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A BIBLIOGRAPHY OF REPORTS ON LOW-ASPECT-RATIO LIFTING SURFACES AND ELONGATED BODIES IN SUBSONIC FLOW

by

J.L. Johnson

CLASSIFICATION CHANGED TO
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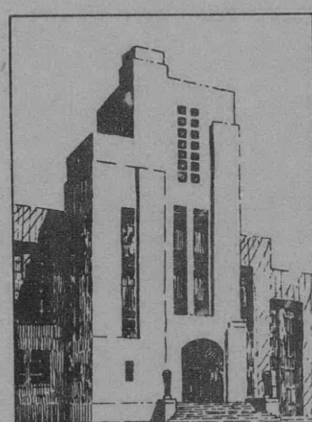

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November 1952

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Report C-523

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TABLE OF ABBREVIATIONS

AEW	Admiralty Experiment Works (Great Britain)
ARC R & M	Aeronautical Research Committee (Great Britain) Reports and Memoranda
ARL	Admiralty Researrh Laboratory (Great Britain) Teddington
AMC	Air Materiel Command, see ASTIA, below.
ASME Trans.	Transactions of the American Society of Mechanical Engineers
ASTIA	Armed Services Technical Information Agency (formerly Central Air Documents Office), Dayton Ohio
AVA	Aerodynamische Versuchsanstalt, Göttingen
Ber. Lilienthal Ges. LFF	Bericht der Lilienthal Gesellschaft für Luftfahrtforschung
CADO	Central Air Documents Office (now Armed Services Technical Information Agency)
Cen. Aero. Hydro. Inst.	Central Aero-Hydrodynamical Institute, Moscow
Ergeb. d. AVA, Göttingen	Ergebnisse des Aerodynamischen Versuchsanstalt zu Göttingen
EES	Engineering Experiment Station (U.S. Navy).
FB	Forschungsbericht
FFA MED	Flygtekniska Försöksanstalten Meddelande, Stockholm
Forsch. Ing. Wes.	Forschung auf dem Gebiete des Ingenieurwesens
GALCIT	Guggenheim Aeronautical Laboratory, California Institute of Technology
GTD	German Torpedo Documents
IAS	Institute of the Aeronautical Sciences
Ing. Archiv.	Ingenieur Archiv
J. Aero. Sci.	Journal of the Aeronautical Sciences
J. Appl. Phys.	Journal of Applied Physics
Jahrb. d.D.L.	Jahrbuch der Deutschen Luftfahrtforschung
K. Tekn. Högsk.	Kungliga Tekniska Högskolan, Stockholm
LFF	Luftfahrtforschung
MAP	Ministry of Aircraft Production, Great Britain (now known as the Ministry of Supply)
MOS	Ministry of Supply (Great Britain)
MOS ARE	MOS Armament Research Establishment (Great Britain)
NACA	National Advisory Committee for Aeronautics
NACA ACR	NACA Advance Confidential Report
NACA ARR	NACA Advance Restricted Report
NACA CB	NACA Confidential Bulletin
NACA RM	NACA Research Memorandum
NACA TM	NACA Technical Memorandum

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NACA TN	NACA Technical Note
NACA TR	NACA Technical Report
NACA WR	NACA Wartime Report
NOL	Naval Ordnance Laboratory
Publ. Sci. Tech.	Publications Scientifiques et Techniques du Ministère de L'Air, Paris
Proc. Int. Cong. Appl. Math.	Proceedings of International Congress of Applied Mathematics
Proc. Nat. Acad. Sci.	Proceedings of the National Academy of Sciences
Quart. Appl. Math.	Quarterly of Applied Mathematics, Brown University
Quart. J. Mech. Appl. Math.	Quarterly Journal of Mechanics and Applied Mathematics, Oxford University Press
Rech. Aéro.	La Recherche Aéronautique de l'Office National d'Études et de Recherches Aéronautiques, Paris
RAE	Royal Aircraft Establishment (Great Britain)
RAE TN	RAE Technical Note
Schiffbau	Schiffbau, Schiffahrt, un Hafenbau, Zeitschrift für die gesamte Industrie auf Schiffbautechnischen und verwandten Gebieten, Berlin
SIT ETT	Stevens Institute of Technology Experimental Towing Tank
SNAME Trans.	Transactions of the Society of Naval Architects and Marine Engineers
TIB	Technical Information Bureau, Ministry of Supply (Great Britain)
TMB	David Taylor Model Basin (U.S. Navy)
Uchen. Zapiski Moskov. Gos. Univ. Mech.	Ucheni Zapiski Moskovski Universiti Mechanika
UWDA	Underwater Weapons Department (Admiralty)
VDI	Zeitschrift des Vereines Deutscher Ingenieure, Düsseldorf
ZAMM	Zeitschrift für angewandte Mathematik und Mechanik
ZFM	Zeitschrift für Flugtechnik und Motorluftschiffahrt
ZWB	Zentrale für wissenschaftliches Berichtswesen der Luftfahrtforschung des Generalluftzeugmeisters, Berlin Adlershof

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ABSTRACT

This report presents a survey of the literature dealing with subsonic low-aspect-ratio phenomena, with emphasis on subjects of importance in the design of submarines and undersea weapons.

INTRODUCTION

The information contained herein was accumulated in the course of a survey of the literature pertaining to such low-aspect-ratio phenomena as are of importance in the design of submarines and undersea weapons, with particular reference to problems arising in the design of stabilizing and control surfaces. Consequently, most emphasis has been placed on incompressible- and low-subsonic-flow phenomena, although, owing to the importance of wind-tunnel testing, and also because of the close relationship between critical Mach number in compressible flow and the critical cavitation index, some attention has been given to compressibility phenomena.

This bibliography represents an attempt to present, as completely as possible, an index to available literature on the field of investigation. The presentation in each category is mostly chronological. No attempt at evaluation has been made--such a task would far transcend the time and funds available for the completion of this project. Abstracts have been included for a considerable number of the reports; however the reader is cautioned that neither the length of abstract nor its absence necessarily reflects the importance of any reference cited.

In accordance with ideas presented by R.P. Harrington and other more recent investigators, deep elongated three-dimensional bodies, not necessarily of circular cross section, are considered to be a form of low-aspect-ratio airfoil whose flow phenomena may be complicated by the absence of a sharp trailing edge. Consequently, all available references dealing with surfaces for which the geometrical aspect ratio, defined as the square of the extreme span divided by the planform area is equal to or less than four, regardless of sweep and thickness, have been considered to be of interest and have been included.

Unfortunately, owing to time limitations it has not been possible to give a complete presentation of references under all headings. It is believed that Section AAb, WINGS AND TAIL SURFACES, LOADING, THEORETICAL is reasonably complete; other sections are less so. Time permitting, these will be augmented in a subsequent revision of this bibliography.

SOURCES OF ABSTRACTS

Most of the abstracts are based on the author's summary, shortened or otherwise slightly modified in some cases in order better to serve the purposes of this bibliography. A few abstracts were prepared in total by the compiler;* the remainder are quoted, with possible minor modifications, from the sources indicated below. The compiler regrets that owing to the more informal original conception of this

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*See ACKNOWLEDGMENTS.

bibliography, the customary individual credits for source of abstract have not been given. The publications listed below were freely drawn upon in preparing the abstracts contained herein:

Aeronautical Engineering Review
Applied Mechanics Reviews
ASTIA (CADO) Technical Data Digest
Mathematical Reviews
NACA Index Cards

METHOD OF PRESENTATION

The bibliography is divided into seven major headings:

A. Wings and Tail Surfaces
B. Bodies
C. Components in Combination
D. Stability and Control
E. Unsteady Flow
F. Surface Effects
G. Cavitation

These in turn are subdivided into secondary headings:

A. Wings and Tail Surfaces
  AA. Loading
  AB. Flow Field, Wake, Downwash
  AC. Boundary Layer

and so forth; the subsequent headings of which will be evident from the outline which appears below. In the case of the major heading: "A. Wings and Tail Surfaces," there is also a system of tertiary headings indicated by lower case letters:

A. Wings and Tail Surfaces
  AA. Loading
    AAa. Experimental
    AAb. Theoretical

and so forth.

The author, title, source, date and, where available, the abstract of each report are given in full only once in the bibliography, under the subheading to which the report appears most applicable. Under each subheading the listing is approximately chronological in order to facilitate the insertion of pages dealing with future reports. The reports are given serial numbers, denoting the subject classification and chronological order under that classification, e.g., ADb3, Zimmermann, C.H., Characteristics of Clark Y Airfoils of Small Aspect Ratio, NACA TR 431, 1932. Cross indexing is provided by listing, on the last page of each subheading, a tabulation of the serial numbers of applicable reports under other subheadings.

OUTLINE OF BIBLIOGRAPHY

A. Wings and Tail Surfaces
  AA. Loading
    AAa. Experimental
    AAb. Theoretical

[redacted]

- AB. Flow Field, Wake, Downwash
- AC. Boundary Layer
- AD. Geometric Variables
  - ADa. Airfoil Section
  - ADb. Aspect Ratio
  - ADc. Dihedral
  - ADd. Sweep
  - ADe. Taper
  - ADf. Tip
  - ADg. Twist
  - ADh. End Plates
- AE. High-Lift Devices
  - AEa. Flaps
  - AEb. Slots and Slats
- AF. Controls
  - AFa. Flap Type
  - AFb. Spoilers
- AG. Reynolds Number Effects
- AH. Mach Number Effects

B. Bodies
- BA. Total Forces and Moments
- BB. Load Distribution
- BC. Flow Field
- BD. Boundary Layer
- BE. Effect of Shape
- BF. Reynolds Number Effects
- BG. Mach Number Effects

C. Components in Combination
- CA. Wing-Wing
- CB. Wing-Body
- CC. Wing-Body-Tail
- CD. Tail-Body

D. Stability and Control
- DA. Longitudinal
- DB. Lateral
- DC. Directional

E. Unsteady Flow Phenomena

F. Surface Effects
- FA. Free Boundary
- FB. Rigid Boundary

G. Cavitation

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ACKNOWLEDGMENTS

The compiler gratefully acknowledges the assistance given by Mr. S.M. Gay in the organization and the initial phases of the compilation of this bibliography, by Mr. I. Pollin who contributed forty-five references to recent research that served as a convenient starting point for subsequent investigation, by Mr. Paul Golovato who contributed several references to the section on free-surface phenomena, and by Mr. H. Weiner who contributed to the section on components in combination. He is also indebted to Mrs. Marjorie H. Padgett for her very careful attention to the tedious task of cross indexing the entries.

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A. WINGS AND TAIL SURFACES

A1 Gorski, V.P., AERODYNAMIC INVESTIGATIONS OF TAIL SURFACES WITH BALANCED AND UNBALANCED ELEVATORS, Rept. 49, Cen. Aero Hydro. Inst. 1930, pp. 49-90.

A2 von Kármán, Th. and Burgers, J.M., GENERAL AERODYNAMIC THEORY - PERFECT FLUIDS. AIRFOILS AND AIRFOIL SYSTEMS OF FINITE SPAN, Vol. 2 of Aerodynamic Theory, Div. E., Ch. IV, Sec. 13-14, W.F. Durand, ed., Julius Springer (Berlin), 1935, pp. 192-195.

A3 Hoerner, S., FORCES AND MOMENTS ON YAWED AIRFOILS (Kräfte und Momente schrägangeströmter tragflügel), LFF Bd. 16, Nr. 4, April 20, 1939, pp. 178-183.

A4 Root, L.E., EMPENNAGE DESIGN WITH SINGLE AND MULTIPLE VERTICAL SURFACES, J. Aero. Sci., Vol. 6, No. 9, July 1939.

A5 Silverstein, Abe, TOWARD A RATIONAL METHOD OF TAIL PLANE DESIGN, J. Aero. Sci., Vol. 6, No. 9, July 1939, pp. 361-369.

A6 Silverstein, Abe and Katzoff, S., AERODYNAMIC CHARACTERISTICS OF HORIZONTAL TAIL SURFACES, NACA TR 688, 1940.

Collected data are presented on the aerodynamic characteristics of 17 horizontal tail surfaces including several with balanced elevators and two with end plates. Curves are given for coefficients of normal force, drag, and elevator hinge moment. A limited analysis of the results has been made. The normal-force coefficients are in better agreement with the lifting-surface theory of Prandtl and Blenk for airfoils of low-aspect ratio than with simple lifting line theory. Only partial agreement exists between the elevator hinge-moment coefficients and those predicted by Glauert's thin airfoil theory.

A7 Anderson, A.E., AN INVESTIGATION AT LOW SPEED OF A LARGE SCALE TRIANGULAR WING OF ASPECT-RATIO 2. I - CHARACTERISTICS OF A WING HAVING A DOUBLE-WEDGE AIRFOIL SECTION WITH MAXIMUM THICKNESS AT 20 PERCENT CHORD, NACA RM A7F06, 1946.

An investigation was made of the low-speed characteristics of a 25-ft span triangular wing having an aspect ratio of 2. Force and moment data were obtained at several angles of sideslip for various flap configurations. Lift and drag data were obtained from the plain wing through a limited angle of attack range for Reynolds numbers from 13×10^6 to 34×10^6.

A8 Anderson, A.E., AN INVESTIGATION AT LOW SPEED OF A LARGE-SCALE TRIANGULAR WING OF ASPECT RATIO 2, II - THE EFFECT OF AIRFOIL SECTION MODIFICATIONS AND THE DETERMINATION OF THE WAKE DOWNWASH, NACA RM A7H28, Dec. 1947.

The report presents force and moment data obtained throughout the angle-of-attack range for a triangular wing having a symmetrical double-wedge airfoil section and various degrees of rounding of wing leading edge and maximum thickness. The dynamic pressure and downwash angles in the wake are also presented.

A9 Bates, W.R., COLLECTION AND ANALYSIS OF WIND TUNNEL DATA ON THE CHARACTERISTICS OF ISOLATED TAIL SURFACES WITH AND WITHOUT END PLATES, NACA TN 1291, 1947.

[redacted]

A10 Whittle, E.F. and Lovell, J.C., FULL-SCALE INVESTIGATION OF AN EQUILATERAL TRIANGULAR WING HAVING 10 PERCENT THICK BICONVEX AIRFOIL SECTIONS, NACA RM L8G05, 1948.

A11 Bandettini, A. and Reed, V.D., THE AERODYNAMIC CHARACTERISTICS THROUGHOUT THE SUBSONIC SPEED RANGE OF A THIN, SHARP-EDGED HORIZONTAL TAIL OF ASPECT RATIO 4, EQUIPPED WITH A CONSTANT-CHORD ELEVATOR, NACA RM A9E05, June 30, 1949.

A12 Anderson, A.E., AN INVESTIGATION AT LOW SPEED OF A LARGE-SCALE TRIANGULAR WING OF ASPECT RATIO TWO. III - CHARACTERISTICS OF WING WITH BODY AND VERTICAL TAIL, NACA RM A9H04, Oct. 1949, RESTRICTED.

Investigation was undertaken to determine the aerodynamic characteristics in sideslip of a triangular wing of aspect ratio 2.04 in combination with a body of fineness 12.5 and a vertical tail surface. Force and moment data were obtained at several angles of sideslip for various configurations of constant-chord split flaps, semispan split flap type ailerons, and a constant-chord rudder. The Reynolds number was 15.4×10^6 and the Mach number 0.13.

A13 Berndt, S.B., WIND TUNNEL INTERFERENCE DUE TO LIFT FOR DELTA WINGS OF SMALL AR, K. Tekn. Högsk. TN 19, NA Stockholm Ser. 81-51, 25 Sept. 1950, 18 pp.

A14 Harper, J.J., WIND-TUNNEL INVESTIGATION OF EFFECTS OF VARIOUS AERODYNAMIC BALANCE SHAPES AND SWEEPBACK ON CONTROL-SURFACE CHARACTERISTICS OF SEMISPAN TAIL SURFACES WITH NACA 0009, 0015, 66-009, 66(215)-014 AND CIRCULAR-ARC AIRFOIL SECTIONS, NACA TN 2495, Oct. 1951, 127 pp., 22 Refs.

See also AAb12, AB1, AD15, BA1, BA7, DA16, DA17, and DB6.

 [redacted]

AA. WINGS AND TAIL SURFACES, LOADING

See AB1, AB4, AB8, AB13, AC3, AD2, AD3, AD4, AD19, ADb8, ADb20, ADb30, AF6,AB10, and CB12 for miscellaneous topics under this heading.

[redacted]

AAa. WINGS AND TAIL SURFACES, LOADING, EXPERIMENTAL

AAa1 Hansen, M., MEASUREMENTS ON CIRCULAR LIFTING SURFACES AND COMPARISON WITH LIFTING SURFACE THEORY, (Messungen an Kreistragflachen und Vergleich mit der Theorie der Tragenden Flache), ZFM, Bd. 18, 1938, p. 368; also in Ing. Archiv, Bd. 10, 1939.

The results of tests made on a series of plane and cambered lifting surfaces of circular plan form are presented and a comparison is made with Kinner's potential-flow lifting surface theory, Reference AAb3.

AAa2 Swanson, R.S , Crandall, S.M. and Miller, S., A LIFTING-SURFACE-THEORY SOLUTION AND TESTS OF AN ELLIPTIC TAIL SECTION OF ASPECT-RATIO 3 WITH A 0.5-CHORD, 0.85-SPAN ELEVATOR, NACA TN 1275, May 1947.

An electromagnetic-analogy model of the vortex load, estimated from lifting line theory with an arbitrary fairing near the elevator tip, on a thin elliptic horizontal tail surface of aspect ratio 3 with a 0.5-chord, 0.85-span plain elevator was constructed and tested. The aspect-ratio corrections to lift and hinge moment were calculated from measured results. A comparison of aspect-ratio corrections for partial-span elevators made with those previously presented indicates that incremental differences in lift parameters between full-span and partial-span elevators may be estimated satisfactorily by lifting line theory.

AAa3 Wick, B.H., CHORDWISE AND SPANWISE LOADINGS MEASURED AT LOW SPEED ON A TRIANGULAR WING HAVING AN ASPECT RATIO OF TWO AND AN NACA 0012 AIRFOIL SECTION, NACA TN 1650, June 1948.

Pressure measurements made on a triangular wing of aspect ratio 2 and an NACA 0012 airfoil section parallel to the centerline. The wing angle of attack was varied from 4.3 to 48.1 deg. with airspeed held constant at approximately 100 mph (Mach No. 0.13 and Reynolds No. 2.4 x 10^6, based on M.A.C.). Chordwise pressure distributions are presented for wing sections at 0, 14.6, 39.6, 60.4, and 79.7 percent semispan. Also given are span load distribution values of normal force coefficient, lift coefficient, and center of pressure, obtained by mechanical integration of the chordwise pressure distributions.

AAa4 Orlick-Rückemann, K., EXPERIMENTAL DETERMINATION OF PRESSURE DISTRIBUTION AND TRANSITION LINES OF PLANE DELTA WINGS AT LOW SPEEDS AND ZERO YAW, K. Tekn. Högsk. Aero TN3, 1948.

Pressure measurements were made on two plane delta wings of symmetrical profile at zero angle of yaw, one triangular with aspect ratio 2.50 and the other trapesoidal with aspect ratio 1.34 and taper ratio 0.303. Test results are given in the form of perspective sketches of a semi-wing with curves of pressure distribution in the chordwise direction at all measured sections and similar sketches showing curves of the resultant pressure distribution in the spanwise direction. There are also isobar charts, curves of local normal force coefficients for chordwise sections and the local center of pressure position as function of span, some curves of the local normal force coefficient and local load coefficient for spanwise cross sections as function of relative distance of section from trailing edge, and curves of local and total normal force coefficient as function of angle of attack. The investigation also includes study of location of transition for various angles of attack and Reynolds numbers.

AAa5 Weber, J., LOW SPEED MEASUREMENTS OF THE PRESSURE DISTRIBUTION NEAR THE TIPS OF SWEPT BACK WINGS AT NO LIFT, RAE Report Aero 2318, March 1949, RESTRICTED.

