the tunnel wall to the NAB. This interference can be minimized by using a swept strut; however, the optimum strut sweep angle and strut location is a function of Mach number and NAB geometry.

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

120 *Compton, W. B., III: **Jet Exhaust and Support Interference Effects on the Transonic Aerodynamic Characteristics of a Fighter Model With Two Widely Spaced Engines.** NASA-TM-X-3424, Dec. 1976, 135 pp.

N77-15978#

Jet exhaust, nozzle installation, and model support interference effects on the longitudinal aerodynamic characteristics of a twin-engine fighter model were determined. Realistic jet exhaust nozzle configurations and a reference configuration with a simulated vertical-tail support were tested. Free-stream Mach number was varied from 0.6 to 1.2, and model angle of attack from 0 deg to 9 deg. The jet exhaust affected drag more than it affected lift and pitching moment. The largest effects occurred at a Mach number of 0.9 and for the afterburning mode of exhaust nozzle operation. The combined differences between the aerodynamic characteristics of the realistic and reference configurations (which were due to afterbody and nozzle contours, jet operation, and simulated reference support interference) were considerably different from those for the jet interference alone. A translating-flap exhaust nozzle, a hinged-flap exhaust nozzle, and a flow-through-nacelle reference model were tested at both cruise and afterburner power settings; variables include afterbody drag coefficient, afterbody lift coefficient, afterbody pitching moment coefficient, scheduled jet pressure ratio, flow-through-nacelle pressure ratio, jet-off drag, jet total pressure ratio, Mach number, angle of attack, and incidence angle of horizontal tail; 20 figures and 5 tables include numeric data.

*NASA, Langley Research Center, Hampton, Va.

121 *Ericsson, L. E.; and *Reding, J. P.: **Viscous Interaction or Support Interference – The Dynamicist's Dilemma—Slender Vehicle Dynamics in Hypersonic Low Density Flow.** Presented at the 15th AIAA Aerospace

Sciences Meeting, Los Angeles, Calif., Jan. 24 – 26, 1977. Also, AIAA Journal, vol. 16, no. 4, Apr. 1978, pp. 363 – 368, AIAA Paper 77-78.

A77-19812#

In hypersonic low density flows slender vehicle dynamics are affected by various viscous flow phenomena. The true-viscid-inviscid interaction is often difficult to extract from the background of support interference in wind tunnel tests and nonlinear six degrees of freedom amplitude effects in ballistic range tests. The paper is intended to help the vehicle designer to decide how to obtain the best possible information about the full scale vehicle dynamics using subscale dynamic test data. It is found that it may not be possible in some cases to eliminate aerodynamic sting interference without introducing appreciable sting plunging. Although the sting plunging effect can be large, especially in the case of nonlinear aerodynamics, corrections can be made relatively simply to obtain the true single degree-of-freedom pitch data.

*Lockheed Missiles and Space Co., Sunnyvale, Calif.

122 *Hozumi, K.: **Support-Interference Effects on Hypersonic Base Pressure.** Presented at the 12th Intern. Symp. on Space Technology and Science, Tokyo, Japan, May 16 – 20, 1977, A78-47001, pp. 161 – 166.

A78-47022#

Results are presented for a hypersonic wind tunnel experiment designed to predict the base pressure of models supported by a system consisting of a sting, a sting-flare and a sting-pod. The models are four spherically blunted cones with a base diameter of 100 mm, a semi-vertex angle of 10 deg, and a zero angle of attack, supported by stings of different length. Correlation of results obtained and previous free-flight base-pressure results is examined. Effects of sting, sting flare, and strut on base pressure are stressed. It is shown that the base pressure is dependent on the local Reynolds number, Mach number and thickness of the boundary layer immediately preceding the base. The sting length should be selected so as to avoid interaction between the model and the sting-flare flow. The strut is avoided by using a 10-cm-long pod.