Pressure distribution measurements were obtained at zero lift near the tip of two swept-back wings of different profile with square tips. The expression obtained for the pressure coefficient implies forward movement of isobars at tip. Methods of correcting this effect were explored. The effect of rounding

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the tip was small. Tests made on wings having an aspect ratio of 2 and 53 deg. sweepback showed that at no lift the disturbances due to the center section and tip were just separated. A wing of aspect ratio 1 was tested, and in this case the distributions of pressure at the tip and center were almost identical, but the isobars never became parallel to the leading edge.

AAa6 Wegener, P.P., SUB- AND SUPERSONIC WIND-TUNNEL TESTS ON RECTANGULAR AIRFOILS OF SMALL ASPECT RATIO, FU7175, NOL Memo No. NOLM 9928, Apr. 15, 1949, 10 pp.

Experimental data are given on some basic airfoils of small aspect ratio for possible use as wings and control surfaces on guided missiles. Center of pressure location and normal force coefficient were determined as functions of angle of attack in the range Mach 0.4 to 3.0. All six airfoils had an equal aspect ratio of "one-third" but showed different profiles. Measurement technique and evaluation are described. Final results are given on a number of plates.

AAa7 Anderson, A.E., CHORDWISE AND SPANWISE LOADINGS MEASURED AT LOW SPEED ON LARGE TRIANGULAR WINGS, NACA RM A9B17, April 1949, RESTRICTED.

Pressure distributions were obtained for 3 triangular wing models; a wing alone model with aspect ratio 2.04 and a modified double-wedge airfoil section; the same wing combined with a body of fineness 12.5; and a mock-up of a triangular wing airplane which had an aspect ratio of 2.31 and an NACA 65-006.5 section. Pressure data were obtained through an angle-of-attack range at zero sideslip. Chordwise pressure distribution, section lift characteristics, section center of pressure, and span load distribution are presented.

AAa8 Lange, R.H., Whittle, E.F., and Fink, M.P., INVESTIGATION AT LARGE SCALE OF THE PRESSURE DISTRIBUTION AND FLOW PHENOMENA OVER A WING WITH THE LEADING EDGE SWEPT BACK 47.5 DEG. HAVING CIRCULAR-ARC AIRFOIL SECTIONS AND EQUIPPED WITH DROOPED-NOSE AND PLAIN FLAPS, NACA RM L9G15, Sept. 8, 1949.

AAa9 Weber, J., LOW SPEED MEASUREMENTS OF THE PRESSURE DISTRIBUTION AND OVERALL FORCES ON WINGS OF SMALL ASPECT RATIO AND 53 DEG. SWEEPBACK, RAE Tech. Note Aero. 2017, Sept. 1949, RESTRICTED.

AAa10 May, R.W., Jr., and Haines, J.G., LOW-SPEED PRESSURE DISTRIBUTION AND FLOW INVESTIGATION FOR A LARGE PITCH AND YAW RANGE OF THREE LOW-ASPECT-RATIO POINTED WINGS HAVING LEADING EDGE SWEPT BACK 60 DEG. AND BICONVEX SECTIONS, NACA RM L9J07, Nov. 18, 1949, RESTRICTED.

An investigation of pressure and flow fields was undertaken for three small-scale low-aspect-ratio pointed wings with 10 percent thick biconvex sections, 60 deg. sweptback leading edge and 0, 30, and -30 deg. sweptback trailing edge, through a yaw range of 0 to 35 deg. and angle-of-attack range through stall. Also given are section lift coefficients and center of pressure at zero yaw and wing spanwise load distribution and force and moment coefficients throughout yaw range. A correlation is established between the pressure distribution and the vortex flow characteristics.

AAa11 Berndt, S.B. and Orlik-Rückemann, K., COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL LIFT DISTRIBUTIONS OF PLANE DELTA WINGS AT LOW SPEEDS AND ZERO YAW, K. Techn. Högsk. Aero TN 10, 1949.

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AAa12 Scholz, N., FORCE AND PRESSURE DISTRIBUTION MEASUREMENTS ON AIRFOILS OF SMALL ASPECT RATIO (Kraft-und Druckverteilungsmessungen an Tragflachen kleiner Streckung) Forsch. Ing.Wes., Part B, Vol. 16, No. 3, 1949-1950, pp. 85-91.

AAa13 Graham, D., CHORDWISE AND SPANWISE LOADINGS MEASURED AT LOW-SPEED ON A LARGE TRIANGULAR WING HAVING AN ASPECT-RATIO OF 2 AND A THIN SUBSONIC TYPE AIRFOIL SECTION, NACA RM A50A04a, Mar. 1950, 55 pp. RESTRICTED.

Pressure distribution and force data were measured at various angles of attack of a triangular wing of aspect ratio 2 and having an NACA 0005 Modified Section with a plain constant-chord trailing edge flap which was deflected 0 and ±10 deg. The tests were performed at a Reynolds number of 15.3×10^6 and a Mach number of 0.13.

AAa14 Weiberg, J.A. and Carel, H.C., WIND-TUNNEL INVESTIGATION AT LOW SPEED OF A WING SWEPT BACK 63 DEG. AND TWISTED AND CAMBERED FOR A UNIFORM LOAD AT A LIFT COEFFICIENT OF 0.5, NACA RM A50 A23, May 9, 1950, 53 pp. CONFIDENTIAL

Tests were conducted to determine the low-speed longitudinal stability characteristics and spanwise distribution of load of a semispan wing model having the leading edge swept back 63 deg. and an aspect ratio of 3.5, with a large amount of twist and camber. Tests were also made of the wing with a fuselage, with upper-surface fences and with leading-edge and trailing-edge flaps. Comparison is made with results of tests of an untwisted and uncambered wing. Within the angle of attack range in which the lift is not appreciably affected by spanwise boundary-layer flow and separation, good agreement was obtained between measured spanwise load and that computed by method of Weissinger.

AAa15 Raney, D.J., LOW-SPEED WIND-TUNNEL INVESTIGATION OF THE PRESSURE DISTRIBUTION OVER A DELTA WING OF ASPECT RATIO 3.0 AT SMALL INCIDENCES, RAE Tech. Note Aero 2062, July 1950.

Measurements are presented of pressure distribution over a delta wing having 48 deg. leading-edge sweepback and aspect ratio 3.0 at low speed. Chordwise and spanwise lift distribution and center of pressure position are obtained from pressure measurements and isobar patterns are plotted. The spanwise lift distribution and local lift slope is in good agreement with the theoretical method of Falkner.

AAa16 Holme, A.M., MEASUREMENTS OF PRESSURE DISTRIBUTION ON RECTANGULAR WINGS OF DIFFERENT ASPECT RATIOS, FFA MED 37, Aeronautical Research Committee of Sweden, 1950.

Pressure distribution measurements on wings of aspect ratio from 0.52 to 4.50.

AAa17 Taylor, A.S., AN ANALYSIS OF AVAILABLE DATA ON THE LOCAL AERODYNAMIC CENTERS OF AIRFOILS IN TWO- AND THREE-DIMENSIONAL FLOW, RAE Report Aero 2407, Jan. 1951, CONFIDENTIAL.

AAa18 Babister, A.W., MEASUREMENT OF THE PRESSURE DISTRIBUTION ON SWEPTBACK WINGS WITH TRAILING EDGE SPLIT FLAPS, The College of Aeronautics, Cranfield, Report 43, March 1951.

This is an interim report giving measurements made thus far of the pressure distribution on two tapered wings swept back 45 deg. with aspect ratios 2 and 4, fitted with both full-span and part-span trailing edge split flaps. The Reynolds number of the tests was about 0.5×10^6.

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AAa19 Malavard, L. and Duquenne, R., STUDY OF LIFTING SURFACES BY RHEO-ELECTRIC ANALOGIES (In French), Rech. Aéro., No. 23, Sept.-Oct. 1951, pp. 3-12.

AAa20 Lipson, S. and Barnett, U.R., COMPARISON OF SEMISPAN AND FULL-SPAN TESTS OF A 47.5 DEG. SWEPT BACK WING WITH SYMMETRICAL CIRCULAR-ARC SECTIONS AND HAVING DROOPED-NOSE FLAPS, TRAILING-EDGE FLAPS AND AILERONS, NACA RM L51H15, Dec. 5, 1951, RESTRICTED.

An investigation is reported in which wing surface pressure measurements and force data were obtained from comparative full-span and semi-span tests of a wing having 47.5 deg. sweepback at the leading edge and an aspect ratio of 3.5. The results indicate a close agreement between full-span and semi-span tests. Slight differences in $C_{L_{max}}$ and pitching moment are attributed to the boundary layer of the ground plane.

See also A13, AAa19, AAb22, AAb24, AAb36, AAb49, AB17, ADb34, ADd5, and DA11.

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AAb. WINGS AND TAIL SURFACES, LOADING, THEORETICAL

AAb1 Blenk, H., THE MONOPLANE AS A LIFTING VORTEX SURFACE, NACA TM 1111, Feb. 1947 (Translation of Article in ZFM, Bd. 5, Nr. 1, Feb. 1925).

In Prandtl's airfoil theory the monoplane was replaced by a single lifting vortex line. This yielded practical results; however in its original form, these results were restricted to straight wings. The present report develops a method extending Birnbaum's two-dimensional lifting surface theory to the three-dimensional case, permitting the computation of yawed as well as straight wings of finite span. Substantial agreement with experiment is shown at small angles for aspect ratios 1 and 2.

AAb2 Kinner, W., CONCERNING AIRFOILS WITH CIRCULAR PLANFORM (Uber Tragflügel mit kreisförmigem Umrise) ZAMM Bd. 16,1936, p. 349.

AAb3 Kinner, W., THE CIRCULAR LIFTING SURFACE BASED ON POTENTIAL THEORY (Die kreisförmige Tragfläche auf potential theoretischer Grundlage) Ing. Archiv, Bd. 8, 1937, p. 47.

AAb4 Mangler, W., THE LIFT DISTRIBUTION OF WINGS WITH END PLATES, NACA TM 856, 1938 (Translation of Article in LFF, Bd. 14, 1937), p. 504.

This report describes the lift distribution on wings with end plates for the case of minimum induced drag (induced downwash constant over the span). The moments on the end plates are also determined.

AAb5 Prandtl, L., RECENT WORK ON AIRFOIL THEORY, NACA TM 962, 1940 (Translation of Article in Proc. of 5th Int. Cong. Appl. Mech., 1938).

Basis ideas of a new (1938) approach to treating the lifting surface problem are presented and a review is given of the problems thus far computed for incompressible and supersonic flows. As a supplement, a theory based on the older methods is presented for the rectangular wing of small aspect ratio.

AAb6 Weissinger, J., THE YAWED WING IN STRAIGHT FLOW (Der schiebende Tragflügel bei gesunder Strömung), Ber. S2 d. Lilienthal Ges. LFF, 1938-39, pp. 13-51.

AAb7 Sherman, A., A SIMPLE METHOD OF OBTAINING SPAN LOAD DISTRIBUTIONS, NACA TN 732, Oct. 1939.

A method of successive approximations involving superposition of component loads is presented. The author does not state aspect ratio limits for the application of method.

AAb8 Krienes, K., THE ELLIPTIC WING BASED ON THE POTENTIAL THEORY, NACA TM 971, March 1941 (Translation of Article in ZAMM, Bd. 20, Nr. 2, April 1940).

An approximation is given based on the linearized theory of the acceleration potential and yielding the lift and downwash of an elliptical wing.

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AAb9 Schrenk, O., A SIMPLE APPROXIMATION METHOD FOR OBTAINING THE SPANWISE LIFT DISTRIBUTION, NACA TM 948, August 1940 (Translation of Article in Luftwissen, Bd. 7, Nr. 4, April 1940.).

A simple approximation method, good for aspect ratios as low as 3, for rapidly computing the lift distributions of arbitrary airfoils. The numerical results are compared with those obtained by an exact method and for many purposes show a satisfactory degree of accuracy.

AAb10 Ginzel, I., THE LIFT DISTRIBUTION OF A DEEP TWISTED RECTANGULAR WING (Die auftriebsverteilung eines tiefen verwundenen Rechteckflügels) Jahrb. d.D.L., 1950, p. I 238.

This report considers the lift distribution of twisted rectangular wings of large chord and also of wings having a fluctuating or discontinuous distribution of angle of incidence.

AAb11 Wieghardt, K., CHORDWISE LOAD DISTRIBUTION OF A SIMPLE RECTANGULAR WING, NACA TM 963, 1940.

AAb12 Katzoff, S., and Mutterperl, W., THE END-PLATE EFFECT OF A HORIZONTAL TAIL SURFACE ON A VERTICAL TAIL SURFACE, NACA TN 797, February 1941.

The end-plate effect of a horizontal tail surface on the vertical tail surface was studied theoretically by derivation of the flow corresponding to the condition of minimum induced drag and by solution of the lifting-line equation. The results obtained by the two methods were considerably different. The derived span-load distributions are given, together with equations and curves for total lift forces and moments of horizontal and vertical tail surfaces about their intersection. The results obtained indicate a considerable increase in the effectiveness of the vertical tail, for instance, the effective aspect ratio in terms of the elliptical airfoil is about 1.5 times the geometric aspect ratio for a tail group in which the span of the horizontal tail is twice the span of the vertical tail.

AAb13 Mutterperl, W., THE CALCULATION OF SPAN LOAD DISTRIBUTION ON SWEPTBACK WINGS, NACA TN 834, Dec. 1941.

A method is described for computing the span-load distribution of sweptback wings. The method used is to replace the wing with a bound vortex at the quarter-chord line and to calculate the downwash due to the system of bound and trailing vortices to conform at the 3/4-chord line to the slope of the flat-plate wing surface. Results are given for constant-chord and 5:1 tapered plan forms, for sweep angles of 0, 30, and 45 deg. and for aspect ratios of 3, 6, and 9. Some comments on the stalling of sweptback wings are included.

AAb14 Cohen, D., A METHOD FOR DETERMINING THE CAMBER AND TWIST OF A SURFACE TO SUPPORT A GIVEN DISTRIBUTION OF LIFT, NACA TN 855, Aug. 1942.

A graphical method is presented for finding the shape (camber and twist) of an airfoil having an arbitrary distribution of lift. The method consists in replacing the lifting surface and its wake with an equivalent arrangement of vortices and in finding the associated vertical velocity. By division of the vortex pattern into circular strips concentric about the downwash point instead of into usual rectangular strips, the lifting surface is reduced for each downwash point to an equivalent loaded line for which the induced velocity is readily computed. The ratio of the vertical velocity to the stream velocity is the slope of the surface in the free-stream direction. The shape of the wing is found for two wings; a straight elliptical wing and one with 30 deg. sweepback.

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AAb15 Weissinger, J., THE LIFT DISTRIBUTION OF SWEPT-BACK WINGS, NACA TM 1120, March 1947 (Trans. of ZWB Forsch. 1553 den 27.2, 1942).

Two procedures for calculating the lift distribution along the span are given in which better account is taken of the circulation over the area than in the Prandtl lifting-line theory.

AAb16 Falkner, V.M., THE CALCULATION OF AERODYNAMIC LOADING ON SURFACES OF ANY SHAPE, ARC R & M 1910, 1943.

AAb17 Kriesis, P., CONCERNING RECTANGULAR AIRFOILS OF VERY LARGE CHORD (Über rechteckige Tragflügel sehr grober Tiefe) ZAMM, Bd. 24, Heft 1, 1944, pp. 1-5.

AAb18 Jones, W.P., NOTE ON THE INFLUENCE OF THE SPANWISE FLOW ON LIFT DISTRIBUTION, ARC R & M No. 2181, March 1946.

The influence of spanwise flow on the lift distribution of a thin flexible wing of any plan form is considered. By the use of Euler's equations for incompressible inviscid flow, it is shown that the lift distribution is not appreciably affected provided the displacements of the wing are small.

AAb19 Jones, R.T., PROPERTIES OF LOW-ASPECT RATIO POINTED WINGS AT SPEEDS ABOVE AND BELOW THE SPEED OF SOUND, NACA TN 1032, 1946; also NACA TR 835, 1946.

Low aspect ratio pointed plan form wings are treated on the assumption that the flow potentials in planes at right angles to the longitudinal axis of the airfoil are similar to the corresponding two-dimensional potentials. For the limiting case of small angles of attack and low aspect ratio the theory brings out the following significant properties:

(1) The lift of a slender pointed airfoil moving in the direction of the longitudinal axis depends on the increase in width of the sections in a downstream direction. Sections behind the section of maximum width develop no lift.

(2) Spanwise loading is independent of plan and approaches the minimum induced drag distribution.

(3) The lift distribution of pointed airfoils traveling point foremost is relatively unaffected by compressibility below or above the speed of sound.

AAb20 Ginzel, I. and Ludwieg, H., ON THE THEORY OF AIRSCREWS WITH LARGE-CHORD BLADES, MOS R & T No. 812, April 15, 1947, (Trans. of MAP Völkenrode Monograph).

A step towards the calculation of the supporting surface of large-chord propeller blades is presented which goes beyond the theory of the lifting line and considers the induced curvature of the streamline. The calculation is made for the case of a circular arc profile in a flow with stagnation point at the leading edge.

AAb21 Falkner, V.M., THE SOLUTION OF LIFTING PLANE PROBLEMS BY VORTEX LATTICE THEORY, ARC Report 10895 Sept. 1947 (British/U.S. RESTRICTED).

AAb22 van Dorn, N.H. and De Young, J., A COMPARISON OF THREE THRORETICAL METHODS OF CALCULATING SPAN LOAD DISTRIBUTION ON SWEPT WINGS, NACA TN 1476, Nov. 1947.

The Falkner, Mutterperl, and Weissinger methods for estimating span loading have been studied to establish their relative accuracy and ease of application. The experimentally determined loading and force characteristics of five wings having sweep angles of from 45 deg. forward to 45 deg. back

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were used as a basis for judging the accuracy. It was found that the Weissinger method gave good accuracy with least effort, whereas the Falkner method gave best accuracy but at considerable expense in computing effort.

AAb23 Ginzel, I., F_1. THEORY OF THE THREE-DIMENSIONAL AIRFOIL. 3. APPLIED WING THEORY. 3.1. WINGS OF SMALL ASPECT RATIO. MOS R & T No.1025, Dec. 15, 1947 (Trans. of MAP Völkenrode AVA Monograph).

This is a critical comment on existing theoretical methods for calculating the lift and distribution of load on wings of small aspect ratio.

AAb24 De Young, J., THEORETICAL ADDITIONAL SPAN LOADING CHARACTERISTICS OF WINGS WITH ARBITRARY SWEEP, ASPECT RATIO, AND TAPER RATIO, NACA TN 1491, Dec. 1947.

The Weissinger method has been used to find the lift-curve slope, spanwise center of pressure, aerodynamic center location, and span loading coefficients of untwisted and uncambered wings having a wide range of plan forms. The results are presented in graphical form to facilitate interpolation. Methods are also included for determining induced drag and the approximate effects of compressibility.

AAb25 Stevens, V.I., PREDICTION OF AIR LOAD DISTRIBUTION AND ITS EFFECT ON AERODYNAMIC CHARACTERISTICS AT SUBSONIC SPEEDS FOR WINGS OF ARBITRARY PLAN FORM, Aero. Eng. Rev., June 1948.

This paper investigates several theoretical methods for the prediction of loading on wings of arbitrary form and shows the application of one of these methods to a wide range of plan forms.

AAb26 Stevens, V.I., THEORETICAL BASIC SPAN LOADING CHARACTERISTICS OF WINGS WITH ARBITRARY SWEEP, ASPECT RATIO AND TAPER RATIO, NACA TN 1772, Dec. 1948.

A procedure based on the Weissinger method is presented so that the basic span loading, the angle of zero lift, and the pitching moment due to twist can readily be predicted for a wide range of plan forms. To establish the effect of sweep, aspect ratio and taper ratio on the basic loading characteristics, the method is applied to a few representative wings with uniform twist and the results are discussed.