*National Aerospace Lab., Chofu, Tokyo, Japan

123 *Uselton, B. L.; and *Cyran, F. B.: **Critical Sting Length as Determined by the Measurement of Pitch-Damping Derivatives for Laminar, Transitional and Turbulent Boundary Layers at Mach Number 3 for Reduced Frequencies of 0.0033 and 0.0056: Final Report, July 1, 1975 – Apr. 17, 1977.** Rept. Nos. ARO-VKF-TR-77-35; AEDC-TR-77-66, July 1977, 67 pp.

N78-10033#

Support interference in supersonic wind tunnels is studied. The critical sting length at alpha = 0 was determined by the measurement of pitch-damping derivatives for laminar, transitional, and turbulent boundary layers at the model base. The effect of wedge splitter plates on sting interference was also investigated. By utilizing the small amplitude forced oscillation technique, data were obtained at Mach number 3 on a blunt 7 deg cone for reduced frequencies of 0.0033 and 0.0056. Model base pressure and a model surface pressure near the base were measured in addition to the pitch damping derivatives. The results showed that the critical sting length with respect to sting interference on pitch-damping data was two model diameters for the two reduced frequencies investigated and was independent of the type of boundary layer at the model base. The critical sting length for minimal base pressure interference is 2.5 model diameters for this model and these test conditions.

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

124 *Dietz, W. E., Jr.; and *Altstatt, M. C.: **Experimental Investigation of Support Interference on an Ogive Cylinder at High Incidence.** Presented at the 16th AIAA Aerospace Sciences Meeting, Huntsville, Ala., Jan. 16 – 18, 1978, 8 pp., AIAA Paper 78-165.

A78-20717#

A wind tunnel test was conducted to determine the support and tunnel wall interference on an ogive-cylinder model at high angles of attack in transonic flow. The model was supported by either a base-mounted sting or a strut attached to the leeside of the model. The strut support acted as a splitter plate and generally reduced the normal-force coefficient, whereas the sting support increased the normal-force coefficient slightly. The support interference diminished with increasing Mach number. A simple algebraic method of estimating support interference was postulated. Two semi-empirical methods for calculation of aerodynamic coefficients were compared with test results.

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

125 *Altstatt, M. C.; and *Dietz, W. E.: **Support Interference on an Ogive-Cylinder Model at High Angle of Attack in Transonic Flow; Final Report, 1 July 1976 – 30 Sept. 1977.** Rep. No. AEDC-TR-78-8, March 1978, 66 pp.

AD-A051689 N78-24088#

A combined experimental and analytical study was conducted to determine the relative magnitude of the support and tunnel wall interferences on an ogive-cylinder model at a high angle of attack in transonic flow. The tests were conducted in the AEDC Aerodynamic Wind Tunnel (4T). The results indicate that the strut support causes large reductions in the normal force on the model, while the effect attributable to the sting support is much smaller. A correction procedure applied to the data to remove support interference gives consistent results. The test data, combined with an inviscid analytic study, indicate that the wall interference effects were negligible. Solutions obtained using two computational methods compare well with experimental results.

*Arnold Engineering and Development Center, ARO, Inc., Arnold Air Force Station, Tenn.

126 *Swamy, M. S.; *Ahmed, S., and *Sreenath, G. S.: **Model Support System Interference on Zero-Lift Drag at Transonic Speeds.** Presented at the 10th AIAA Aerodynamic Testing Conference, San Diego, Calif., Apr. 19 – 21, 1978.

Technical Papers A78-32326, pp. 293 – 296, AIAA Paper 78-809.

A78-32363#

In this paper the support system interference on the zero-lift drag of an axisymmetric and an aircraft type model is discussed. Two different techniques were adopted for the two models tested to evaluate the support sting interference. It is found from these tests that the presence of a rear sting support would result in a reduction in the zero-lift drag of as much as 20 to 50 percent of the true value. This apparent reduction in drag is found to be a strong function of the free stream Mach number close to unity. Detailed pressure measurements over the aft-body of the axisymmetric model suggests that due to the positive pressure field imposed by the sting over the boat-tail region of the model the free stream Mach number at which the shocks appear in the boat-tail region will be higher when the sting is present than that without it. This will result in an increased drag divergence Mach number for the model in the presence of the sting. It is argued that because of this reason the sting effect on zero-lift drag strongly depends on the Mach number close to unity.

*National Aeronautical Laboratory, Bangalore, India.

127 *Mouch, T. N.; and *Nelson, R. C.: **The Influence of Aerodynamic Interference on High Angle of Attack Wind Tunnel Testing.** Presented at the 10th AIAA Aerodynamic Testing Conference, San Diego, Calif., April 19–21, 1978, Technical Papers. A78-32326, pp. 426–432, AIAA Paper 78-827.

A78-32378#

Also published as Rept. AFOSR-78-1079 TR, June 1978, 38 pp.

AD-A056045 N79-11002#

Results from an experimental investigation of strut support interference on high angle of attack aerodynamic measurements are presented. The influence of the strut support on the leeward wake structure was investigated by means of a two-dimensional experiment of a cylinder-splitter plate combination. Pressure distributions, pressure drag coefficient and wake flow visualization data for various cylinder-splitter plate combinations are presented for high subcritical Reynolds numbers. The influence of plate position and size on the pressure drag coefficient was also examined. The results show the splitter plate can alter the vortex wake formation significantly and, as a consequence, reduces the pressure drag coefficient by as much as 30% or more. Plate sizes of 0.5, 1.1, and 1.5 diameter were tested with the 1.1 diameter plate yielding the largest drag reduction.

*Notre Dame Univ., Notre Dame, Indiana. Contract AF-AFOSR-3299-77.

128 *Uselton, B. L.: **Sting Effects as Determined by the Measurement of Pitch-Damping Derivatives and Base Pressures at Mach Number 3.** Presented at the 10th AIAA Aerodynamic Testing Conference, San Diego, Calif., April 19 – 21, 1978, Technical Papers. A78-32326, pp. 451 – 466, AIAA Paper 78-830.

A78-32381#

A research program was initiated for the purpose of investigating some of the problem areas in regard to support interference. The critical sting length at alpha = 0 was determined by the measurement of pitch-damping derivatives for laminar, transitional, and turbulent boundary layers at the model base. Data were obtained at a freestream Mach number of 3 on a blunted 7-deg cone. The results showed that the critical sting length with respect to sting interference on pitch-damping data was two model diameters and was independent of the type of boundary layer at the model base. The effects of sting length on base pressure and wedge plates on sting interference were also investigated.

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

129 *Ericsson, Lars E.: **Effect of Sting Plunging on Measured Nonlinear Pitch Damping.** Presented at the 10th AIAA Aerodynamic Testing Conference. San Diego, Calif., April 19 – 21, 1978, Technical Papers. A78-32326, pp. 475 – 486, AIAA Paper 78-832.

A78-32383#

In dynamic tests of slender vehicles at hypersonic speeds sting interference is a serious problem. In order to minimize aerodynamic sting interference the sting diameter has to be small and the sting-strut juncture must be far downstream. This introduces appreciable sting plunging. Although the sting plunging effect can be large, especially in the case of nonlinear aerodynamics, it is shown that corrections can be made relatively simply to obtain the true single degree-of-freedom pitch data.

*Lockheed Missiles and Space Co., Sunnyvale, Calif.

130 *Lucas, E. J.; **Fanning, A. E.; and ***Steers, L. I.: **Comparison of Nozzle and Afterbody Surface Pressures from Wind Tunnel and Flight Tests of the YF-17 Aircraft.** Presented at the 14th AIAA and SAE Joint Propulsion Conference, Las Vegas, Nev., July 25 – 27, 1978, 12 pp., AIAA Paper 78-992.