AAb27 Falkner, V.M., TABLES OF MULTHOPP AND OTHER FUNCTIONS FOR USE IN LIFTING LINE AND LIFTING PLANE THEORY, ARC Report 11234, 1948, RESTRICTED.

AAb28 Diederich, F.W., A SIMPLE APPROXIMATE METHOD FOR OBTAINING SPANWISE LIFT DISTRIBUTIONS OVER SWEPT WINGS, NACA RM L7107, 1948.

This presents an adaptation of Schrenk's empirical method for estimating the lift distribution over straight wings to swept wings by replacing the elliptical distribution with a new "ideal" distribution which varies with sweep.

AAb29 De Young, J. and Harper, C.W., THEORETICAL SYMMETRIC SPAN LOADING FOR WINGS OF ARBITRARY PLAN FORM AT SUBSONIC SPEEDS, NACA Rep. 921, 1948.

A simple method is described for finding symmetric span loading of wings with straight quarter-chord line over semispan and no discontinuities in twist.

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AAb30 Golubev, V.V., ON THE THEORY OF A WING OF SMALL SPAN (In Russian) Uchen. Zapiski Moskov. Gos. Univ. Mech. 122, 1948, pp. 3-16.

It is well known that the agreement between experiment and the theoretical load distribution based on lifting line theory breaks down for aspect ratios less than one. The paper under review presents a modification of the conventional theory by assuming that the free vortex sheet does not leave the wing at the trailing edge but at some line of the suction side at a distance approximately one-quarter chord from the leading edge and in the same plane as the main stream. The wing itself is supposed to be replaced by a plane. The first assumption leads to a secondary stream leaving the wing at the tips. The secondary stream, contrary to the main stream, is not supposed to be subject to Joukowski's hypothesis. The presence of the secondary stream, in the case of elliptic loading, produces an increase in circulation proportional to the square of the angle of attack. An improved aspect-ratio correction formula is thus derived.

AAb31 Jones, A.L. and Sluder, L., AN APPLICATION OF FALKNER'S SURFACE-LOADING METHOD TO PREDICTIONS OF HINGE-MOMENT PARAMETERS FOR SWEPT-BACK WINGS, NACA TN 1506, 1948.

AAb32 Reissner, E., NOTE ON THE THEORY OF LIFTING SURFACES, Proc. Nat. Acad. Sci., Vol. 35, No. 4, April 1949, pp. 208-215.

Steady motion of a rectangular lifting surface in incompressible flow is considered and a modified derivation is given of Weissinger's improvement of Prandtl's lifting-line theory. The integral equation of lifting line theory (and Weissinger's improvement) for the spanwise variation of lift intensity is generalized to two simultaneous integral equations for lift intensity and moment intensity; in so doing certain difficulties of the lifting line theory are substantially ameliorated. The two-equation procedure of this paper is shown to be applicable to a problem which is outside of the scope of the lifting line equation.

AAb33 Pope, A. and Haney, W.R., SPANWISE LIFT DISTRIBUTION FOR SWEPT BACK WINGS, J. Aero. Sci., Vol. 16, No. 8, Aug. 1949, pp. 505-506.

AAb34 Diederich, F.W. and Zlotnich, M., THEORETICAL SPANWISE LIFT DISTRIBUTIONS OF LOW ASPECT-RATIO WINGS AT SPEEDS BELOW AND ABOVE THE SPEED OF SOUND, NACA TN 1973, Oct. 1949.

AAb35 Legras, J., CONTRIBUTION TO THE STUDY OF WINGS (In French), Publ. Sci. Tech. No. 222, 1949, v + 93 pp.

AAb36 Polhamus, E.C., A SIMPLE METHOD OF ESTIMATING THE SUBSONIC LIFT AND DAMPING IN ROLL OF SWEPTBACK WINGS, NACA TN 1862, 1949.

A method is derived for modifying existing correction factors of lifting-surface theory to account approximately for effect of sweepback, and these factors are applied to existing lifting-line theory for the lift and damping in roll of sweptback wings. Despite the simplicity of the resulting formulas, the agreement with experimental data for low speeds is very good. The equation for lift is expressed entirely in terms of the geometrical characteristics of the wing and the section lift-curve slope. The results can be applied to sweptback wings at subsonic speed by application of the Prandtl-Glauert rule.

AAb37 Multhopp, H., METHODS FOR CALCULATING THE LIFT DISTRIBUTION OF WINGS (SUBSONIC LIFTING-SURFACE THEORY), RAE Report Aero 2353, Jan. 1950, CONFIDENTIAL.

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AAb38 Holme, O., A NUMERICAL SOLUTION OF THE PROBLEM OF THE LIFTING SURFACE WITH CONTINUOUS DISTRIBUTION OF VORTICITY, FFA MED 32, 1950.

AAb39 Lawrence, H.R., THE CHORDWISE LIFT DISTRIBUTION OF LOW ASPECT RATIO WINGS AND WING-BODY COMBINATIONS, Cornell Aero. Lab., Inc., Rep. No. AF-673-A-1, May 1950. (Rev. in J. Aero. Sci., Oct. 1951.)

AAb40 Diederich, F.W., APPROXIMATE AERODYNAMIC INFLUENCE COEFFICIENTS FOR WINGS OF ARBITRARY PLAN FORM IN SUBSONIC FLOW, NACA TN 2092, July 1950, 17 pp.

AAb41 Küchemann, D., A SIMPLE METHOD FOR CALCULATING THE SPAN AND CHORDWISE LOADINGS ON THIN SWEPT WINGS, RAE Report Aero 2392, Aug. 1950, CONFIDENTIAL.

AAb42 Lawrence, H.R., THE LIFT DISTRIBUTION ON LOW ASPECT-RATIO WINGS AT SUBSONIC SPEEDS, IAS Preprint No. 313, Jan. 1951; also J. Aero. Sci., Vol. 18, No. 10, Oct. 51, pp. 683-695, and Cornell Aero. Lab., Inc., AF-67 A-1, 76601, 9 Nov. 1950, CADO AF-673-A-1.

A systematic procedure is developed for obtaining an approximate integral equation from the linearized theory of a lifting surface in a steady incompressible flow. The procedure leads to a system of classification of various theories currently employed in the calculation of lift distribution and to a new theory for chordwise lift distribution over wings of low-aspect ratio.

AAb43 Bird, J.D., SOME THEORETICAL LOW-SPEED SPAN LOADING CHARACTERISTICS OF SWEPT WINGS IN ROLL AND SIDESLIP, NACA TR 969, 1950.

The Weissinger method for determining additional span loading for incompressible flow is used to find the damping in roll, the lateral center of pressure of the rolling load, and the span loading coefficients caused by rolling for wing plan forms of various aspect ratios, taper ratios, and sweep angles. In addition, the applicability of the method to the determination of certain other aerodynamic derivatives is investigated, and corrections for the first-order effects of compressibility are indicated.

AAb44 De Young, J., SPANWISE LOADING FOR WINGS AND CONTROL SURFACES OF LOW ASPECT RATIO, NACA TN 2011, 1950.

A two-dimensional fore and aft vortex sheet is used to predict the spanwise loading of low-aspect-ratio wings or moderate-aspect-ratio wings at the speed of sound. The treatment is limited to plan forms having all points of the trailing edge at or behind the upstream line of maximum wing span. Spanwise loadings that include the additional loading due to angle of attack, that due to roll, basic loading due to twist and that due to control surfaces of low-aspect-ratio are found to be independent of plan form for wings considered. For low-aspect-ratio control surfaces, the spanwise loading is also found to be independent of the chordwise location of the control surface hinge line.

AAb45 Dickson, R., COMPARISON OF TWO METHODS OF CALCULATING AERODYNAMIC LOADING ON AN AEROFOIL WITH LARGE SWEEPBACK AND SMALL ASPECT RATIO, ARC R & M 2353, 1950.

The aerodynamic characteristics of a wing of large sweepback and small aspect ratio are calculated by Falkner's 9-point solution, and by a simplified version of this method using only a lifting line at the quarter-chord and three pivotal points situated on the 3/4-chord line. The simplified method is of value for rapid estimation of all properties except the location of the aerodynamic center.

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AAb46 Scholtz, N., CONTRIBUTION TO THE THEORY OF THE LIFTING SURFACE (In German), Ing. Archiv. Bd. 18, Nr. 2, 1950, pp. 84-105.

Consider a two-dimensional flat-plate airfoil of chord ℓ at incidence in a stream. If circulation is replaced by a single vortex at the 1/4-chord point ($\ell/4$) and the streaming condition is satisfied at the rear 1/4 chord point, the total lift and moment are unaltered. If the plate is divided into equal strips (ℓ/n) and the corresponding substitution is made for each strip, the same result holds for n = 1, 2, 3, 4 and, presumably, for n > 4, although no proof is offered of this case. This strip method applied to an airfoil of finite aspect ratio yields an integro-differential equation. This is replaced by nm linear equations by satisfying the streaming condition at m points ($3\ell/4n$) of each strip. The coefficients depend upon the downwash angles at these points. By assuming a continuous chordwise distribution of circulation, these downwash angles can be calculated once for all; tables are given for their values, corresponding to the first three terms of a Fourier Series.

AAb47 Sivels, J.C., AN IMPROVED APPROXIMATE METHOD FOR CALCULATING LIFT DISTRIBUTIONS DUE TO TWIST, NACA TN 2282, Jan. 1951.

A new method for calculating lift distribution due to twist which gives a closer approximation than the empirical method of Schrenk (NACA TM 948) and requires about the same amount of computing. The new method, based on lifting-line theory, makes use of the lift distribution due to angle of attack and takes into account the aspect ratio of the wing. Examples are presented for the four main types of twist: Symmetrical, antisymmetrical, continuous, and discontinuous. The application of the method to sweptback wings is also presented. An example is given of its use in the case of a swept wing of aspect ratio 1.5.

AAb48 De Young, J., THEORETICAL SYMMETRIC SPAN LOADING DUE TO FLAP DEFLECTION FOR WINGS OF ARBITRARY PLAN FORM AT SUBSONIC SPEEDS, NACA TN 2278, Jan. 1951.

A procedure based upon simplified lifting surface theory that includes effect of compressibility and spanwise variation of section lift curve slope is presented in such a manner that the spanwise loading due to flap deflection can be found simply for wings with symmetrical plan forms with constant spanwise sweepback angle of the quarter-chord line. Aerodynamic characteristics due to flap deflection are considered, and values of certain of these characteristics for straight tapered wings are presented in charts for a range of sweptback plan forms.

AAb49 Dods, J.B., ESTIMATION OF LOW-SPEED LIFT AND HINGE-MOMENT PARAMETERS FOR FULL-SPAN TRAILING-EDGE FLAPS ON LIFTING SURFACES WITH AND WITHOUT SWEEPBACK, NACA TN 2288, Feb. 1951.

The experimentally measured low-speed lift and hinge-moment characteristics of various unswept and swept-back flapped lifting surfaces were compared with those predicted by the use of several theoretical procedures. On the basis of these limited results, a method is proposed for preliminary design estimates of the low-speed lift and hinge-moment parameters of lifting surfaces having full-span trailing-edge flaps. The method is based upon lift predictions made by the Weissinger method and upon estimates of the induced-camber aspect-ratio corrections to the hinge-moment parameters computed from a lifting-surface solution by the Falkner method. Design charts for the induced-camber correction are provided so that the method may be applied without extensive lifting-surface computations.

AAb50 Reissner, E., NOTE ON THE RELATION OF LIFTING-LINE THEORY TO LIFTING-SURFACE THEORY, J. Aero. Sci., Vol. 18, No. 3, March 1951.

AAb51 Campbell, G.S., A FINITE-STEP METHOD FOR THE CALCULATION OF SPAN LOADINGS OF UNUSUAL PLAN FORMS, NACA RM L50L13, July 1951, CONFIDENTIAL.

The applicability of a finite-step method to the calculation of subsonic spanwise load distribution, lift curve slope, lateral center of pressure, and aerodynamic center of unusual plan forms was

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investigated. Computing forms are presented to simplify the calculation of span loadings for conventional swept, M plan form, and W plan form wings. Tables of the downwash in the plane of a yawed vortex are presented. Spanwise loadings have been compared with those obtained by Falkner and Weissinger for several plan forms. The effect of an extra vortex located near the tip, the use of yawed vortices, and the number of steps necessary are discussed in the light of calculated results.

AAb52 Ginzel, G.I., THE CAP OF A SPHERE AND THE CAP OF AN ELLIPSOID OF REVOLUTION AS SURFACES OF CONSTANT DOWNWASH DERIVATIVE, ARL/R2/G/AE/2/5 July 1951, ACSIL/ADM/51/540.

The method of camber correction is an approximate method derived from lifting-surface theory for the calculation of the lift distribution of wings or propeller blades with small aspect ratio. The exact calculation of the lifting surface is very difficult and has only been carried out for a very small number of surfaces, mainly for the circular and elliptic discs. The case of the cap of a sphere has been calculated exactly by Kinner; a comparison with results of the present method indicates satisfactory agreement. The derivative of the downwash and the camber correction factor are constant along the span of the cap of a sphere and of an ellipsoid of revolution and are given as functions of the axis ratio of the elliptic boundary.

AAb53 Diedrich, F.W and Latham, W.O., CALCULATED AERODYNAMIC LOADINGS OF M, W, AND Λ WINGS IN INCOMPRESSIBLE FLOW, NACA RM L51E29, Aug. 1951, CONFIDENTIAL.

Results of the incompressible flow calculation of spanwise lift distribution and some associated aerodynamic parameters of 20 M, W, and Λ wings are presented. These results are compared with similarly calculated results for ordinary sweptback and unswept wings.

AAb54 Goodman, T.R., CALCULATION OF AERODYNAMIC CHARACTERISTICS OF LOW-ASPECT RATIO WINGS AT SUBSONIC SPEEDS, Cornell Aero. Lab., Inc. Report AF-743-A-1, August 1951.

The Lawrence low-aspect ratio theory is applied to a general class of wings. Numerical results are charted in matrix form. With the aid of the matrices, the lift distribution for any arbitrary twist, camber, flap, etc. is easily found with but a few minutes calculation, provided the wing is of the general class considered.

AAb55 Flax, A.H. and Lawrence, H.R., AERODYNAMICS OF LOW-ASPECT-RATIO WINGS AND WING-BODY COMBINATIONS, Cornell Aero. Lab., Inc., Report CAL.37, Sept. 1951.

This paper considers the determination of aerodynamic characteristics of low aspect ratio wings (AR < 3). Linear theory is not adequate for large angles but is in good agreement with the theory for small angles. From this it is concluded that a proper line of approach is to use the linear theory as a basis and to determine suitable additional correction terms for nonlinear effect. Approximations to the lifting surface equations appropriate to low AR plan forms are investigated. These approximations reduce the two-variable integral equation of lifting surface theory to a one-variable approximate integral equation.

AAb56 Voss, H.M., ON NONPLANAR SURFACES OF VERY LOW ASPECT RATIO, J. Aero. Sci., Vol. 19, No. 2, Feb. 1952, pp. 136-137.

A new approach to the problem of determining the air forces on a wing of very low aspect ratio is presented that may be applied to nonplanar wing surfaces. The method involves expansion in a finite Fourier series in y/S(x), where y is the distance in the direction of the semispan and S(x) is the span at a station a distance x from the forward extremity of the surface.

See also AAa1, AAa11, AAa12, AAa14, AAa19, AB14, ADb6, ADb10, ADb11, AEa14, E8, E11, and E12.

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AB. WINGS, FLOW FIELD

AB1 Winter, H., FLOW PHENOMENA ON PLATES AND AIRFOILS (PROFILED BODIES) OF SHORT SPAN, NACA TM 798, July 1936 (Translation of report published in VDI, Special Issue (Aviation) 1936; also in Forsch. Ing. Wes., Bd. 6, 1935, Edition A, pp. 40,and 67. An improved translation in which corrections are made of several errors in the NACA version is now under preparation at the Taylor Model Basin, and will be issued as T-250.)

Investigations of the flow phenomena at plates and cambered models were carried out with the aid of force measurements, some pressure distribution measurements, and photographic observation. The experimental methods are described and the results presented. Section III of this work gives a comprehensive account of the results and indicates how nearly the lifting line and lifting surface theories agree with experimental results.

AB2 Sherman, A.. AN INTEGRATOR FOR EVALUATING THE DOWNWASH FROM A SPAN-LOADING CURVE, J. Aero. Sci., Vol. 5, No. 4, Feb. 1938, pp. 148-150.

AB3 Silverstein, A., Katzoff, S., and Bullevant, W.K., DOWNWASH AND WAKE BEHIND PLAIN AND FLAPPED AIRFOILS, NACA TR 651, 1939.

Extensive experimental measurements are presented of the downwash angle and wake characteristics behind airfoils of aspect ratio 3 and 6, with and without flaps. The data are analyzed and correlated with theory. A detailed study was made of errors involved in applying lifting line theory. By the use of a theoretical treatment indicated by Prandtl, it has been possible to generalize the available experimental tal results so that predictions can be made of wake parameters in terms of the distance behind the airfoil trailing edge and the profile drag coefficient. The method of application of the theory to design and the satisfactory agreement between predictions and experimental results are demonstrated.

AB4 Swanson, R.S. and Crandall, S.M., AN ELECTROMAGNETIC-ANALOGY METHOD OF SOLVING LIFTING-SURFACE-THEORY PROBLEMS, NACA Wartime Report L-120, May 1945.

A method is presented for making lifting-surface calculations by means of magnetic measurements of an electromagnetic-analogy model. The method is based on the perfect analogy between the strength of the magnetic field around a conductor and the strength of the induced vortex field around a vortex. Electrical conductors are arranged to represent the vortex sheet. The magnetic field strength is determined by measuring with an electronic voltmeter the voltage induced in a small search coil by an alternating current in the wires representing the vortex sheet. Solutions of nonlinear lifting-surface problems may be obtained by placing conductors representing trailing vortices along the fluid lines (Helmholtz condition). A potential-flow solution for distortion and rolling-up of trailing vortex sheet may be obtained.

AB5 Schlichting, H., CALCULATIONS OF THE DOWNWASH BEHIND WINGS OF SMALL ASPECT RATIO WITH ZERO SWEEP (Part II) RAE Report Aero. 2228, Oct. 1947.

AB6 Tolhurst, W.H., AN INVESTIGATION OF THE DOWNWASH AND WAKE BEHIND LARGE-SCALE SWEPT AND UNSWEPT WINGS, NACA RM A7L05, Feb. 1948, RESTRICTED.

Results of investigation at large scale of the downwash and wake behind wings of 0, ±30, and ±45 deg. sweepback. They include contour maps of downwash angle in a vertical plane at the normal tail position and the spanwise variation of wake limits and pressure losses in the wake for several angles of attack. Wings of aspect ratio 3.12 to 4.84 were tested.

AB7 Hoggard, H.P., and Hagerman, J.R., DOWNWASH AND WAKE BEHIND UNTAPERED WINGS OF VARIOUS ASPECT RATIOS AND ANGLES OF SWEEP, NACA TN No. 1703, Oct. 1948.

The report contains downwash angle and dynamic pressure ratios observed behind ten different untapered wings of various aspect ratios and sweep. The rate of change of downwash angle with angle of attack and effect of sweep are presented.

Data presented may be used for determining most suitable horizontal tail positions.

AB8 Furlong, G.C. and Bolech, T.V., DOWNWASH, SIDEWASH AND WAKE SURVEYS BEHIND A 42 DEG SWEPTBACK WING AT A REYNOLDS NUMBER OF 6.8×10^6 WITH AND WITHOUT A SIMULATED GROUND, NACA RM L8G22, Dec. 13, 1948, RESTRICTED.