A78-43540#

Results are reported from the initial phase of an effort to provide an adequate technical capability to accurately predict the full scale, flight vehicle, nozzle-afterbody performance of future aircraft based on partial scale, wind tunnel testing. The primary emphasis of this initial effort is to assess the current capability and identify the cause of limitations on this capability. A direct comparison of surface pressure data is made between the results from an 0.1-scale model wind tunnel investigation and a full-scale flight test program to evaluate the current subscale testing techniques. These data were acquired at Mach numbers 0.6, 0.8, 0.9, 1.2, and 1.5 on four nozzle configurations at various vehicle pitch attitudes. Support system interference increments were also documented during the wind tunnel investigation. In general, the results presented indicate a good agreement in trend and level of the surface pressures when corrective increments are applied for known effects and surface differences between the two articles under investigation.

*ARO, Inc., Arnold Air Force Station, Tennessee
**USAF, Aero Propulsion Lab., Wright-Patterson AFB, Ohio
***NASA, Dryden Flight Research Center, Edwards, Calif.

131 *Orlik-Rüeckemann, K. J.: **Techniques for Dynamic Stability Testing in Wind Tunnels.** In AGARD CP-235, Dynamic Stability Parameters, Nov. 1978 (See N79-15061), 24 pp.

N79-15062#

A systematic review is presented of the methods and techniques that are used for wind tunnel measurements of the dynamic stability parameters (derivatives) of an aircraft. The review is illustrated by numerous examples of experimental equipment available in various aerospace laboratories in Canada, France, the United Kingdom, the United States, and West Germany. (This report is included because of the numerous support systems illustrated.)

*National Aeronautical Establishment, Ottawa, Ontario, Canada

132 Ivanova, V. M.; and Tagirov, R. K.: **Calculation of Transonic Flows Past Axisymmetric and Plane Bodies With Allowance for the Influence of Ventilated Wind-Tunnel Walls and for the Tail Sting.** TsAGI. Uchenye Zapiski, vol. 9, no. 6, 1978, pp. 28 – 37. (In Russian).

A80-21340#

Based on Godunov's finite difference scheme, a method and computer program for transonic wind tunnel corrections are developed. Numerical results obtained for various degrees of ventilation are examined.

133 *Ericsson, Lars E.; and *Reding, J. P.: **Transonic Sting Interference.** Presented at the 17th AIAA Aerospace Sciences Meeting, New Orleans, La., Jan. 15 – 17, 1979, AIAA Paper 79-0109.

A79-19536#

See Journal of Spacecraft, vol. 17, no. 2, Mar./Apr. 1980, pp. 140 – 144, for revised version.

Recently it has been discussed extensively how one in the future will be demanding substantially improved accuracy of the results obtained in ground facilities. One of the problems that has to be solved to accomplish this in the case of wind tunnel tests is that of support interference, especially in regard to dynamic test data. While the dynamic sting interference has been well documented for hypersonic flow, it is generally only expected at transonic speeds in the cases where the body has a bulbous, dome-shaped base or a boat-tail. However, it is shown in the present paper that when boundary layer transition occurs on the aft body, sting interference becomes a problem for all body geometries.

*Lockheed Missiles and Space Co., Inc., Sunnyvale, Calif.

134 *Barna, P. S.: **Experimental Studies on the Effects of a Sting Support on the Pressure Distribution Around a Spherical Object.** Progress Rep., Aug. 1977 – Aug. 1978. NASA-CR-158127, Feb. 1979, 38 pp.

N79-17800#

Experiments were conducted on a spherical object, 2.5 inches in diameter, to obtain the pressure distribution around its meridian plane. In most of the tests the sphere was provided with a tail consisting of a circular cylinder that was attached directly to the rear with its axis in alignment with the center of the sphere. In some tests the tail was removed and the sphere alone was tested for comparison purposes. The main object of the tests was to obtain information on tail interference with the pressure distribution. The results of the tests show that the pressure distribution was affected by the presence of the tail to a minor extent only, while major differences occurred with the variation of the Reynolds number. The experiments were performed both in an open as well as inside a closed wind tunnel under steady flow conditions at Reynolds numbers ranging from 0.91 to 2.6 × 100000.

*Old Dominion Univ. Research Foundation, Norfolk, Virginia

Grant no. NsG-1143

135 *Binion, Travis W.: **Limitations of Available Data.** 8 pp. (In N79-31159, AGARD-AR-138, Experimental Data Base for Computer Program Assessment.)

N79-31161#

The factors affecting wind tunnel test results are discussed. These include: flow nonuniformity, three-dimensional effects in two-dimensional tests, support interference, aeroelastic effects, flow unsteadiness, wall interference, wave reflections, and boundary conditions.

*ARO, Inc., Arnold Air Force Station, Tennessee

136 *Finnerty, C. S.; and **Price, E. A., Jr.: **A Parametric Study of Support System Interference Effects on Nozzle/Afterbody Throttle Dependent Drag in Wind Tunnel Testing.** Presented at the 15th AIAA, SAE, and ASME, Joint Propulsion Conference, Las Vegas, Nevada, June 18 – 20, 1979, 14 pp., AIAA Paper 79-1168.

A79-38968#

A series of wind tunnel tests were conducted in the Arnold Engineering Development Center 16-foot transonic wind tunnel. These test results utilized an 11% F-16 nozzle/afterbody model. During the test, Mach number, Reynolds number, angle-of-attack, nozzle pressure ratio, and horizontal tail deflection were varied as well as support system geometry. The paper presents the support system interference effects resulting from the variations in the strut, wing-tip, and sting support systems. Support system variations include wing-tip support blade position, support boom diameter, length, spacing, and sting taper location. In general, the results presented indicate that the sting support with annular jet is the most interference free support system as compared to both the wing-tip and strut support systems.

*USAF, Aero Propulsion Lab., Wright-Patterson AFB, Ohio
**ARO, Inc., Arnold Air Force Station, Tennessee

137 *Ericsson, Lars E.: **Modification of Aerodynamic Prediction of the Longitudinal Dynamics of Tactical Weapons. Final Technical Report.** Lockheed Rep. No. LMSC-D646354, June 1979. **Appendix A: Transonic Support Interference.** (5 pp.)

An analytic method has been developed for fast prediction of the damping in pitch of tactical weapons. The method covers the complete speed range from incompressible flow to hypersonic speeds for body alone. For finned bodies the analysis covers both subsonic and supersonic speeds. It is indicated that the Reynolds number range commonly available for transonic tests will introduce the problem of transition-amplified sting interference, which can affect the measurements greatly, especially in dynamic tests. Thus, the experimental data base for slender vehicle dynamics at transonic speeds has to be examined closely in regard to these effects. Much more detailed experimental data are needed before this transition-amplified sting interference can be defined better.

*Lockheed Missiles and Space Company, Inc., Sunnyvale, Calif.

Contract N60921-77C-A294

138 *Corlett, W. A.: **Test Technique Development in Interference Free Testing, Flow Visualization, and Remote Control Model Technology at Langley's Unitary Plan Wind Tunnel.** 18 pp. *Presented at the 52nd Semi-Annual Meeting,* Supersonic Tunnel Association, Notre Dame, Ind., Sept. 13 – 14, 1979.

A79-51093#

A metric half-span model is considered as a means of mechanical support for a wind-tunnel model which allows measurement of aerodynamic forces and moments without support interference or model distortion. This technique can be applied to interference-free propulsion models. The vapor screen method of flow visualization at supersonic Mach numbers is discussed. The use of smoke instead of water vapor as a medium to produce the screen is outlined. Vapor screen data are being used in the development of analytical vortex tracking programs. Test results for a remote control model system are evaluated. Detailed control effectiveness and cross-coupling data were obtained with a single run. For the afterbody tail configuration, tested control boundaries at several roll orientations were established utilizing the facility's on-line capability to 'fly' the model in the wind tunnel.

*NASA, Langley Research Center, Hampton, Va.

139 *Regard, D.. **Essai en Soufflerie de Missile à Grande Incidence – Influence du Dispositif d'Essai en Subsonique 'Elevé.** (Wind Tunnel Testing of Missiles at High Angle of Attack – Influence of the Test Apparatus at Transonic Speeds.) Presented at the 2nd Israel Annual Conference on Aviation and Astronautics, Haifa, Israel, March 12 – 13, 1980, 9 pp. (In French). ONERA, TP No. 1980-16.