Results of an investigation with and without a simulated ground, to provide flow inclination and wake data behind a 42 deg. sweptback wing. Tests were made for two model configurations namely, the plain wing and the wing with inboard trailing-edge split flaps and outboard leading-edge flaps deflected. Contour charts of downwash, sidewash, and dynamic pressure ratio at two longitudinal stations behind the wing are presented. Integrations have been made to obtain variations of average downwash and dynamic pressure ratio with angle of attack. The possibility of extending the lifting-line method used for calculating the downwash behind unswept wings to the case of the sweptback wing has been investigated briefly. The wing of aspect ratio 4.01 was tested at a Mach number of 0.14.

AB9 Lock, R.C., Ross, T.G. and Meiklem, P., WIND TUNNEL TESTS ON A 90 DEG. APEX DELTA WING OF VARIABLE ASPECT RATIO - PART II, MEASUREMENTS OF DOWNWASH AND THE EFFECT OF HIGH-LIFT DEVICES, RAE Report Aero 2284, 1948.

Wind-tunnel measurements of downwash were made on a delta wing of aspect ratio 4, 3, and 2.3, using a tail of delta plan form in three vertical positions at two chordwise stations behind the wing. The tests also included the effect of the tail and of split flaps and nose flaps on the stability near the stall and on $C_{L_{max}}$. A method is given for calculation of downwash at small angles which agree with measurements.

AB10 Berndt, S.B., THREE COMPONENT MEASUREMENTS AND FLOW INVESTIGATION OF PLANE DELTA WINGS AT LOW SPEEDS AND ZERO YAW (Eng. Edition publ. in Sweden) K. Tekn. Högsk. Aero TN4, 1949.

AB11 Newmark, S. and Collingbourne, J., VELOCITY DISTRIBUTION ON UNTAPERED SHEARED AND SWEPTBACK WINGS OF SMALL THICKNESS AND FINITE ASPECT RATIO AT ZERO INCIDENCE, RAE Report Aero 2316, March 1949, RESTRICTED.

This continuation of an earlier report puts forward several new solutions of the problems of velocity distribution on finite or semi-infinite untapered wing at zero incidence. The solutions are based on the first-order method of sources and sinks, which is shown to be sufficiently accurate to deal with problems involving tips or kinks.

AB12 Walker, H.J. and Stivers, L.S., Jr., INVESTIGATION OF THE DOWNWASH AND WAKE BEHIND A TRIANGULAR WING OF ASPECT RATIO 4 AT SUBSONIC AND SUPERSONIC MACH NUMBERS, NACA RM A50I14a, Dec. 12, 1950, CONFIDENTIAL.

AB13 Spreiter, J.R. and Sacks, A.H., THE ROLLING UP OF THE TRAILING VORTEX SHEET AND ITS EFFECT ON THE DOWNWASH BEHIND WINGS, J. Aero. Sci., Vol. 18, No. 1, Jan. 1951, pp. 21-32, 72.

The motion of the trailing vortex associated with a lifting wing is investigated by theoretical and visual-flow methods at subsonic and supersonic speeds.

AB14 Harmon, S.M., METHOD FOR CALCULATING DOWNWASH FIELD DUE TO LIFTING SURFACES AT SUBSONIC AND SUPERSONIC SPEEDS, NACA TN 2344, April 1951.

AB15 Foster, G.V. and Griner, R.F., LOW-SPEED LONGITUDINAL AND WAKE AIRFLOW CHARACTERISTICS AT A REYNOLDS NUMBER OF 5.5×10^6 OF A CIRCULAR ARC 52 DEG. SWEPTBACK WING WITH A FUSELAGE AND A HORIZONTAL TAIL AT VARIOUS VERTICAL POSITIONS, NACA RM L51C30, June 19, 1951, RESTRICTED.

Results of an investigation to determine the effect of a fuselage and horizontal tail on the longitudinal characteristics of a circular arc swept wing are presented. They include a wake airflow survey at station representative of the location of a horizontal tail. Plain and flapped wings are considered.

AB16 Spreiter, J.R., DOWNWASH AND SIDEWASH FIELDS BEHIND CRUCIFORM WINGS, NACA RM A51L17, Jan. 1952, CONFIDENTIAL.

AB17 Bird, J.D. and Riley, D.R., SOME EXPERIMENTS ON VISUALIZATION OF FLOW FIELDS BEHIND LOW-ASPECT-RATIO WINGS BY MEANS OF A TUFT GRID, NACA TN 2674, May 1952.

See also A8, AAa8, AAa10, AAb52, AC3, AD9, ADa1, ADb1, ADb23, CB10, and DA13.

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AC. WINGS, BOUNDARY LAYER

AC1 Pasamanick, J. and Proterra, A.J., THE EFFECT OF BOUNDARY LAYER CONTROL BY SUCTION AND SEVERAL HIGH-LIFT DEVICES ON THE LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF A 47.5 DEG. SWEPTBACK WING-FUSELAGE COMBINATION, NACA RM L8E18, Nov. 1948, RESTRICTED.

This describes an investigation in the Langley full-scale tunnel of a 47.5 deg. sweptback wing-fuselage combination equipped for boundary-layer control by suction. The wing aspect ratio was 3.5, the taper ratio 0.5, and the airfoil section normal to quarter-chord line, NACA 64-A112. The wing configurations tested included the wing with various combinations of extensible leading-edge and split flaps. The effect of Reynolds number, suction slot location, and suction flow coefficient on the aerodynamic characteristics was determined for the model at zero yaw over a range of angles of attack.

AC2 Pasamanick, J. and Sellers, T.B., FULL-SCALE INVESTIGATION OF BOUNDARY-LAYER CONTROL BY SUCTION THROUGH LEADING-EDGE SLOTS ON A WING-FUSELAGE CONFIGURATION HAVING 47.5 DEG. LEADING EDGE SWEEP WITH AND WITHOUT FLAPS, NACA RM L50B15, April 1950, RESTRICTED.

This report gives the results of an investigation in Langley full-scale tunnel of leading-edge boundary-layer control by suction in combination with high-lift devices on a wing-fuselage configuration having 47.5 deg. leading-edge sweep. The wing aspect ratio was 3.4, the taper ratio 0.5 and the airfoil sections normal to the quarter chord line were NACA 64_1A112. The data include effect of suction-slot location and suction flow quantities on the force measured, visual flow studies, and surface pressure distribution measurements at zero yaw over a range of angles. Reynolds number effect was determined for Reynolds numbers 3.0 - 7.5 x 10^6 for wing in sealed and faired condition.

AC3 Brebner, G.G., BOUNDARY LAYER MEASUREMENTS ON A 59 DEG. SWEPTBACK WING AT LOW SPEED, RAE Report Aero. 2311a, Aug. 1950, CONFIDENTIAL.

Measurements are presented of boundary layer at the trailing edge of a 59 deg. sweptback wing of aspect ratio 3.6 and taper ratio 4:1 at low speed. Total head, velocity and angle of flow were found throughout the region in which these quantities differ from their free-stream value. A new type yaw meter was used. It was found that the displacement thickness and the associated loss of lift are considerable. The displacement thickness rises quickly with incidence and varies along the span. Thus the spanwise load will be quite different from that calculated on the basis of potential flow, even at quite small incidences.

AC4 Pasamanick, J. and Scallion, W.I., THE EFFECTS OF SUCTION THROUGH POROUS LEADING-EDGE SURFACES ON THE AERODYNAMIC CHARACTERISTICS OF A 47.5 DEG. SWEPTBACK WING-FUSELAGE COMBINATION AT A REYNOLDS NUMBER OF 4.4 x 10^6, NACA RM L51K15, Mar. 1952, CONFIDENTIAL.

See also AAa8, AB1, AD5, AD9, ADb28, ADd5, AFa5, AFa6, AG4, and CB9.

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AD. WINGS, GEOMETRIC VARIABLES

AD1 Lange-Wacke, TEST REPORT ON THREE- AND SIX-COMPONENT MEASUREMENTS ON A SERIES OF TAPERED WINGS OF SMALL ASPECT RATIO, PARTIAL REPORT: TRAPEZOIDAL WING WITH FUSELAGE, NACA TM 1129 (Work performed about 1943).

AD2 Lange-Wacke, TEST REPORT ON THREE- AND SIX-COMPONENT MEASUREMENTS ON A SERIES OF TAPERED WINGS OF SMALL ASPECT RATIO, PARTIAL REPORT: ELLIPTICAL WINGS, NACA TM 1146, June 1947.

Three- and six-component low-speed measurements are given for a series of elliptical wings of aspect ratio 1 to 2 with sweepback. The influence of contour and sweepback upon the neutral point is shown. The report is based on German research performed about 1943.

AD3 Lange-Wacke, TEST REPORT ON THREE- AND SIX-COMPONENT MEASUREMENTS ON A SERIES OF TAPERED WINGS OF SMALL ASPECT RATIO, PARTIAL REPORT: TRIANGULAR WING, NACA TM 1176, 1948.

Three- and six-component force data are shown for a series of four triangular wings of aspect ratio 1 to 3 at low speed for various angles of attack and yaw. The report is based on German research performed about 1943.

AD4 Lange-Wacke, TEST REPORT ON THREE- AND SIX-COMPONENT MEASUREMENTS ON A SERIES OF TAPERED WINGS OF SMALL ASPECT RATIO, PARTIAL REPORT: TRAPEZOIDAL WING, NACA TM 1225, May 1949.

This report describes low-speed force measurements on three wings with NACA 0012 profile and aspect ratio 4 to 3. The wings varied in taper through variations in sweep of the leading-edge only.

AD5 Dods, J.B., Jr., WIND-TUNNEL INVESTIGATION OF HORIZONTAL TAILS, I - UNSWEPT AND 35 DEG. SWEPT-BACK PLAN FORMS OF ASPECT RATIO 3, NACA RM A7K24, April 22, 1948.

Results are given of a wind-tunnel investigation of the low-speed characteristics of horizontal tails of aspect ratio 3 with unswept and swept-back plan forms. Two models were tested which had identical areas, aspect ratio, taper ratio, and airfoil section, and which differed only in the angle of sweepback and elevator area ratios. Data are presented for Reynolds numbers of 3.0×10^6 and 4.0×10^6 with the elevator sealed and for a Reynolds number of 3.0×10^6 with the seal removed and with standard roughness applied to the leading edge.

AD6 Dods, J.B., Jr., WIND-TUNNEL INVESTIGATION OF HORIZONTAL TAILS. II - UNSWEPT AND 35 DEG. SWEPT-BACK PLAN FORMS OF ASPECT RATIO 4.5, NACA RM A8B11, 1948.

AD7 Dods, J.B., Jr., WIND-TUNNEL INVESTIGATION OF HORIZONTAL TAILS. III - UNSWEPT AND 35 DEG. SWEPT-BACK PLAN FORMS OF AR 6, NACA RM A8H30, 1948.

AD8 Dods, J.B., Jr., WIND-TUNNEL INVESTIGATION OF HORIZONTAL TAILS. IV - UNSWEPT PLAN FORM OF AR 2 AND A TWO-DIMENSIONAL MODEL, NACA RM A8J21, 1948.

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AD9 Dods, J.B., Jr., WIND-TUNNEL INVESTIGATION OF HORIZONTAL TAILS. V - 45 DEG. SWEPT-BACK PLAN FORM OF ASPECT RATIO 2, NACA RM A9D05, Sept. 27, 1949.

The results of a wind-tunnel investigation of the low-speed aerodynamic characteristics of a 45 deg. swept-back horizontal tail model of aspect ratio 2 are presented and compared with previous results for a model of the same aspect ratio having an unswept hinge line. Test results are presented for the 45 deg. sweptback model with and without standard roughness on the leading edge, and with a sealed and with an unsealed radius-nose elevator. The test Reynolds number varied from 3.0 to 7.5 millions. Tests included measurement of model lift and pitching moment, elevator hinge moment, and pressure difference across the elevator nose seal. Tuft studies are presented of the airflow over the model both with the elevator deflected and undeflected.

AD10 Smith, D.W. and Heitmeyer, J.C., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - PLANE TRIANGULAR WING OF ASPECT RATIO 2 WITH NACA 008-63 SECTION, NACA RM A50K20, Feb. 1951, CONFIDENTIAL.

Results of an investigation to ascertain aerodynamic characteristics of the wing at a Mach number range of 0.24 - 1.70 at a Reynolds number of 3.0×10^6 are reported. The variation of characteristics with Reynolds number is also shown for several Mach numbers.

AD11 Smith, D.W. and Heitmeyer, J.C., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT-RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - PLANE TRIANGULAR WING OF ASPECT RATIO 2 WITH NACA 0005-63 SECTION, NACA RM A50K21, Feb. 1951, CONFIDENTIAL.

An investigation was undertaken to ascertain lift, drag and pitching moment of a wing-body combination having a plane triangular wing of aspect ratio 2 and having NACA 0005-63 sections in streamwise planes. The results are shown for Mach 0.24 to 1.70 at a Reynolds number of 3.0×10^6. The variation of characteristics with Reynolds number is also shown for several Mach numbers.

AD12 Heitmeyer, J.C. and Stephenson, J.D., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT-RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - PLANE TRIANGULAR WING OF ASPECT RATIO 4 WITH NACA 0005-63 SECTION, NACA RM A50K24, February 1951, CONFIDENTIAL.

A wing-body combination with a plane wing of aspect ratio 4 and NACA 0005-63 sections in streamwise planes was investigated at both subsonic and supersonic speeds. Lift, drag and pitching moment are presented for Mach numbers ranging from 0.25 to 0.96 and 1.20 to 1.70 at a Reynolds number of 1.5×10^6. The variation of characteristics with Reynolds number is also shown for several Mach numbers.

AD13 Heitmeyer, J.C. and Smith, W.G., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT-RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - PLANE TRIANGULAR WING OF ASPECT RATIO 2 WITH NACA 0003-63 SECTION, NACA RM A50L24a, February 1951, CONFIDENTIAL.

The results of an investigation to ascertain lift, drag and pitching moment of a wing-body combination with a plane triangular wing of aspect-ratio 2 and NACA 0003-63 section in streamwise planes are given for Mach 0.60-0.90 and from 1.3-1.7 at Reynolds number 5.0×10^6. Variation of characteristics with Reynolds number is also shown for several Mach numbers.

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AD14 Phelps, E.R. and Smith, W.G., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - TRIANGULAR WING OF ASPECT RATIO 4 WITH NACA 0005-63 THICKNESS DISTRIBUTION, CAMBERED AND TWISTED FOR TRAPEZOIDAL SPAN LOAD DISTRIBUTION, NACA RM A50K24b, Feb. 1951, CONFIDENTIAL.

Results are given of an investigation to ascertain lift, drag and pitching moment of a wing-body combination having a triangular wing of aspect-ratio 4 and NACA 0005-63 thickness distribution in streamwise planes and cambered and twisted for trapezoidal span load distribution. These results are presented for Mach number ranges of 0.25 to 0.96 and 1.2 to 1.7 at a Reynolds number of 1.5 x 10^6. Variation of characteristics with Reynolds number is also shown for several Mach numbers.

AD15 Hall, C.F. and Heitmeyer, J.C., LIFT, DRAG AND PITCHING MOMENT OF LOW AR WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - TWISTED AND CAMBERED TRIANGULAR WING OF AR 2 WITH NACA 0003-63 THICKNESS DISTRIBUTION, NACA RM A51E01, June 12, 1951, CONFIDENTIAL.

AD16 Heitmeyer, J.C. and Hightower, R.C., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT-RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - PLANE TRIANGULAR WING OF ASPECT RATIO 4 WITH 3 PERCENT THICK ROUNDED NOSE SECTION, NACA RM A51F21, August 1951, CONFIDENTIAL.

Results of an investigation to ascertain the lift, drag and pitching moment of a wing-body combination having a triangular wing of aspect ratio 4 are shown for Mach numbers ranging from 0.60 to 0.92 and from 1.20 to 1.70 and Reynolds numbers from 2.91 x 10^6 to 4.15 x 10^6.

AD17 Heitmeyer, J.C., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT-RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - PLANE TRIANGULAR WING OF ASPECT RATIO 3 WITH NACA 0003-63 SECTION, NACA RM A51H02, Sept. 1951, CONFIDENTIAL.

Results of an investigation to ascertain lift, drag and pitching moment of a wing-body combination having a triangular wing of aspect ratio 3 with NACA 0003-63 sections in streamwise planes are shown for Mach numbers 0.60 to 0.92 and from 1.20 to 1.70 at a Reynolds number of 4.80 x 10^6. Variation of characteristics with Reynolds number is also shown for several Mach numbers.

AD18 Heitmeyer, J.C., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT-RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - PLANE 45 DEG. SWEPT WING OF ASPECT RATIO 3, TAPER RATIO 0.4 WITH 3 PERCENT THICK BICONVEX SECTION, NACA RM A51H10, Sept. 1951, CONFIDENTIAL.

Results of an investigation to ascertain the lift, drag and pitching moment of a wing-body combination having a plane 45 deg. swept wing of aspect ratio 3 and taper ratio 0.4 with 3 percent thick biconvex sections in streamwise planes are given. Results are included for Mach 0.60 to 0.92 and 1.20 to 1.70 at Reynolds number 3.8 x 10^6. The variation of characteristics with Reynolds number is also shown for several Mach numbers.

AD19 Dods, J.B., and Tinling, B.E., SUMMARY OF RESULTS OF A WIND-TUNNEL INVESTIGATION OF NINE RELATED HORIZONTAL TAILS, NACA RM A51G31a, October 12, 1951, RESTRICTED.

Results of tests of nine related tails are summarized to indicate effects of aspect ratio, sweepback, and changes in Mach number and to provide experimental values of the lift and hinge-moment parameters for comparison with values computed by lifting surface theory.

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AD20 Heitmeyer, J.C. and Peterson, R.B., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - TWISTED AND CAMBERED TRIANGULAR WING OF ASPECT RATIO 2 WITH NACA 0005-63 THICKNESS DISTRIBUTION, NACA RM A52B08, Apr. 1952, CONFIDENTIAL.

See also AAb25.

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ADa. WINGS, GEOMETRIC VARIABLES, AIRFOIL SECTION

ADa1 Wilson, H.A. and Lovell, J.C., FULL-SCALE INVESTIGATION OF THE MAXIMUM LIFT AND FLOW CHARACTERISTICS OF AN AIRPLANE HAVING APPROXIMATELY TRIANGULAR PLAN FORM, NACA RM L6K20, 1946.

An investigation of the DM-1 glider, of approximately triangular plan form airfoil section similar to NACA 0015-64 and having an aspect ratio of 1.8 and 60 deg. sweptback leading edge was conducted in the Langley full-scale wind tunnel and in a 1/15-scale model of the full-scale tunnel. The glider had a $C_{L_{max}}$ of 0.60 and the 1/15-scale model 1.0. Other changes increased $C_{L_{max}}$ to 1.24. It was concluded that airfoil sections with sharp leading edges or small leading-edge radii which are believed desirable for supersonic speeds will also have acceptable and perhaps superior low-speed charactersteristics when used in highly sweptback wings. A $C_{L_{max}}$ of 1.2 can be obtained for an aspect-ratio of 2 at large angles.

ADa2 Letko, W. and Jaquet, B.M., EFFECT OF AIRFOIL PROFILE OF SYMMET RICAL SECTIONS ON THE LOW-SPEED STATIC STABILITY AND YAWING DERIVATIVES OF 45 DEG. SWEPTBACK WING MODELS OF ASPECT RATIO 2.61, NACA RM L8H10, Nov. 9, 1948.

ADa3 Letko, W. and Brewer, J.D., EFFECT OF AIRFOIL PROFILE OF SYMMETRICAL SECTIONS ON THE LOW-SPEED ROLLING DERIVATIVES OF 45 DEG. SWEPTBACK WING MODELS OF ASPECT RATIO 2.61, NACA RM L8L31a, Mar. 4, 1949.

ADa4 Jones, J.L. and Demele, F.A., AERODYNAMIC STUDY OF A WING-FUSELAGE COMBINATION EMPLOYING A WING SWEPT BACK 63 DEG. CHARACTERISTICS THROUGHOUT THE SUBSONIC SPEED RANGE WITH THE WING CAMBERED AND TWISTED FOR A UNIFORM LOAD AT A LIFT COEFFICIENT OF 0.25, NACA RM A9D25, Aug. 1949, CONFIDENTIAL.