A80-28948#

Wind tunnel testing of high-performance missile models requires specific mounting devices making it possible to reach high angles of attack at transonic speeds; the presence of such supports may modify the flow around the model and alter measurements of normal force and pitching moment. An experimental study was performed in the ONERA S3MA wind tunnel on a model fitted with low-aspect-ratio wings and rear control surfaces at Mach numbers of 0.7 and 0.9 and angles of attack of 40 and 60 deg. The effects of the mounting devices are indicated, with particular emphasis on the rear sting.

*ONERA, Châtillon-sous-Bagneux, Hauts-de-Seine, France

140 *Corlett, William A.; *Shaw, David S.; and *Covell, Peter F.: **Development of a Metric Half-Span Model for Interference Free Testing.** Presented at the 11th AIAA Aerodynamics Testing Conference, Colorado Springs, Colo., March 18 – 20, 1980, 5 pp., AIAA Paper 80-0460.

A80-29950#

A metric half-span model has been developed which allows measurement of aerodynamic forces and moments without support interference or model distortion. This is accomplished by combining the best features of the conventional sting/balance and half-span splitter plate *supports. For example, forces and moments are measured on* one-half of a symmetrical model which is mechanically supported by a sting on the nonmetric half. Tests were performed in the Langley Unitary Plan wind tunnel over a Mach range of 1.60 to 2.70 and an angle-of-attack range of 04 deg to 20 deg. Preliminary results on concept evaluation, and effect of fuselage modification to house a conventional *balance and sting are presented.*

*NASA, Langley Research Center, Hampton, Virginia

141 *Tuttle, Marie H.; *Kilgore, Robert A.; and *Boyden, Richmond P.: **Magnetic Suspension and Balance Systems – A Selective, Annotated Bibliography.** Rep. No. NASA-TM-80225, Apr. 1980, 44 pp.

N80-22368

This bibliography, with abstracts, consists of 188 citations arranged in chronological order by dates of publication. Selection of the citations was made for their relevance to the problems involved in understanding, designing, and constructing magnetic suspension and balance systems for use in wind tunnels.

*NASA, Langley Research Center, Hampton, Va.

142 *Price, E. A., Jr.: **The Annular Jet Technique for Nozzle/Afterbody Throttle Dependent Drag Testing.** Presented at the AIAA, SAE, and ASME 16th Joint Propulsion Conference, Hartford, Conn., June 30 – July 2, 1980, 14 pp., AIAA Paper 80-1163.

A80-38945#

Results are reported from several tests conducted in the Arnold Engineering Development Center Propulsion Wind Tunnel (16T) to develop the annular jet technique for obtaining throttle dependent afterbody drag data. The first test utilized an axisymmetric model to parametrically investigate the effects of nozzle pressure ratio, sting-to-nozzle exit diameter ratio, and nozzle area ratio with the annular jet technique. Test results demonstrated that the annular jet technique is a viable method of obtaining afterbody drag and helped define the limits of its use. Tests have since been conducted on two aircraft configurations to determine the degree of correlation between full and annular jet afterbody drag data for single- and twin-jet configurations. Results were obtained for different nozzle configurations over the Mach number range from 0.6 to 1.5. When compared with test data using other support systems, a sting-supported model with annular jet simulation provides a minimum interference support system with reasonable jet simulation.

*ARO, Inc., Arnold Engineering Development Center, Arnold Air Force Station, Tenn.

143 *Uselton, B. L.; and *Cyran, Fred B.: **Sting Interference Effects as Determined by Measurements of Dynamic Stability Derivatives, Surface Pressure, and Base Pressure for Mach Numbers 2 Through 8.** Final Rept. May 25, 1977 – Mar. 2, 1978. AEDC-TR-79-89, Oct. 1980, 147 pp. (47 refs.) (Available from DTIC).