Results are given for tests of a wing-fuselage combination having a cambered and twisted wing with 63 deg. leading-edge sweep, aspect ratio of 3.5 and taper ratio of 0.25. Results are also given for the fuselage alone. Aerodynamic characteristics are presented for Mach numbers ranging from 0.20 to 0.93 at Reynolds numbers 0.8×10^6 to 2.0×10^6 and for Reynolds numbers from 0.8×10^6 to 9.0×10^6 at Mach 0.20. Comparisons are made with results for a similar wing without camber or twist.

ADa5 Cahill, J.F. and Gottlieb, S.M., LOW-SPEED AERODYNAMIC CHARACTERISTICS OF A SERIES OF SWEPT WINGS HAVING NACA 65A006 AIRFOIL SECTIONS, NACA RM L50F16 (Rev.), Oct. 1950, RESTRICTED.

ADa6 McLemore, H.C., LOW-SPEED INVESTIGATION OF THE EFFECTS OF WING LEADING EDGE MODIFICATIONS AND SEVERAL OUTBOARD FIN ARRANGEMENTS ON THE STATIC STABILITY CHARACTERISTICS OF A LARGE-SCALE TRIANGULAR WING, NACA RM L51J05, RESTRICTED.

An investigation of a large-scale triangular wing with 60 deg. leading-edge sweep and with 10 percent thick circular-arc airfoil section parallel to the plane of symmetry was conducted in the Langley full-scale wind tunnel to determine the effect of wing leading-edge modifications and several outboard fin arrangements on low-speed static stability characteristics. The Reynolds number varied from 2.7×10^6 to 9.7×10^6.

See also A8, A14, AAa6, AAa14, AAb14, AAb48, AAb54, AAb56, ADb2, ADb29, AEa2, AG3, and AG4.

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ADb. WINGS, GEOMETRIC VARIABLES, ASPECT RATIO

ADb1 Flügel, G., CONCERNING THE FLOW ON PLATES AND PLATELIKE BODIES (Ueber die Strömung an Platten und Plattenähnlichen Körpern), Schiffbau, Bd. 30, 1929, p. 336.

A brief theoretical treatment is given of the flow over plates and platelike bodies of various aspect ratios.

ADb2 Flaschbart, O., MEASUREMENTS ON PLAIN AND CAMBERED PLATES (Messungen an ebenen und gewölbten Platten) Ergeb. d. AVA Göttingen, IV, Lief. 1932, p. 96.

ADb3 Zimmerman, C.H., CHARACTERISTICS OF CLARK Y AIRFOILS OF SMALL ASPECT RATIOS, NACA TR 431, 1932.

ADb4 Zimmerman, C.H., AERODYNAMIC CHARACTERISTICS OF SEVERAL AIRFOILS OF LOW ASPECT RATIO, NACA TN 539, 1935.

ADb5 Schilhansl, M., THE INDUCED DRAG OF WINGS WITH SMALL ASPECT RATIO (Der induzerte Widerstand von Flügeln mit kleinem Seitenverhältnis) LFF Bd. 12, 1935, p. 55.

ADb6 Weinig, F., CONTRIBUTION TO THE THEORY OF FINITE AIRFOILS, ESPECIALLY OF SMALL SPAN (Beitrag zur Theorie des Tragflügels endlicher insbesondere kleiner Spannweite) LFF Bd. 13, 1936, p. 405.

ADb7 Weinig, F.,CONTRIBUTION TO THREE-DIMENSIONAL AIRFOIL FLOW (Beitrag zur räumlichen Tragflügelstromung) ZAMM Bd. 16, 1936, pp. 376-377.

ADb8 Bollay, William, A THEORY FOR RECTANGULAR WINGS OF SMALL ASPECT RATIO, J. Aero.Sci., Vol. 4, No. 7, May 1937, p. 294.

The results of a theoretical investigation of the wing of finite span but zero aspect ratio are described. A nonlinear wing theory is derived which correctly predicts the asymptotic values of normal force coefficient for both zero and infinite aspect ratios: For the first $C_N = 2 \sin^2 \alpha$, and for the second $C_N = 2 \pi \sin \alpha \cos \alpha$. At intermediate aspect ratios, it holds well for aspect ratios less than one; however, approximate values are given even for larger aspect ratios.

ADb9 Weinig, F., THE CALCULATION OF THE INDUCED RESISTANCE IN THE CASE OF SMALL ASPECT RATIO (Die Berechnung des induzierten widerstandes bei kleinem Seitenverhältnis), LFF, Bd. 14, 1937, p. 439.

ADb10 Bollay, W., A NONLINEAR WING THEORY AND ITS APPLICATION TO RECTANGULAR WINGS OF SMALL ASPECT RATIO ZAMM Bd. 19, 1939; p. 21, also in Jahrb. d.D.L. I, 139, 1939.

ADb11 Mangler, W., THE MINIMUM INDUCED DRAG OF WINGS OF SMALL ASPECT RATIO (Der kleinste induzierte Widerstand eines Tragflügels mit kleinem Seitenverhältnis) Jahrb. d.D.L. Luftfahrt-Forsch. I, 139, 1939.

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ADb12 Jones, R.T., CORRECTION OF THE LIFTING-LINE THEORY FOR THE EFFECT OF THE CHORD, NACA TN 817, July 1941.

It is shown that a simple correction for the chord of a finite wing can be deduced from the three-dimensional potential flow around an elliptic plate. When this flow is compared with the flow around a section of an endless plate, it is found that the edge velocity is reduced by the factor 1/E, where E is the ratio of the semiperimeter to the span. Applying this correction to the circulation brings the theoretical lift into closer agreement with experiments.

ADb13 Jones, R.T., THEORETICAL CORRECTION FOR THE LIFT OF ELLIPTIC WINGS, J. Aero. Sci., Vol. 9, No. 1, Nov. 1941, pp. 8-10.

The aspect-ratio correction for the lift of elliptical wings is discussed.

ADb14 Wood, K.D., ASPECT RATIO CORRECTIONS, J. Aero. Sci., Vol. 10, No. 8, Oct. 1943, pp. 270-272.

Assumptions and results of various theoretical analyses are summarized, and a new form of plotting is proposed showing the discrepancies between various theories and between theory and experiment. Empirical relationships consistent with acceptable theory are proposed which closely approximate the experimental results.

ADb15 Glaliahu, M., A SUMMARY OF RESULTS OF SOME GERMAN MODEL TESTS ON WINGS OF SMALL ASPECT RATIO, RAE TN No. Aero. 1917, 1944.

ADb16 Lyons, D.J. and Bisgood, P.L., AN ANALYSIS OF THE LIFT SLOPE OF AEROFOILS OF SMALL ASPECT RATIO, INCLUDING FINS, WITH DESIGN CHARTS FOR AEROFOILS AND CONTROL SURFACES, ARC R & M 2308, Jan. 1945.

Prediction is given of the lift curve slope of airfoils (including tail fins) of low aspect ratio, allowing for the influence of the body and end plate effect of horizontal surface on vertical tail surface.

ADb17 Crandall, S.M., LIFTING-SURFACE-THEORY RESULTS FOR THIN ELLIPTIC WINGS OF ASPECT RATIO 3 WITH CHORDWISE LOADINGS CORRESPONDING TO 0.5-CHORD PLAIN FLAP AND TO PARABOLIC ARC CAMBER, NACA TN 1064, May 1946.

The electromagnetic-analogy method is used to obtain lifting-surface-theory solutions applicable to the determination of aspect-ratio corrections for the slope of the curve of hinge-moment coefficient against flap deflection. Solutions were obtained for two vortex patterns representing unswept elliptic wings having aspect ratios of 3. The actual method of applying the results to hinge-moment and lift computations is not discussed.

ADb18 Hills, B.A., Lock, R.C. and Ross, J.G., INTERIM NOTE ON WIND TUNNEL TESTS OF A MODEL DELTA WING, RAE TN Aero. 1869, Feb. 1947, RESTRICTED.

Preliminary results are presented from the first of a series of low-speed wind-tunnel tests which were made on a wing of delta plan form. The basic plan form consisted of a triangle with 45 deg. sweep back of leading edge and aspect ratio 4.0 with the wing-tip removable in two stages to give aspect ratios of 3.0 and 2.3. The wing and detachable fuselage were both of symmetrical section. Tests were made with chord constant and tapered (elevons) and included effect of ground.

$C_{L_{max}}$ was 0.86 for all plan forms with elevons zero. This reduces to a trimmed value of 0.65 with a static margin of $0.10\bar{c}$ due to loss of lift due to elevons. All aspect ratios gave large nose down pitching moments at the stall.

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ADb19 Adler, A.A., EFFECT OF COMBINATION OF ASPECT RATIO AND SWEEPBACK AT HIGH SUBSONIC MACH NUMBERS, NACA RM L7C24, June 4, 1947, 21 pp.

ADb20 Weinig, F., LIFT AND DRAG OF WINGS WITH SMALL SPAN, NACA TM 1151, Aug. 1947, (Translation of Deutsche Luftfahrtforschung Forschungsbericht Nr. 1665, Sept. 8, 1942.).

The lift coefficient of a wing of small span at first shows a linear increase for increasing angle of attack, but to a lesser degree than is to be expected according to the theory of the lifting line; thereaftet the lift coefficient increases more rapidly than linearly as predicted by lifting line theory. The induced drag coefficient for a given lift coefficient, on the other hand, is obviously much smaller than it would be according to this theory. The author, by analogy to the theory of airfoils in cascade, has derived correction factors which can be applied to lifting line predictions to give results which agree more closely with experimental investigation.

ADb21 Goodman, A. and Brewer, J.D., INVESTIGATION AT LOW SPEEDS OF THE EFFECT OF ASPECT RATIO AND SWEEP ON STATIC AND YAWING STABILITY DERIVATIVES OF UNTAPERED WINGS, NACA TN 1669, Aug. 1948.

A low-scale wind-tunnel investigation was conducted in straight and yawing flow to determine the effect of aspect ratio and sweep (when varied independently) on the static and yawing stability derivatives for a series of untapered wings. The curved flow equipment of the Langley stability tunnel was used for the tests. Tests were made for sweep angles of 0, 45, and 60 degrees; aspect ratios 1.34, 2.61, 5.16; Reynolds numbers 190,000 - 1,580,000 and Mach number 0.13.

ADb22 Voepel, H., TESTS ON WINGS OF SMALL ASPECT RATIO (Messungen an Tragflügeln kleiner Streckung) MOS Library Translation 276, October 1948 (German original in AVA Goettingen Report 19/9/46).

This report summarizes results of a series of 6-component tests initiated by the author on wings of aspect ratio 0.5-33.0, in various German wind tunnels during World War II. The influence of the fuselage and the effect of plain flaps were investigated, some at Mach numbers up to 2. A critical review of existing theories of wings of small aspect ratio, as complete as possible from the point of view of practical application, precedes the diagrams in which the results are collected.

ADb23 Lindsey, W.F. and Humphreys, M.D., EFFECTS OF ASPECT RATIO ON AIR FLOW AT HIGH-SUBSONIC MACH NUMBERS, NACA RM L8G23, Oct. 4, 1948, 13 pp.

ADb24 Swanson, R.S. and Crandall, S.M., LIFTING-SURFACE THEORY ASPECT RATIO CORRECTIONS TO THE LIFT AND HINGE MOMENT PARAMETERS FOR FULL-SPAN ELEVATORS ON HORIZONTAL TAIL SURFACES, NACA TR 911, 1948, also RM L6D26a and TN 1175.

The available lifting surface theory solutions for wings with chordwise loadings resulting from angle of attack, parabolic arc camber, and flap deflection were studied with the purpose of determining a method for extrapolating the results in such a way that they could be used to determine lifting surface theory values of the aspect ratio correction to the lift and hinge-moment parameters for both angle of attack and flap-deflection type loading that could be used to predict the characteristics of horizontal tail surfaces from section data with sufficient accuracy for engineering purposes. In spite of the complexity of the theory the application is simple and requires no knowledge of lifting surface theory.

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ADb25 Locke, F.W.S., AN EMPIRICAL STUDY OF LOW ASPECT RATIO LIFTING SURFACES WITH PARTICULAR REGARD TO PLANING CRAFT, J. Aero. Sci., Vol. 16, No. 3, Mar. 1949.

The results of a brief empirical study of the lift characteristics in incompressible flow of low aspect ratio lifting surfaces.

ADb26 Ross, J.G., Hills, R. and Lock, R.C., WIND TUNNEL TESTS ON A 90 DEG. APEX DELTA WING OF VARIABLE ASPECT RATIO. - PART I - GENERAL STABILITY, RAE Report Aero. 2333, Aug. 1949, CONFIDENTIAL.

An investigation of three low-aspect-ratio delta wings of different taper ratio was undertaken with consideration given to effect of body.

ADb27 Goodman, A. and Fisher, L.R., INVESTIGATION AT LOW SPEEDS OF THE EFFECT OF ASPECT RATIO AND SWEEP ON ROLLING STABILITY DERIVATIVES OF UNTAPERED WINGS, NACA TN 1835, 1949.

ADb28 Nelson, W.H. and Erickson, A.L., THE EFFECT OF ASPECT RATIO ON THE SUBSONIC AERODYNAMIC CHARACTERISTICS OF WINGS WITH NACA 65_1-210 SECTIONS, NACA RM A9K18, Feb. 1950, CONFIDENTIAL.

Lift, drag, and moment characteristics of four model wings with aspect ratios 1, 2, 4 and 6 are presented. All wings had 65_1-210 section, taper ratio 0.4 and 3 deg. dihedral, with no sweep at the quarter-chord line. The data are obtained for Mach numbers 0.4 to 0.9 and angle of attack range 4 to 20 deg. Transition location and its effect on drag are studied.

ADb29 Goodman, A. and Jaquet, B., LOW-SPEED PITCHING DERIVATIVES OF LOW ASPECT RATIO WINGS OF TRIANGULAR AND MODIFIED TRIANGULAR PLAN FORMS, NACA RM L50C02, April 1950, RESTRICTED.

The results of an investigation in the Langley stability tunnel to determine the effects of changes in profile and aspect ratio on the pitching derivative of triangular and modified triangular wings are compared with available theory.

ADb30 Robinson, A , AEROFOIL THEORY FOR SWALLOW-TAIL WINGS OF SMALL ASPECT RATIO, College of Aeronautics, Cranfield, England, Report 41, Oct. 1950, 18 pp.

The development of a procedure for calculating the aerodynamic forces acting on the wing.

ADb31 Goodman, A. and Fisher, L.R., INVESTIGATION AT LOW SPEEDS OF THE EFFECT OF ASPECT RATIO AND SWEEP ON ROLLING STABILITY DERIVATIVES OF UNTAPERED WINGS, NACA TR 968, 1950.

The paper presents the results of tests conducted at low scale in the rolling flow section of the Langley stability tunnel to determine the effect of independent variation of aspect-ratio and sweep on the rolling stability derivatives of a series of untapered wings.

ADb32 Hopkins, E.J., LIFT, PITCHING MOMENT AND SPAN LOAD CHARACTERISTICS OF WINGS AT LOW SPEED AS AFFECTED BY VARIATIONS OF SWEEP AND ASPECT RATIO, NACA TN 2284, January 1951.

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ADb33 Fischel, J. and Hagerman, J.R., EFFECT OF ASPECT RATIO AND SWEEPBACK ON THE LOW-SPEED LATERAL CONTROL CHARACTERISTICS OF UNTAPERED LOW-ASPECT-RATIO WINGS EQUIPPED WITH RETRACTABLE FLAPS, NACA TN 2347, May 1951.

A low-speed wind-tunnel investigation was made to determine the lateral control characteristics of three untapered, unswept wings of aspect ratio 1.13, 2.13, and 4.13 and an untapered 45 deg. sweptback wing of aspect ratio 2.09 equipped with 0.60-semispan retractable ailerons having various projections.

ADb34 Küchemann, D., Weber, J, and Brebner, G.G., LOW SPEED TESTS ON WINGS OF 45 DEG. SWEEP. PART II - BALANCE AND PRESSURE MEASUREMENTS ON WINGS OF DIFFERENT ASPECT RATIOS, RAE Report Aero. 2419, May 1951, CONFIDENTIAL.

ADb35 Naeseth, R.L. and O'Hare, W.M., EFFECT OF ASPECT RATIO ON THE LOW-SPEED LATERAL CONTROL CHARACTERISTICS OF UNSWEPT UNTAPERED LOW-ASPECT RATIO WINGS, NACA TN 2348, May 1951.

An investigation of a series of untapered unswept complete wings of aspect ratio 1.13, 2.13, 4.13 , and 6.13 at a Mach number of 0.26 was undertaken to determine the effect of aspect ratio on lateral control characteristics of wings equipped with 0.25-chord sealed ailerons of various spans and various spanwise locations. Design charts are presented for computing aileron effectiveness on low aspect ratio untapered unswept wings. Experimental values of control effectiveness are compared with values estimated by theoretical methods.

ADb36 Purser, P.E. and Spearman, M.L., WIND TUNNEL TESTS AT LOW SPEED OF SWEPT AND YAWED WINGS HAVING VARIOUS PLAN FORMS, NACA TN 2445 (formerly RM L7D23), Dec. 1951.

Results of wind-tunnel tests made at low speed with various small-scale models of sweptback, sweptforward, and yawed wings are described. The tests covered changes in aspect ratio, taper ratio and tip shape. Some data were obtained with high-lift devices on sweptback wings and with ailerons on sweptforward wings. The data are briefly analyzed and some comparisons are made with available theory.

See also A3, AAa2, AAa5, AAa16, AAa18, AAb13, AAb23, AAb24, AAb26, AAb29, AAb30, AAb42, AAb43, AAb45, AAb54, AAb55, AAb56, AB1, AB5, AB7, AB9, AD1, AD2, AD3, AD8, AD19, ADa5, ADd1, ADe1, ADe2, ADh2, AFa18, BG6, D7, DA4, DA5, and DA15.

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ADc. WINGS, GEOMETRIC VARIABLES, DIHEDRAL

ADc1 Maggin, B. and Schanks, R.E., THE EFFECT OF GEOMETRIC DIHEDRAL ON THE AERODYNAMIC CHARACTERISTICS OF A 40 DEG. SWEPTBACK WING OF ASPECT RATIO 3, NACA TN 1169, 1946.

ADc2 Queijo, M.J. and Jaquet, B.M., INVESTIGATIONS OF EFFECTS OF GEOMETRIC DIHEDRAL ON LOW-SPEED STATIC STABILITY AND YAWING CHARACTERISTICS OF AN UNTAPERED 45 DEG. SWEPT-BACK-WING MODEL OF ASPECT RATIO 2.61, NACA TN 1668, 1948.

An investigation was conducted to determine the effect of geometric dihedral on low-speed static stability and yawing characteristics of an untapered 45 deg. sweptback wing model of aspect ratio 2.61. The results of the tests indicated that an increase in positive dihedral causes an increase in rolling moment due to sideslip and also causes maximum value of rolling moment due to sideslip to occur at increasingly higher lift coefficients.

See also ADb26 and ADd3.

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ADd. WINGS, GEOMETRIC VARIABLES, SWEEP

ADd1 Letko, W. and Goodman, A., PRELIMINARY WIND-TUNNEL INVESTIGATION AT LOW-SPEED OF STABILITY AND CONTROL CHARACTERISTICS OF SWEPT-BACK WINGS, NACA TN 1046, 1946.

Tests to investigate the effect of sweepback on stability and control effectiveness were performed on untapered constant span wings of 0, 30, 45, and 60 deg. sweepback, of aspect ratio 2.52 to 5.03. The tests were run at a q of 39.7 lb/ft^2, a Mach number of 0.165, and Reynolds number of 0.99 to 1.98 x 10^6.

ADd2 McCormack, G.M. and Stevens, V.I., AN INVESTIGATION OF THE LOW-SPEED STABILITY AND CONTROL CHARACTERISTICS OF SWEPT-FORWARD AND SWEPT-BACK WINGS IN THE AMES 40- BY 80-FOOT WIND TUNNEL, NACA RM A6K15, June 10, 1947, RESTRICTED.

ADd3 Tosti, L.P., LOW-SPEED STATIC STABILITY AND DAMPING IN ROLL CHARACTERISTICS OF SOME SWEPT AND UNSWEPT LOW-ASPECT-RATIO WINGS, NACA TN 1468, Oct. 1947.

Investigation at low speed was made in the Langley free-flight tunnel and 15-ft free-spin tunnel to determine the static stability and damping in roll characteristics of a number of low-aspect-ratio inclined sweptback wings of approximately triangular plan. Static longitudinal stability, directional stability, effect of dihedral, and damping in roll were investigated for a range of lift coefficients through maximum lift. Most wings were of aspect ratio less than 3, although four wings of higher aspect ratio were included for comparison.

ADd4 Goodman, A. and Feigenbaum, D., PRELIMINARY INVESTIGATION AT LOW SPEEDS OF SWEPT WINGS IN YAWING FLOW, NACA RM L7109, Feb. 4, 1948, RESTRICTED .

Results of a wind-tunnel investigation to determine the rotary stability characteristics in yawing flow of a series of untapered wings having angles of sweep of -45, 0, 45, and 60 deg. The curved flow equipment of the Langley stability tunnel was used for the greater part of the tests. For comparison purposes, a free-oscillation method was used to obtain the damping in yaw for the same wings. Wings of aspect ratio 5.16, 2.61, and 1.34 were tested at a Mach number of 0.13 and Reynolds numbers of approximately 10^6.

ADd5 McCormack, G.M. and Cook, W.L., A STUDY OF STALL PHENOMENA ON A 45 DEG. SWEPT-FORWARD WING, NACA TN 1797, Jan. 1949.

See also A3, A14, AAb13, AAb15, AAb22, AAb24, AAb26, AAb29, AAb31, AAb36, AAb43, AAb44, AAb49, AAb51, AAb53, AB7, AB11, AD2, AD4, AD5, AD6, AD7, AD9, AD19, ADa5, ADb19, ADb21, ADb27, ADb31, ADb32, ADb33, ADb36, ADe1, ADe2, AEa11, AF6, AFa11, AFa12, AFa18, AG1, AG2, CB3, D7, DA4, and DA15.

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ADe. WINGS, GEOMETRIC VARIABLES, TAPER

ADe1 Anderson, R.F., CHARTS FOR DETERMINING THE PITCHING MOMENT OF TAPERED WINGS WITH SWEEPBACK AND TWIST, NACA TN 483, Dec. 1933.

A convenient method is described for calculating the pitching moment characteristics of tapered wings with sweepback and twist. Data for calculating these characteristics are presented in curves which apply to wings having a linear distribution of twist along the span and which cover a large range of aspect ratios (aspect ratio 3 and above).

ADe2 Anderson, R.F., DETERMINATION OF THE CHARACTERISTICS OF TAPERED WINGS, NACA TR 572, 1936.

Tables and charts are presented for determining the characteristics of tapered wings for a range of aspect ratios from 2 to 20; the factors given include effects of twist and sweepback. Tests are described for nine tapered wings, including wings with sweepback and twist. A final section is given outlining a method for estimating the lift coefficient at which a tapered wing begins to stall. The author states that the factors presented in this report become less reliable as aspect ratio is decreased; however he presents no comparisons with experiment other than for an aspect ratio of six.

ADe3 Letko, W. and Cowan, J.W., EFFECT OF TAPER RATIO ON LOW-SPEED STATIC AND YAWING STABILITY DERIVATIVES OF 45 DEG. SWEPTBACK WINGS WITH ASPECT RATIO OF 2.61, NACA TN 1671, 1948.

See also AAb13, AAb19, AAb24, AAb26, AAb29, AAb43, AAb48, AAb54, AD3, AD4, ADa5, ADh2, D7, and DA15.

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ADf. WINGS, WING VARIABLES, TIP

See AAa4, AAa5, AAa9, and ADb36.

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ADg. WINGS, WING VARIABLES, TWIST

See AAa14, AAb26, AAb29, AAb47, ADa4, ADe1, ADe2, and DA15.

ADh. WINGS, WING VARIABLES, END PLATES

ADh1 Mangler, W., THE LIFT DISTRIBUTION ON WINGS WITH LATERAL DISCS (Die auftriebsverteilung am Tragflügel mit seitlichen Scheiben), LFF, Bd. 16, 1939, p. 219; see also TIB Translation 2338.

ADh2 Riebe, J.M. and Watson, J.M., THE EFFECT OF END PLATES ON SWEPT WINGS AT LOW SPEEDS, NACA TN 2229, Nov. 1950.

An investigation was carried out in the Langley 300-mph 7- × 10-ft tunnel to determine the effect of various sizes and shapes of end plates on the aileron characteristics and the aerodynamic characteristics in pitch and yaw of (1) an untapered wing of aspect ratio 2 and a sweepback of 45 deg. and (2) a wing of aspect ratio 4, taper ratio 0.6 and sweepback of 46.7 deg. Free roll characteristics were obtained with two end-plate configurations on a wing of aspect ratio 3, taper ratio 0.6 and a sweepback of 35 deg. in order to determine the effect of end plates on wing damping in roll.

ADh3 Wadlin, K.L., Fontana, R.E. and Shuford, C.L., THE EFFECT OF END PLATES, END STRUTS AND DEPTH OF SUBMERGENCE ON THE CHARACTERISTICS OF A HYDROFOIL, NACA RM L51B13, April 1951, CONFIDENTIAL.

An investigation in Langley Tank 2 of the effect of end plates and end-mounted struts indicated that at subcavitation speeds only small improvements might be expected in the maximum lift-drag ratios by the addition of end plates. End struts reduced the lift-drag ratio attainable with a single strut. The effect of end plates and end struts on effective aspect ratio was in good agreement with theory. An approximate theoretical solution of the effect of depth on lift of a hydrofoil was developed. The hydrofoil, of aspect ratio 4, was tested at speeds above the limiting speed (13.9 fps) of wave propagation for the 6-ft. depth of tank used.

See also A6, A9, AAb12, AF1, AF7, AF8, and DC4.

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AE. WINGS, HIGH-LIFT DEVICES

See entries under AEa and AEb.

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AEa. WINGS, HIGH-LIFT DEVICES, FLAPS

AEa1 Tamburello, V., Smith, B.J., and Silvers, H.N., WIND TUNNEL INVESTIGATION ON CONTROL SURFACES. CHARACTERISTICS OF PLAIN AND BALANCED FLAPS ON AN NACA 0009 ELLIPTICAL SEMISPAN WING, NACA ARR L5L18, (also WR L41), 1946.

Results of a series of force tests in the Langley 4 x 6 vertical wind tunnel on an NACA 0009 elliptical semispan wing of aspect ratio 3, equipped with a flap either 50 percent of the wing area or 30 percent of the wing area. The 30 percent flap was tested as a plain flap and with 35 percent flap-chord and 50 percent flap-chord elliptical nose overhangs.

AEa2 Neely, R.H. and Koven, W., LOW-SPEED CHARACTERISTICS IN PITCH OF A 42 DEG. SWEPTBACK WING WITH ASPECT-RATIO 3.9 AND CIRCULAR-ARC AIRFOIL SECTION, NACA RM L7E23, Nov. 1947, RESTRICTED.

Tests were conducted in the Langley 19-ft. pressure tunnel on low-speed aerodynamic characteristics of a 42 deg. sweptback wing with circular-arc airfoil sections at Reynolds numbers from 3 to 9 x 10^6. The effects of extensible round-nose leading-edge flaps and of a fuselage at several vertical positions are shown and the results are compared with those of a wing with same plan form but incorporating NACA 64-series airfoil sections.

AEa3 Lichtenstein, J.H., EFFECT OF HIGH-LIFT DEVICES ON THE LOW-SPEED STATIC LATERAL AND YAWING STABILITY CHARACTERISTICS OF AN UNTAPERED 45 DEG. SWEPTBACK WING, NACA RM L8G20, Sept. 30, 1948, RESTRICTED.

This paper describes a wind-tunnel investigation undertaken in the Langley stability tunnel to determine the effect of lift flaps (nose and split trailing edge) on lateral stability derivatives and yawing derivatives of an untapered sweptback wing of aspect ratio 2.61 at low speed. The results indicated that in general the addition of inboard trailing edge split flaps tended to displace the curves for both the rolling moment due to yaw and the rolling moment due to yawing velocity negatively, whereas addition of 0.9-span outboard split flaps tended to displace the curves for both rolling moments positively. Trailing edge flaps tended to increase both directional stability and damping in yaw.

AEa4 Stephenson, J.D. and Amuedo, A.R., TESTS OF A TRIANGULAR WING OF ASPECT RATIO 2 IN THE AMES 12-FT PRESSURE WIND TUNNEL. II - THE EFFECTIVENESS AND HINGE MOMENTS OF A CONSTANT-CHORD FLAP, NACA RM A8E03, Sept. 1948, RESTRICTED.

The results of tests of a semi-span model of a triangular wing of aspect ratio 2 are presented. The effects of deflecting a constant-chord plain flap were investigated for Reynolds numbers ranging from 5.3 x 10^6 to 15 x 10^6.

AEa5 Lange, R.H. and May, R.W., EFFECT OF LEADING-EDGE HIGH-LIFT DEVICES AND SPLIT FLAPS ON THE MAXIMUM LIFT AND LATERAL CHARACTERISTICS OF A RECTANGULAR WING OF ASPECT RATIO 3.4 WITH CIRCULAR ARC AIRFOIL SECTIONS AT REYNOLDS NUMBERS FROM 2.9 x 10^6 TO 8.4 x 10^6, NACA RM L8D30, Nov. 10, 1948, RESTRICTED.

Results are presented of an investigation at high Reynolds number and low Mach number in the Langley full-scale wind tunnel to determine the effect of leading-edge high-lift devices and split flaps on $C_{L_{max}}$ and lateral characteristics of a rectangular wing of aspect ratio 3.4 with circular-arc airfoil section. Measurements were made of the static aerodynamic characteristics in pitch and in yaw of the basic wing and of the wing with several leading-edge high-lift devices and 0.20-chord split flaps deflected alone and in combination with one another. Scale effects were investigated at Reynolds numbers 2.9 x 10^6 to 8.4 x 10^6.

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AEa6 Johnson, B.H. and Reed, V.D., INVESTIGATION OF A THIN WING OF ASPECT RATIO 4 IN THE AMES 12-FT PRESSURE WIND TUNNEL, IV - THE EFFECT OF A CONSTANT-CHORD LEADING-EDGE FLAP AT HIGH SUBSONIC SPEEDS, NACA RM A8K19, Jan. 20, 1949, CONFIDENTIAL.

Tests were made at Mach 0.20 - 0.94 of a thin straight wing of aspect ratio 4 with a full-span, constant-chord leading-edge flap. The wing profile was a modified diamond with thickness ratio of 0.042. Investigation was made at Reynolds number 2 x 10^6. The deflection of leading-edge flap produced an increase in $(C_L/C_D)_{max}$ and an increase in C_L at $(C_L/C_D)_{max}$ for all Mach numbers below 0.94. At Mach 0.94, deflection of the flap resulted in a decrease in $(C_L/C_D)_{max}$.

AEa7 Wick, B.H. and Graham, D., EXPLORATORY INVESTIGATION OF EFFECT OF OF SKEWED PLAIN NOSE FLAPS ON THE LOW-SPEED CHARACTERISTICS OF A LARGE-SCALE TRIANGULAR-WING-FUSELAGE MODEL, NACA RM A9K22, Jan. 12, 1950, RESTRICTED.

An investigation was undertaken the effect of skewed plain nose flaps on a thin, low-aspect ratio triangular wing in combination with … fineness-ratio fuselage conducted at low speed and high Reynolds number. The plan form of the flaps was such that the flap chord varied from zero percent of chord at centerline to 100 percent at 91 percent semispan. Lift, drag and pitching moment were obtained over an angle of attack range of -2 to 30 deg. at zero sideslip. The Reynolds numbers of the investigation were 12.5 x 10^6 and 14.1 x 10^6 (based on wing mean aerodynamic chord of 16.37 ft.).

AEa8 Johnson, H.S. and Hagerman, J.R., WIND TUNNEL INVESTIGATION AT LOW SPEED OF AN UNSWEPT, UNTAPERED SEMISPAN WING OF ASPECT-RATIO 3.13 EQUIPPED WITH VARIOUS 25 PERCENT CHORD PLAIN FLAPS, NACA TN 2080, April 1950.

Wind-tunnel force and moment data were obtained at low speed to determine characteristics of an unswept, untapered semispan wing of NACA 64A010 section of aspect ratio 3.13 equipped with 25 percent chord unsealed plain flaps having various span and spanwise locations. Lift, drag and pitching moment, and flap hinge moment data were obtained for the wing with the various flaps deflected up to 60 deg.

AEa9 Pasamanick, J. and Sellers, T., LOW-SPEED INVESTIGATION OF LEADING EDGE AND TRAILING EDGE FLAPS ON A 47.5 DEG. SWEPTBACK WING OF ASPECT RATIO 3.4 AT A REYNOLDS NUMBER OF 4.4 X 10^6, NACA RM L50E02, June 1950, RESTRICTED.

Various extensible leading-edge and plain trailing-edge flaps were investigated in the Langley full-scale tunnel on a wing-fuselage combination. The wing leading-edge sweepback was 47.5 deg., the aspect ratio was 3.4, the taper ratio 0.51, and the airfoil sections were NACA 64_1A112. The data presented include effect of flap design parameters on lift, drag and pitching moment characteristics at zero yaw for a range of angles of attack at a Reynolds number of 4.4 x 10^6.

AEa10 Foster, G.V. and Griner, R.F., LOW-SPEED LONGITUDINAL CHARACTERISTICS OF A CIRCULAR-ARC 52 DEG. SWEPTBACK WING OF ASPECT RATIO 2.84, WITH AND WITHOUT LEADING-EDGE AND TRAILING-EDGE FLAPS AT REYNOLDS NUMBERS FROM 1.6 x 10^6 to 9.7 x 10^6, NACA RM L50F16a, Aug. 11, 1950, RESTRICTED.

The results of tests to determine the low-speed longitudinal characteristics of a 52 deg. swept-back wing with circular-arc airfoil sections and an aspect-ratio of 2.84 are presented. The Reynolds number was varied from 1.6 x 10^6 to 9.7 x 10^6. The effects of several variations of flap span on the aerodynamic characteristics of the wing were investigated.

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AEa11 Johnson, H.S. and Hagerman, J.R., WIND TUNNEL INVESTIGATION AT LOW SPEED OF A 45 DEG. SWEPTBACK UNTAPERED SEMISPAN WING OF ASPECT RATIO 1.59 EQUIPPED WITH VARIOUS 25 PERCENT CHORD PLAIN SLAPS, NACA TN 2169, Aug. 1950, 26 pp.

AEa12 Johnson, H.I. and Goodman, H.R., MEASUREMENTS OF AERODYNAMIC CHARACTERISTICS OF A 35 DEG. SWEPTBACK NACA 65-009 AIRFOIL MODEL WITH QUARTER-CHORD FLAP HAVING A 31 PERCENT FLAP CHORD OVERHANG BALANCE BY THE NACA WING-FLOW METHOD, NACA RM L50H09, Sept. 25, 1950, CONFIDENTIAL.

AEa13 Lacaine, J., CHARACTERISTICS AT LANDING SPEEDS OF 60 DEG. SWEPT WINGS EQUIPPED WITH TRAILING-EDGE FLAPS (Caracteristiques aux Vitesses d'atterrissage d'Ailes en Flèche a 60 Deg. équipees de Dispositifs Hypersustentateurs Arrières) La Recherche Aéronautique, No. 19, 1951 1951, pp. 29-40.

AEa14 Stone, H.N., AERODYNAMIC CHARACTERISTICS OF LOW-ASPECT-RATIO WINGS WITH VARIOUS FLAPS AT SUBSONIC SPEEDS, Cornell Aero. Lab. Report No. AF-743-A-2. Jan. 1952.

The low-aspect-ratio theory of Lawrence is used to calculate the lift slope per unit flap deflection, wing center of pressure location, flap hinge moment and lift acting on the flap for a class of straight trailing-edge wing plan forms with various symmetric flaps.

See also A7, A12, AAa8, AAa18, AAb48, AAb54, AB3, AB8, AB9, AB15, AC1, AC2, ADb17, ADb22, ADb33, AF8, AFa9, DA5, DA11, and DA13.

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AEb. WINGS, HIGH-LIFT DEVICES, SLOTS AND SLATS

See AC2 and AEa5.

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AF. WINGS, CONTROLS

AF1 Bradfield, F.B., MAXIMUM LIFT COEFFICIENT OF RAF 30 ALL-MOVING RUDDER, ARC R & M 1321, Feb. 1930.

AF2 Goett, H.J. and Reeder, J.P., EFFECTS OF ELEVATOR NOSE SHAPE, GAP, BALANCE, AND TABS ON THE AERODYNAMIC CHARACTERISTICS OF A HORIZONTAL TAIL SURFACE, NACA TR 675, 1939.

Results are presented showing the effects of gap, elevator nose shape, balance, cut-out, and tabs on the aerodynamic characteristics of a horizontal tail surface tested in the NACA full-scale tunnel. A comparison of the various experimental aerodynamic characteristics with those computed from Glauert's thin-airfoil theory for hinged flaps is also given.

AF3 Wenzinger, C.J. and Rogallo, M., WIND-TUNNEL INVESTIGATION OF SPOILER, DEFLECTOR, AND SLOT LATERAL-CONTROL DEVICES ON WINGS WITH FULL-SPAN SPLIT AND SLOTTED FLAPS, NACA TR 706, 1941.

AF4 Jones, R.T. and Kleckner, H.F., THEORY AND PRELIMINARY FLIGHT TESTS OF AN ALL-MOVABLE VERTICAL TAIL SURFACE, NACA WR L-496, Jan. 1943.

This investigation demonstrates the advantages of an all-movable tail surface as compared with the conventional flap type.

AF5 Sears, R.I., WIND TUNNEL DATA ON THE AERODYNAMIC CHARACTERISTICS OF AIRPLANE CONTROL SURFACES, NACA WR L-663, Dec. 1943, also NACA ACR 3L08.

AF6 Toll, T.A. and Schneiter, L.E., APPROXIMATE RELATIONS FOR HINGE-MOMENT PARAMETERS OF CONTROL SURFACES ON SWEPT WINGS AT LOW MACH NUMBERS, NACA TN 1711, Oct. 1948.

This report describes an approximate method of accounting for the effect of sweep, applied to previously determined equations for hinge-moment parameters of control surfaces on unswept wings. The method accounts for the effect of sweep on section parameters and makes use of the approximation that, regardless of the sweep angle, the relation between average induced angle of attack and C_L is the same as that for an unswept elliptical wing. Lifting-surface theory corrections for induced camber effect are considered in an approximate manner. No attempt is made to account for subsonic compressibility effect, although a brief discussion of such effects is included.

AF7 Fischel, J. and Watson, J.M., LOW-SPEED INVESTIGATION OF DEFLECTABLE WING-TIP AILERONS ON AN UNTAPERED 45 DEG. SWEPTBACK SEMISPAN WING WITH AND WITHOUT AN END PLATE, NACA RM L9J28, Dec. 1949.

A low-speed wind-tunnel investigation to determine the characteristics of deflectable wing-tip ailerons on an untapered 45 deg. sweptback semispan wing was made in the Langley 300-mph 7- by 10-ft. tunnel. The ailerons were tested on a plain wing and on a wing with a rectangular end plate mounted inboard of the ailerons. The wing aspect ratios were 1.87 and 2.31.