N81-13073#

Wind tunnel tests were conducted to provide support interference information for planning and directing wind tunnel tests at supersonic and hypersonic Mach numbers. Sting-length and sting-diameter effects on base and surface pressures of a blunt 6-deg cone with a sliced base were investigated at Mach numbers 2, 3, 5, and 8 in the Arnold Engineering Development Center (AEDC) von Karman Gas Dynamics Facility (VKF). Dynamic stability tests on a blunt 7-deg cone were also conducted at AEDC-VKF at Mach numbers 2, 5, and 8. The objectives of the 7-deg cone test were to define critical sting lengths as determined by the measurement of dynamic stability derivatives, static pitching moment, and base pressure. Two frequencies of oscillation were investigated, and data were obtained for laminar, transitional, and turbulent boundary-layer conditions at the model base. The data from the 6- and 7-deg cone tests showed that the critical sting length depended on the interference indicator, Mach number, angle of attack, state of the model boundary layer, and frequency of oscillation. The critical sting length was generally less for models with turbulent boundary layers than for those with laminar boundary layers. A critical sting length of 2.5 model diameters was determined to be suitable for all test conditions that produced a turbulent boundary layer at or ahead of the model base.

*ARO, Inc., Arnold Engineering Development Center/DOT, (AFSC) Arnold Air Force Station, Tenn.

AUTHOR INDEX

Adams, P. A. 88
Adcock, J. B. 77
Agnone, A. 59
Ahmed, S. 126
Allen, H. J. 50
Altstatt, M. C. 124, 125

Bacon, D. L. 1
Bailey, F. R. 94
Barna, P. S. 134
Baryshev, Y. V. 73
Baughman, L. E. 12
Berrier, B. L. 93
Binion, T. W. 135
Birtwell, E. P. 103, 107
Blackerby, W. T. 104
Blaha, B. J. 105
Bogdonoff, S. M. 6, 22
Boyden, R. P. 141
Brown, C. A., Jr. 85, 110
Buckner, J. K. 108
Burt, G. E. 109

Cahn, M. S. 27
Cahill, J. F. 80
Campbell, J. H., II 111, 113
Carmel, M. M. 85
Carter, E. C. 64, 74, 100
Cassanto, J. M. 75
Chapman, D. R. 5
Chrisinger, J. E. 56
Coffin, J. B. 56, 103
Coletti, D. E. 10
Compton, W. B., III 81, 120
Corlett, W. A. 138, 140
Covell, P. F. 140
Covert, E. E. 28, 56
Crane, J. F. W. 116
Cyran, F. B. 123, 143

Dayman, B., Jr. 52, 68, 86
Delery, J. 69

Dietz, W. E., Jr. 124, 125
Dix, R. E. 118
Donaldson, I. S. 18
Dubois, G. 43

Embury, W. R. 111, 113
Ericsson, L. E. 78, 79, 83, 89, 121, 129, 133, 137
Estabrooks, B. B. 19, 20, 21
Evans, J. Y. G. 90

Fanning, A. E. 130
Ferri, A. 2
Finnerty, C. S. 136
Fisher, S. S. 92
Fuller, D. E. 55

Garringer, D. J. 65
German, R. C. 119
Gilliam, G. 84
Gray, J. D. 45
Greenwood, G. H. 41

Haldeman, C. W. 103
Hamaker, F. M. 7
Hammond, D. G. 87
Harkins, W. D. 15
Hart, R. G. 9
Hartzuiker, J. P. 48
Hastings, R. C. 36
Hensel, R. W. 57
Howell, D. T. 110
Hozumi, K. 122
Huff, R. G. 26
Hughes, P. F. 63

Ivanova, V. M. 132
Iyengar, S. 97

Jack, J. R. 12
Jaffe, P. 114

Kavanau, L. L. 13, 16, 24
Kilgore, R. A. 141
Klann, J. L. 26

Kruse, R. L. 115
Kuhlthau, A. R. 92
Kurn, A. G. 66

LaBerge, J. G. 88, 97
Langhans, V. E. 55
Laurenceau, P. 29
Lee, E. E., Jr. 53
Lee, G. 30
Levy, L. L., Jr. 44
Love, E. S. 11, 14
Loving, D. L. 71
Lucas, E. J. 131
Luoma, A. A. 71