AF8 Jaquet, B.M., Queijo, M., and Lichtenstein, J.H., LOW-SPEED STATIC LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF A 60 DEG. TRIANGULAR WING MODEL HAVING HALF-DELTA TIP CONTROLS, NACA RM L51D20a, Jun. 1951, CONFIDENTIAL.

A low-speed investigation of static longitudinal stability and control effectiveness o. 60 deg. triangular wing model with delta tip controls was undertaken and a comparison made with constant-chord flaps. The effect of fuselage and end plates on stability and control characteristics are presented, and the results are compared with available theory where possible.

AF9 Hagen, G.R., EFFECTS OF VARIATIONS IN THICKNESS/CHORD RATIO OF RUDDERS IN A SLIPSTREAM, TMB Report C-487, Jan. 1952,

See also A6, A11, ADa6, ADb24, DA2, DA12, and DB4.

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AFa. WINGS, CONTROLS, FLAP TYPE

AFa1 Harris, T.A., REDUCTION OF HINGE MOMENTS OF AIRPLANE CONTROL SURFACES BY TABS, NACA TR 528, 1935.

An investigation of control surfaces equipped with tabs for reducing control force or trimming the aircraft was undertaken at the NACA 7- x 10-ft tunnel. Two sizes of ordinary ailerons with several sizes of attached and inset tabs were tested on a Clark Y wing (A = 6) and on a tail-surface model of symmetric section equipped with tabs. The tail surface aspect ratios were 3.0 and 1.5, respectively, with and without a reflection plane.

AFa2 Ames, M.B. and Sears, R.I., DETERMINATION OF CONTROL-SURFACE CHARACTERISTICS FROM NACA PLAIN-FLAP AND TAB DATA, NACA TR 721, 1941.

Data from previous NACA pressure-distribution investigations of plain flaps and tabs with sealed gaps have been analyzed and are presented in this paper in a form readily applicable to control surface design. The experimentally determined variation of aerodynamic parameters with flap chord and tab chord are given in chart form and comparisons are made with theory. A discussion of the basic equations of thin airfoil theory and the development of a number of additional equations pertaining to tail design are given in the appendices. The procedure for applying the data is described, and a sample problem of horizontal tail design is included.

AFa3 Swanson, R.S. and Gillis, C.L., LIMITATIONS OF LIFTING LINE THEORY FOR ESTIMATION OF AILERON HINGE-MOMENT CHARACTERISTICS, NACA WR L281, Dec. 1943.

AFa4 Lowry, J.G., Maloney, J.A. and Garner, I.E., WIND TUNNEL INVESTIGATION OF SHIELDED HORN BALANCES AND TABS ON A 0.7-SCALE MODEL OF XF6F VERTICAL TAIL SURFACE, NACA WR L516, Mar. 1944.

AFa5 Liddell, R.B. and Lockwood, V.E., WIND-TUNNEL INVESTIGATION OF ROUNDED HORNS AND OF GUARDS ON A HORIZONTAL TAIL SURFACE, NACA WR L60, Oct. 1944.

AFa6 Garner, I.E., WIND TUNNEL INVESTIGATION OF CONTROL-SURFACE CHARACTERISTICS XX - PLAIN AND BALANCED FLAPS ON AN NACA 0009 RECTANGULAR SEMISPAN TAIL SURFACE, NACA WR L186, Oct. 1944.

AFa7 Crane, R.M., COMPUTATION OF HINGE-MOMENT CHARACTERISTICS OF HORIZONTAL TAILS FROM SECTION DATA, NACA CB 5B05, April 1945.

AFa8 Lowry, J.G., Turner, T.R. and Liddell, R.B., AERODYNAMIC CHARACTERISTICS OF SEVERAL MODIFICATIONS OF A 0.45-SCALE MODEL OF THE VERTICAL TAIL OF THE CURTISS XP-62 AIRPLANE, NACA WR L736, July 1946.

AFa9 Hoggard, H.P. and McKinney, E.G., WIND-TUNNEL INVESTIGATION OF CONTROL-SURFACE CHARACTERISTICS OF PLAIN AND BALANCED FLAPS WITH SEVERAL TRAILING EDGE ANGLES ON AN NACA 0009 TAPERED SEMISPAN WING, NACA TN 1248, 1947.

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AFa10 Fischel, J. and Schneiter, L.E., AN INVESTIGATION AT LOW SPEED OF A 51.3 DEG. SWEPTBACK SEMISPAN WING WITH A RAKED TIP AND WITH 16.7-PERCENT-CHORD AILERONS HAVING THREE SPANS AND THREE TRAILING-EDGE ANGLES, NACA RM L8F29, July 21, 1948.

AFa11 Lowry, J.G. and Schneiter, L.E., ESTIMATION OF EFFECTIVENESS OF FLAP-TYPE CONTROLS ON SWEPTBACK WINGS, NACA TN 1674, Aug. 1948.

AFa12 Fischel, J. and Schneiter, L.E., AN INVESTIGATION AT LOW SPEED OF A 51.3 DEG. SWEPTBACK SEMISPAN WING EQUIPPED WITH 16.7-PERCENT-CHORD PLAIN FLAPS AND AILERONS HAVING VARIOUS SPANS AND THREE TRAILING-EDGE ANGLES, NACA RM L8H20, Nov. 12, 1948, RESTRICTED.

Lift, drag, pitching-moment, and flap hinge-moment data were obtained for the subject wing equipped with several spans of sealed and unsealed flaps deflected up to 60 deg., and rolling-moment, yawing-moment, hinge-moment, and aileron-seal-pressure data were obtained for the various combinations of aileron span and trailing-edge angles. In addition, the wing aerodynamic characteristics were determined for a spoiler-type aileron configuration having a span of 60 percent of the wing semispan and a projection of 5-percent wing chord in conjunction with a 92.5-percent-span flap deflected 0, 30, and 60 deg.

AFa13 Lange, R.H., FULL-SCALE INVESTIGATION OF A WING HAVING THE LEADING EDGE SWEPT BACK 47.5 DEG. AND HAVING CIRCULAR ARC AND FINITE TRAILING-EDGE THICKNESS AILERONS, NACA RM L9B02, 1949.

Results of an investigation in the Langley full-scale wind tunnel to determine the aerodynamic characteristics of a wing with the leading edge swept back 47.5 deg. and with a 20-percent chord, 50-percent span outboard aileron are presented. The wing had a symmetrical circular-arc airfoil section and was investigated both with a circular-arc contour aileron and with a flat-sided contour aileron with trailing-edge thickness. Tests were also made to determine the aileron effectiveness with and without the modified aileron. All data are presented for a Reynolds number of about 3×10^6 and a Mach number of about 0.7.

AFa14 Naeseth, R.L. and O'Hare, W.M., THE EFFECT OF AILERON SPAN AND SPANWISE LOCATION ON THE LOW-SPEED LATERAL CONTROL CHARACTERISTICS OF AN UNTAPERED WING OF ASPECT-RATIO 2.09 AND 45 DEG. SWEEPBACK, NACA RM L9I09a, Feb. 10, 1950, 20 pp., RESTRICTED.

Low-speed lateral control investigation of untapered complete wing of aspect-ratio 2.09 and 45 deg. sweepback with 0.25-chord flap-type ailerons of variable span and spanwise location. Tests were made at a Reynolds number of 3.1×10^6.

AFa15 Johnson, H.S. and Hagerman, J.R., WIND-TUNNEL INVESTIGATION AT LOW SPEED OF THE LATERAL CONTROL CHARACTERISTICS OF AN UNSWEPT UNTAPERED SEMISPAN WING OF ASPECT RATIO 3.13 EQUIPPED WITH VARIOUS 25 PERCENT CHORD PLAIN AILERONS, NACA TN 2199, Aug. 1950, 32 pp.

Investigation of a wing equipped with 25 percent chord plain unsealed ailerons of various spans and spanwise locations. Changes in wing angle of attack, aileron deflection, aileron span and spanwise aileron location produced trends in the lateral control characteristics that are similar to but of different magnitude from those for unswept wings of higher aspect ratio. An aileron of given percent span was most effective in producing roll when located outboard on wing semispan, and this aileron also retained its effectiveness throughout greater range of angle of attack in this position.

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AFa16 Pasamanick, J. and Sellers, T.B., LOW-SPEED INVESTIGATION OF THE EFFECT OF SEVERAL FLAP AND SPOILER AILERONS ON THE LATERAL CHARACTERISTICS OF A 45.5 DEG. SWEPTBACK WING-FUSELAGE COMBINATION AT A REYNOLDS NUMBER OF 4.4×10^6, NACA RM L50J20, Dec. 1950, CONFIDENTIAL

Results are presented of an investigation in the Langley full-scale tunnel of various plain spoiler and flap-type ailerons on a wing-fuselage combination. The wing leading-edge sweepback was 47.5 deg., the aspect-ratio 3.4, the taper ratio 0.51, and the airfoil section NACA 64_1A112. The data include the effect of aileron span spoiler location and projection on the longitudinal and lateral characteristics at zero yaw for a range of angles at a Reynolds number of 4.4×10^6.

AFa17 Johnson, H.S. and Hagerman, J.R., WIND-TUNNEL INVESTIGATION AT LOW SPEED OF LATERAL CONTROL CHARACTERISTICS OF AN UNTAPERED 45 DEG. SWEPTBACK SEMISPAN WING OF ASPECT RATIO 1.59 EQUIPPED WITH VARIOUS 25-PERCENT CHORD PLAIN AILERONS, NACA TN 2316, Mar. 1951.

This describes a wind-tunnel investigation at low speed to determine lateral control characteristics of a 45 deg. sweptback untapered semispan wing of aspect ratio 1.59 equipped with 25-percent chord plain unsealed ailerons with various spans and span locations. The results indicate that aileron effectiveness increases as aileron span is increased and that a partial-span aileron was most effective in producing rolling moment when located outboard on the wing semispan. The change of hinge-moment coefficient with angle of attack and aileron deflectors at low angles was only slightly affected by aileron span. Existing empirical relationships for predicting aileron effectiveness parameter and aileron hinge-moment parameter gave satisfactory agreement with experimental results.

AFa18 Harper, J.J., WIND-TUNNEL INVESTIGATION OF EFFECTS OF VARIOUS AERODYNAMIC BALANCE SHAPES AND SWEEPBACK ON CONTROL-SURFACE CHARACTERISTICS OF SEMISPAN TAIL SURFACES WITH NACA 0009, 0015, 66-009, 66(215)-014 AND CIRCULAR-ARC AIRFOIL SECTIONS, NACA TN 2495, Oct. 1951.

A summary of force data on unswept and sweptback airplane control surface is presented. Lift and hinge moment characteristics were determined for four unswept semispan control surfaces, and lift, drag, hinge moment and pitching moment were determined for two semispan sweptback control surfaces. Tests were performed in the 9-ft wind tunnel of the Georgia Institute of Technology. Measured values were compared with values computed by lifting surface and lifting line theory. The unswept models were of taper ratio 0.4 and aspect ratio 3.36; the swept models were of taper ratio 0.4 and aspect ratio 3.30, with quarter-chord line sweptback 40 deg.

AFa19 Hammond, A.D., THE EFFECT OF RAKING THE AILERON TIPS ON THE LATERAL CONTROL AND HINGE MOMENT CHARACTERISTICS OF A 20 PERCENT CHORD PARTIAL SPAN OUTBOARD AILERON ON A WING WITH LEADING EDGE SWEPTBACK 51.3 DEG., NACA RM L51H29, Nov. 26, 1951, CONFIDENTIAL.

See also A1, A11, A12, A14, AAa2, AAb49, AB3, AD9, ADb18, ADb31, ADb33, ADb34, ADb35, AG6, D11, DB2, DC1, and DC3.

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AFb. WINGS, CONTROLS, SPOILERS

See AFa16.

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AG. WINGS, REYNOLDS NUMBER EFFECTS

AG1 Sweberg, H.H. and Lange, R.H., SUMMARY OF AVAILABLE DATA RELATING TO REYNOLDS NUMBER EFFECTS ON THE MAXIMUM LIFT COEFFICIENTS OF SWEPTBACK WINGS, NACA RM L6L20a, Mar. 4, 1947.

AG2 Proterra, A.J., AERODYNAMIC CHARACTERISTICS OF A 45 DEG. SWEPTBACK WING WITH ASPECT RATIO OF 3.5 AND NACA 2S-50(05)-50(05) AIRFOIL SECTIONS, NACA RM L7C11, 1947, CONFIDENTIAL.

Results of an investigation to determine the aerodynamic characteristics at high Reynolds number and low Mach number of a 45 deg. swept-back wing with aspect ratio 3.5, taper ratio 0.5 and circular-arc airfoil section are presented. Scale effects were investigated at Reynolds numbers ranging from 2.1×10^6 to 8.0×10^6; the effects of yaw were investigated at a Reynolds number of 4.1×10^6. This wing exhibited poor low-speed characteristics.

AG3 Edwards, G.G. and Stephanson, J.D., TESTS OF A TRIANGULAR WING OF ASPECT RATIO 2 IN THE AMES 12-FOOT PRESSURE WIND TUNNEL. I - THE EFFECT OF REYNOLDS NUMBER AND MACH NUMBER ON THE AERODYNAMIC CHARACTERISTICS OF THE WING WITH FLAP UNDEFLECTED, NACA RM A7K05, Jan. 22, 1948, RESTRICTED.

This report presents results of tests of a semispan model of a wing having a triangular plan form, an aspect ratio of 2, and a double-wedge uncambered airfoil section with the maximum thickness at 20 percent of the chord. The effects of the addition of a fuselage and of minor modifications to the airfoil section were investigated. Aerodynamic characteristics of the model are presented for a range of Reynolds numbers from 5,000,000 to 27,500,000 at 0.18 Mach number and for a range of Mach number from 0.18 to 0.95 at 5,300,000 Reynolds number.

AG4 Johnson, B.H., INVESTIGATION OF A THIN WING OF ASPECT RATIO 4 IN THE AMES 12-FOOT PRESSURE WIND TUNNEL. I - CHARACTERISTICS OF A PLAIN WING, NACA RM A8D07, June 2, 1948, CONFIDENTIAL.

Results of tests of a semispan model of an unswept wing with aspect ratio 4, taper ratio 0.5 and 4.5 percent thick diamond profile are presented. The effect of rounding the profile ridge was also investigated. The Reynolds number was varied from 2.0 to 10.19×10^6 at a Mach number of 0.20 and Mach number was varied from 0.20 to 0.94 at a Reynolds number below 3×10^6. There was boundary layer separation near the ridge at low Reynolds numbers, but rounding the ridge diminished this separation, increased the L/D ratio, and decreased the $C_{D_{min}}$.

AG5 Reynolds, R.M. and Smith, D.W., AERODYNAMIC STUDY OF A WING-FUSELAGE COMBINATION EMPLOYING A WING SWEPT BACK 63 DEG., SUBSONIC MACH AND REYNOLDS NUMBER EFFECTS ON THE CHARACTERISTICS OF THE WING AND ON THE EFFECTIVENESS OF AN ELEVON, NACA RM A8D20, 1949, CONFIDENTIAL.

A wind-tunnel investigation was undertaken of a semispan model of a wing having 63-deg. sweepback, aspect ratio 3.0 and taper ratio (tip chord/root chord) of 0.25. These tests were conducted to evaluate effect of Reynolds number and Mach number on the aerodynamic characteristics of the wing. Included in the investigation were measurements of the effectiveness of an elevon used as a longitudinal control.

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AG6 Kolbe, C.D. and Bandettini, A., INVESTIGATION IN THE AMES 12-FOOT PRESSURE WIND TUNNEL OF A MODEL HORIZONTAL TAIL OF ASPECT RATIO 3 AND TAPER RATIO 0.5 HAVING THE QUARTER-CHORD LINE SWEPT BACK 45 DEG., NACA RM A51D02, June 25, 1951, RESTRICTED.

An investigation was undertaken to evaluate the effect of Reynolds number and Mach number on the aerodynamic characteristics of a horizontal tail of aspect ratio 3, equipped with a plain, sealed, full-span elevator. The line joining the quarter-chord points of the airfoil section was swept back 45 deg. and the sections perpendicular to this line were of NACA 64A010 profile. Increasing the Reynolds number from 2×10^6 to 18×10^6 at Mach 0.25 resulted in a sizable reduction in C_D at moderate to high values of C_L. Within this Reynolds number range, the lift characteristics of the horizontal tail were little affected by the dynamic scale, but the hinge-moment and pitching moment characteristics were affected, especially at high angles of attack or elevator deflection. Increase in Mach number at constant Reynolds number caused an increase in $dC_L/d\alpha$ and elevator effectiveness.

See also A7, AB1, AC2, AD5, AD6, AD7, AD8, AD9, AD10, AD12, AD13, AD14, AD16, AD17, AD18, AD19, AD20, ADa4, ADa5, ADb1, AEa2, AEa4, AEa5, AEa7, AEa10, DA8, DA10, and DA15.

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AH. WINGS, MACH NUMBER EFFECTS

AH1 Heaslet, M.A. and Nitzberg, G.E., THE CALCULATION OF DRAG FOR AIRFOIL SECTIONS AT SUBCRITICAL SPEEDS, NACA RM A7B06, April 1947, 42 pp.

AH2 Stack, J. and Lindsey, W.F., CHARACTERISTICS OF LOW-ASPECT-RATIO WINGS AT SUPERCRITICAL MACH NUMBERS, NACA Report 922, 1949, also NACA TN 1665, Aug. 1948.

AH3 Reese, D.E. and Phelps, E.R., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT-RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - PLANE TAPERED WING OF ASPECT RATIO 3.1 WITH 3 PERCENT THICK BICONVEX SECTION, NACA RM A50K28, Jan. 1951, CONFIDENTIAL.

The report presents the results of an investigation to ascertain the lift, drag and pitching moment of a wing-body combination having a plane tapered wing of aspect ratio 3.1 and 3 percent thick biconvex sections in streamwise planes. Results are given for Mach 0.60 to 0.925 and from 1.2 to 1.9 at a Reynolds number of 2.4×10^6.

See also AAb19, AAb36, AAb48, AB12, AD11, AD12, AD13, AD16, AD17, AD18, AD20, ADa4, ADb19, ADb22, ADb23, ADb28, AEa4, AEa6, AG3, AG4, AG5, AG6, BG1, CC5, D5, DA10, and DB3.

B. BODIES

B1 Landweber, L., STABILITY OF A STREAMLINED BODY FALLING THROUGH A FLUID WITH UNIFORM SPEED, TMB Report R-42, Sept. 1941.

B2 Meixner, J., LAME'S WAVE FUNCTIONS OF THE ELLIPSOID OF REVOLUTION, NACA TM 1224, Apr. 1949, (Translation of German document dated June 1944.)

B3 Albring, W., STABILITY OF BODIES OF REVOLUTION ABOUT THE LONGITUDINAL AXIS, UWDA GTD 3308, 1949, (Translation of German document ZWB-U & M 6424, 18 Nov. 1944.)

B4 Albring, W., STERN CONTROL SURFACE OF SOLIDS OF REVOLUTION FURNISHING OPTIMUM MOMENTS OF RETURN, BuShips Trans. No. 95, 26 Jan. 1945.

B5 Laitone, E.V., THE LINEARIZED SUBSONIC AND SUPERSONIC FLOW ABOUT INCLINED SLENDER BODIES OF REVOLUTION, J. Aero. Sci., Vol. 14, No. 11, Nov. 1947, pp. 631-642.

Rigorous first order linearized solutions are obtained for the subsonic and supersonic flow about bodies of revolution. Surface pressures are found by means of a Taylor series expansion in terms of cross-section area. Resulting simple expressions are shown to be in satisfactory agreement with existing experimental data. It is proved that previous solutions of the linear supersonic flow equations have retained terms that are incompatible with the basic potential equations of compressible flow at high Mach numbers.

Analysis indicates that linear theory correctly predicts the variation of pressure coefficient at high Mach numbers.