MacWilkinson, D. G. 104
Maiden, D. L. 93
Martellucci, A. 59
McDonald, H. 62, 63
Mercer, C. E. 101
Miller, C. G., III 61
Morozov, M. G. 73
Mouch, T. N. 127
Mugler, J. P., Jr. 8
Mundell, A. R. G. 116

Nelson, R. C. 127

O'Donnell, R. M. 11
Orlik-Rückemann, K. J. 88, 97, 131
Osborne, R. S. 4, 8

Page, R. H. 82
Parkin, W. J. 57
Paterson, J. H. 104
Patterson, R. T. 25
Peckham, D. H. 39
Perkins, E. W. 3
Pertsas, N. 84
Pick, G. S. 95
Price, E. A., Jr. 106, 136, 142
Prowse, R. E. 42

Re, R. J. 70
Rebuffet, P. 35

Reding, J. P. 78, 79, 83, 89, 121, 133
Reese, D. E., Jr. 37
Regard, D. 139
Reichenau, D. E. A. 99
Reid, J. 36, 116
Rejeske, J. V. 112
Reller, J. O., Jr. 7
Reubush, D. E. 101
Rogers, E. W. E. 32
Rouge, C. 43
Runckel, J. F. 53, 70, 81

Saltzman, E. J. 65
Sammonds, R. I. 115
Savitsky, D. 42
Schueler, C. J. 23, 38
Secomb, D. A. 40
Shaw, D. S. 140
Sieling, W. R. 76, 82
Siemers, P. M. 98
Simonson, A. J. 53
Sirieix, M. 69
Sivier, K. R. 22
Squire, L. C. 51
Sreenath, G. S. 126
Stanbrook, A. 40
Stanewsky, E. 80
Starr, R. F. 117
Stava, D. 112
Steers, L. I. 130
Steinberg, S. 98
Stephens, T. 84
Stivers, L. S., Jr. 44, 60
Strike, W. T. 23
Sukhnev, V. A. 72
Summers, J. L. 30
Swamy, M. S. 126
Sykes, D. M. 102

Tagirov, R. K. 132
Taylor, C. R. 90
Tilton, E. L., III 56
Tournier, M. 29
Trescott, C. D., Jr. 110

Trucco, H. 59
Tunnell, P. J. 17
Turner, K. J. 46
Tuttle, M. H. 141

Uselton, B. L. 58, 96, 98, 123, 128, 143
Uselton, J. C. 109

Valk, H. 47, 49
Van der Zwaan, J. H. 47
Varner, M. O. 117
Vlajinac, M. 84, 91, 103

Wallace, A. R. 96
Webb, J. B. 108
Wehrend, W. R., Jr. 37, 54
Whitfield, J. D. 31, 33
Wiley, H. G. 67
Wilkerson, C., Jr. 87
Wilmoth, R. G. 70

Zapata, R. N. 43, 92
Zonars, D. 34

1. Report No. NASA TM-81909	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SUPPORT INTERFERENCE OF WIND TUNNEL MODELS – A SELECTIVE ANNOTATED BIBLIOGRAPHY		5. Report Date March 1981
		6. Performing Organization Code 505-31-53-01
7. Author(s) Marie H. Tuttle and Blair B. Gloss		8. Performing Organization Report No. L-14198
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This bibliography, with abstracts, consists of 143 citations arranged in chronological order by dates of publication. Selection of the citations was made for their relevance to the problems involved in understanding or avoiding support interference in wind tunnel testing throughout the Mach number range. An author index is included.

17. Key Words (Suggested by Author(s)) Support interference, Sting interference, Wind tunnel testing, Wind tunnel models	18. Distribution Statement Unclassified – Unlimited. Subject Category 09

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	33	A03

For sale by the National Technical Information Service, Springfield, Virginia 22161