B6 Riegels, F., THE PROBLEM OF THE FLOW AROUND A BODY IN INCOMPRESSIBLE POTENTIAL FLOW (Das Umstromungsproblem bei inkompressiblen Potentialströmungen), Part II, Ing. Archiv. V17N1-2, 1949, pp. 94-106.

B7 Landweber, L. and Gertler, M., MATHEMATICAL FORMULATION OF BODIES OF REVOLUTION, TMB Report 719, Sept. 1950.

B8 Wieghardt, K., ON THE TUNNEL CORRECTION FOR THE ANGLE OF INCIDENCE ON LONG BODIES OF REVOLUTION, ARL Report ARL/R3/G/Hy/4/1; ACSIL/ADM/51/241, Mar. 1951.

See also BB9, FA1, FA3, FA4, FA5, FA6 and FA7.

BA. BODIES, TOTAL FORCES AND MOMENTS

BA1 Lagally, M., COMPUTATION OF THE FORCES AND MOMENTS WHICH FLOWING FLUIDS EXERT ON THEIR BOUNDARY (Berechnung der Kräfte und Momente, die Strömende Flüssigkeiten auf ihre Begrenzung ausüben), ZAMM, Bd. 2, 1922.

BA2 Klemperer, W., WIND-TUNNEL RESEARCH ON A ZEPPELIN AIRSHIP MODEL (Windkanalversuche an einem Zeppelin Luftschiff Model), Abhandlungen aus dem Aerodynamischen Institut an der Technische Hochschule, Aachen, Heft 12, 1932.

BA3 Freeman, H.B., FORCE MEASUREMENTS ON A 1/40-SCALE MODEL OF THE U.S. AIRSHIP ''AKRON'', NACA TR 432, 1932.

BA4 Fomina, N., CALCULATION OF THE FRICTIONAL RESISTANCE OF A FAMILY OF BODIES OF REVOLUTION ACCORDING TO THE EXPONENTIAL LAW, Royal Tech. Press Trans. 796 of Russian publication dated July 1938.

BA5 Young, A., THE CALCULATION OF THE TOTAL AND SKIN FRICTION DRAG OF BODIES OF REVOLUTION AT ZERO INCIDENCE, ARC R & M 1874, Apr. 1939.

BA6 Lange, G., FORCE AND PRESSURE DISTRIBUTION MEASUREMENTS ON EIGHT FUSELAGES, NACA TM 1194, Oct.1948, (Trans. of German document dated Oct. 24, 1941.)

BA7 Hansen, M., THREE-COMPONENT MEASUREMENTS ON BODIES OF REVOLUTION WITH VARIOUS TAIL SURFACES (Dreikomponentenmessungen an Drehkörpern mit Verschieden Leitwerken), AVA FB 1330, 1941.

BA8 Schirmer, M., AERODYNAMIC MODEL TESTS WITH GERMAN AND FOREIGN TYPES OF AIRSHIPS IN THE WIND TUNNEL OF THE LUFTSCHIFFBAU ZEPPELIN AT FRIEDERICHSCHAFFEN, CADO, Wright Field, ATI4-3846, (Trans. of German thesis dated 1942.)

BA9 Kempf, G., MOMENTS OF CAMBERED ROUND BODIES, NACA TM 1227, Aug. 1949, 15 pp.

BA10 Allen, H.J., ESTIMATION OF THE FORCES AND MOMENTS ACTING ON INCLINED BODIES OF REVOLUTION OF HIGH FINENESS RATIO, NACA RM A9126, Nov. 1949, CONFIDENTIAL.

BA11 Laitone, E.V., THE TRANSVERSE FORCE AND MOMENT ON A THREE-DIMENSIONAL BODY, Mare Island Naval Shipyard Report, 1949.

BA12 Ward, G.N., SUPERSONIC FLOW PAST SLENDER POINTED BODIES, Quart. J. Mech. Appl. Math., Vol. 2, Pt. 1, 1949, pp. 75-97.

BA13 Cocke, B.W., Lipson, S. and Scallion, W.I., DATA FROM TESTS OF A 1/5-SCALE MODEL OF A PROPOSED HIGH-SPEED SUBMARINE IN THE LANGLEY FULL-SCALE TUNNEL, NACA RM SL50E09a, May 1950, CONFIDENTIAL.

BA14 Betz, A., THE METHOD OF SINGULARITIES FOR THE DETERMINATION OF FORCES AND MOMENTS ACTING ON A BODY IN POTENTIAL FLOW, TMB Trans. 241 (Rev.), June 1951.

BA15 Moskowitz, B., APPROXIMATE THEORY FOR CALCULATION OF LIFT OF BODIES, AFTERBODIES, AND COMBINATIONS OF BODIES, NACA TN 2669, April 1952.

An expression is developed for the lift of a slender afterbody in terms of the "slender-body" approximate potential at the after end in conjunction with a suitably calculated value of the potential at the forward end. The same expression is used to compute the part of the interference lift generated by the presence of a neighboring body due to the interference upwash . Another expression is developed to compute the remainder of the interference lift due to an interference pressure gradient. Examples are given.

See also BB5, BB7, BB13, BC17, BD1, BF1, BF2, C1, CB9, D2, FA1, FA3, FA4, FA5, FA6, and FA7.

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BB. BODIES, LOAD DISTRIBUTION

BB1 Munk, M.M., THE AERODYNAMIC FORCES ON AIRSHIP HULLS, NACA TR 184, 1924.

This report discusses the computation of lift distribution and moment on an elongated body in an ideal fluid.

BB2 von Kármán, Th., CALCULATION OF PRESSURE DISTRIBUTION ON AIRSHIP HULLS, NACA TM 574, 1930.

BB3 Upson, R.H. snd Klikoff, W.A., APPLICATION OF PRACTICAL HYDRODYNAMICS TO AIRSHIP DESIGN, NACA TR 405, 1931.

BB4 Munk, M.M., AERODYNAMIC THEORY OF AIRSHIPS, Aerodynamic Theory, Vol. VI, Durand, W.F., Editor, Durand Reprinting Committee, California Institute of Technology, 1943 (Reprint of 1934 edition).

BB5 Harrington, R.P., AN ATTACK ON THE ORIGIN OF LIFT OF AN ELONGATED BODY, Publication No. 2, Daniel Guggenheim Airship Institute, 1935, pp. 32-50.

BB6 Maruhn, K., PRESSURE DISTRIBUTION COMPUTATIONS ON ELLIPTICAL BODIES AND IN THEIR SURROUNDING SPACE (Druckverteilungsrechnungen an elliptischen Rümpfen und in ihrem aussenraum) Jahrb. d.D.L., 1941, pp. I135-147.

Formulas and charts are presented for the determination of the pressure distribution and stagnation points of a triaxial ellipsoidal body in uniform rectilinear motion. The solution is obtained for points in the field as well as on the surface.

BB7 Multhopp, H., AERODYNAMICS OF THE FUSELAGE, NACA TM 1036, 1942.

BB8 Bloch, R.M., COMPUTATION OF PRESSURE DISTRIBUTION ABOUT A SERIES OF BODY FORMS, BuShips Computation Project Report No. 22, Harvard University, Cambridge, Mass., Aug. 1944.

BB9 Munzer, H., ROTATIONALLY SYMMETRIC SOURCE-SINK BODIES WITH ALMOST CONSTANT PRESSURE DISTRIBUTION (Rotationssymmetrische quellsenkenkörper mit überwiegend konstanter Druckverteilung), ZWB U & M M6616, Nov. 1944.

BB10 Brand, M., PRESSURE DISTRIBUTIONS OVER BODIES OF REVOLUTION FOR AXIAL FLOW (Druckverteilungen von Rotationskörper bei Achsialer Strömung), TMB Trans. 220, April 1947 (Trans. of AVA UM 3206 dated 30 Dec. 1944).

BB11 Bilharz, K., CALCULATION OF PRESSURE DISTRIBUTION ON BODIES OF REVOLUTION IN THE SUBSONIC FLOW OF A GAS. PART I - AXIALLY SYMMETRICAL FLOW, NACA TM 1153, July 1947 (Trans. of ZWB FB 1169/1).

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BB12 Maruhn, K., PRESSURE DISTRIBUTION ON A TRIAXIAL ELLIPSOID BODY UNIFORMLY MOVED IN A STRAIGHT LINE, FB 1174, Lockheed Aircraft Corp. translation by John Perl of German Microfilm No. 51, Göttingen Documents Reel No .46, n.d.

A method of calculating the pressure distribution and the shockpoint of a triaxial ellipsoid body moving uniformly in a straight line is presented. This calculation may serve for the approximate determination of pressure distributions on airplane fuselages, nacelles, etc. Curves are plotted of pressure distributions for various angles of pitch and yaw for a few examples within the range of the most frequently occurring fuselage and nacelle bodies. For a few cases, comparisons were made between calculation and test results.

BB13 Hoerner, S., THE AERODYNAMICS OF THREE-DIMENSIONAL BODIES, Report No. GT-37, Serial No. 5, CGD 756, McDonnell Aircraft Corp., 25 Feb. 1947.

BB14 Lamb, C.A., THE EFFECT OF ANGLES OF YAW ON PRESSURE DISTRIBUTION AROUND VARIOUS HEAD FORMS, M.S. Thesis, University of Iowa, 1948.

BB15 Allen, H.J., PRESSURE DISTRIBUTION AND SOME EFFECTS OF VISCOSITY ON SLENDER INCLINED BODIES OF REVOLUTION, NACA TN 2044, Mar. 1950.

In connection with a study of the flow around slender inclined bodies of revolution, a simplified solution for the pressure distribution on such bodies was developed by the author. He states that this solution should be suitable for high fineness ratio even at low supersonic speeds, provided the angle of attack is small. Comparison with low-speed experimental results indicates that the observed flow-separation phenomena can be explained in terms of the calculated pressure distributions together with the theory of oblique viscous flows.

BB16 Ackeret, J., Degen, M. and Rott, N., PRESSURE DISTRIBUTION ALONG BODIES OF REVOLUTION IN OBLIQUE SUBSONIC FLOW, L'Aerotecnica, 15 Feb. 1951 (31-1 Irreg.), pp. 11-19.

Wind-tunnel tests were conducted on a truncated paraboloid of revolution to determine the validity of the linearized theory for calculating the pressure distribution at velocities below Mach 0.95 and at various angles of incidence. The measured values show good agreement with those predicted by theory, particularly in the forward region of the body. Further refinement of the theoretical values may be attained by considering some quadratic terms in the pressure formula. Deviation between experimental and theoretical results at the rearward portion of the body is attributable to a boundary-layer effect and is thus dependent on the angle of incidence. It is concluded that the pressure distribution along elongated solids due to transverse flow with respect to the axis is independent of the Mach number.

BB17 Blanks, C., EXAMPLE OF PRESSURE DISTRIBUTION CALCULATION BY NEUMARKS' METHOD WITH EXPERIMENTAL COMPARISON., ARL Report ACSIL/ADM/52/49, Oct. 1951.

BB18 Mathews, C.W., A COMPARISON OF THE EXPERIMENTAL SUBSONIC PRESSURE DISTRIBUTIONS ABOUT SEVERAL BODIES OF REVOLUTION WITH PRESSURE DISTRIBUTIONS COMPUTED BY MEANS OF THE LINEARIZED THEORY, NACA TN 2519, Feb. 1952.

A comparison is made of the theoretical and experimental subsonic compressible pressure-coefficient distribution about several bodies of revolution. The results show that the linearized theory

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predicts the subsonic pressure coefficient over the central portion of the body. An extrapolation of the theory into the supercritical range does not predict the rearward shift of the negative pressure peak which occurs after the flow becomes critical. Two equations are presented for approximately determining the subsonic compressible pressure coefficient distribution from incompressible pressure coefficient distribution.

See also B5, BA2, BA6, BA8, BA10, BA11, BA12, BA14, BA15, BC1, BC3, BC4, BC5, BC7, BC9, BC14, BC15, BC16, BC18, BE1, BE2, BE4, BG8, CB9, CB10 and DC8.

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BC. BODIES, FLOW FIELD

BC1 Fuhrmann, G., THEORETICAL AND EXPERIMENTAL INVESTIGATIONS ON BALLOON MODELS (Theoretische und experimentelle untersuchungen an Ballonmodellen) Diss. Göttingen, 1912, Pub. in ZFM, Vol. 11, 1911.

BC2 Lotz, I., CALCULATION OF POTENTIAL FLOW PAST AIRSHIP BODIES IN YAW, NACA TM 675, July 1932, (Trans. of Article in Ing. Archiv, VII, 1931).

BC3 Smith, R.H., LONGITUDINAL POTENTIAL FLOW ABOUT ARBITRARY BODY OF REVOLUTION WITH APPLICATION TO AIRSHIP "AKRON". J. Aero. Sci., Vol. 3, No. 1, Sept. 1935.

BC4 Kaplan, C., POTENTIAL FLOW ABOUT ELONGATED BODIES OF REVOLUTION, NACA TR 516, 1935.

A method is given for solving the problem of axial and transverse flows about a body of revolution. A section on the determination of inertia coefficients is also included.

BC5 Kaplan, C., ON A NEW METHOD FOR CALCULATING THE POTENTIAL FLOW PAST A BODY OF REVOLUTION, NACA Report No. 752, 1943.

BC6 Yosida, Yosikatu, ON THE PROBLEM OF POTENTIAL FLOW ABOUT BODIES OF REVOLUTION, Nippon, sugaku-buturigakkwai, Tokyo, Proc. Sev. 3, Vol. 25, 1943.

BC7 Young, A.D. and Owen, P.R., A SIMPLIFIED THEORY FOR STREAMLINE BODIES OF REVOLUTION, AND ITS APPLICATION TO THE DEVELOPMENT OF HIGH SPEED SHAPES, ARC R & M 2071, 1943.

BC8 Serebrijsky, J., FLOW PAST BODIES OF REVOLUTION (In Russian with English summary), Prikladnaia matematika i mekanika, n.s. Vol. 8, 1944, pp. 99-108.

BC9 Schmidt, F.K., CALCULATIONS OF AIR FLOW IN THE VICINITY OF FUSELAGES, AMC Intel. Trans. ATI No. 19130, June 1945, 25 pp.

A new method for determining the airflow about a fuselage while at variance with previous methods is not limited to rotationally symmetrical fuselages. For the flow potential about a fuselage which is merged in any given parallel flow, a series expansion is given by means of interference calculation. The single terms of this series can be obtained from explicit finite formulas.

BC10 Riegels, F. and Brand, M., STREAM FUNCTIONS AND VELOCITY FIELDS OF THREE-DIMENSIONAL SOURCE DISTRIBUTIONS AND THEIR HANDY USE IN THE DETERMINATION OF CONTOUR AND PRESSURE DISTRIBUTION OF ROTATIONALLY SYMMETRIC BODIES WITH EXAMPLES (Stromfunctionen und Geschwindigkeitsfelder räumlicher Quellstrecken und ihr handlicher Gebrauch zur Bestimmung von Umriss und Druckverteilung rotationsymmetrischer Körper mit Beispielen) LFF, UM 3106, n.d.

BC11 Laitone, E.V., THE SUBSONIC AND SUPERSONIC FLOW FIELDS OF SLENDER BODIES, Proc. Sixth Int. Cong. Appl. Mech., Sept. 1946.

BC12 Heaslet, M.A., THE CALCULATION OF DRAG FOR AIRFOIL SECTIONS AND BODIES OF REVOLUTION AT SUBCRITICAL SPEEDS, NACA RM A7B06, 23 April 1947.

BC13 Laitone, E.V., THE SUBSONIC FLOW ABOUT A BODY OF REVOLUTION, Quart. Appl. Math., Vol. 5, No. 2, July 1947, pp. 227-231.

BC14 Weinstein, A., ON AXIALLY SYMMETRIC FLOWS, Quart. Appl. Math., Jan. 1948, pp. 429-444.

The method of sources and sinks is extended beyond their distribution on the axis of symmetry to distribution on circumferences, rings, discs, and cylinders. The investigation is based in part on Beltrami's results concerning hydrodynamic flows. By superposition of a parallel flow of constant velocity in the direction of the axis of symmetry and of a flow produced by an axially symmetric distribution of sources and sinks around the axis, essentially new types of flows are obtained, in particular, flows around blunt-nosed profiles.

BC15 Deleted.

BC16 von Wijngaarden, A., POTENTIAL FLOW AROUND A BODY OF REVOLUTION (Écoulement potentiel autour d'un corps de révolution), Colloques Internationaux du Centre National de la Recherche Scientifique, XIV, Méthodes de Calcul dans des Problèmes de Mécanique, Paris, 1948.

BC17 Walton, T., EQUATIONS FOR THE NUMERICAL DETERMINATION OF THE STEADY FLOW OF A VISCOUS LIQUID PAST A SOLID OF REVOLUTION, NOL Memo 9778, 19 Oct. 1949.

BC18 Newmark, S., VELOCITY DISTRIBUTION ON THIN BODIES OF REVOLUTION AT ZERO INCIDENCE IN INCOMPRESSIBLE FLOW - AND APPENDIX, CADO, ATI. 93-935, July 1950, 68 pp., RESTRICTED.

A new method for determining velocity distribution on slender bodies of revolution in axial flow is presented. The method is analogous to the linear perturbation method widely used for slender symmetrical profiles in two dimensions. Simple approximate formulas are given for velocity distribution on a body. The new method avoids many inconveniences of the older procedures and is much more rapid. Accuracy is satisfactory even for considerable thickness ratios. The method was used for computing velocity distributions on twelve different bodies of seven different thickness ratios each. Several practical conclusions have been derived by examination and comparison of these results.

BC19 Klein, M.M. and Perl, W., CALCULATION OF COMPRESSIBLE POTENTIAL FLOW PAST SLENDER BODIES OF REVOLUTION BY AN INTEGRATION METHOD, NACA TN 2245, Dec. 1950.

BC20 Landweber, L., THE AXIALLY SYMMETRIC POTENTIAL FLOW ABOUT ELONGATED BODIES OF REVOLUTION, TMB Report 761, August 1951.

BC21 Vandrey, F., A DIRECT ITERATION METHOD FOR THE CALCULATION OF THE VELOCITY DISTRIBUTION OF BODIES OF REVOLUTION AND SYMMETRICAL PROFILES, ARL Report ACS IL/ADM/51/600, Aug. 1951.

BC22 Woods, L.C., A NEW RELAXATION TREATMENT OF FLOW WITH AXIAL SYMMETRY, Quart. J. Mech. Appl. Math., Vol. 4, Pt. 3, Sept. 1951, pp. 358-370.

To eliminate the disadvantage of "irregular stars" in the relaxation mesh near curved boundaries, the differential equations for axially symmetric inviscid incompressible and compressible flows are transformed so that the velocity potential and Stokes stream function become the independent variables. The radial distance r is taken as the dependent variable in the incompressible flow equation.

See also B5, BA12, BA15, BB2, BB3, BB5, BB6, BB12, BD3, BD4, BD6, BE1, BE2, BE4, BG2, BG7, BG9, CB10 and FB1.

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BD. BODIES, BOUNDARY LAYER

BD1 Milliken, C.B., THE BOUNDARY LAYER AND SKIN FRICTION FOR A FIGURE OF REVOLUTION, APM-54-3, ASME Trans. 1932, pp. 29-43.

BD2 Freeman, H.B., MEASUREMENTS OF FLOW IN BOUNDARY LAYER OF A 1/40-SCALE MODEL OF THE U.S. AIRSHIP "AKRON", NACA TR 443, 1932.

BD3 Lyon, H.M., A STUDY OF THE FLOW IN THE BOUNDARY LAYER OF STREAMLINE BODIES, ARC R & M 1622, May 1934.

BD4 Granville, P., THE BOUNDARY LAYER AND DRAG OF BODIES OF REVOLUTION, TMB Report 726, September 1950.

BD5 Granville, P.S., A METHOD FOR THE CALCULATION OF THE TURBULENT BOUNDARY LAYER IN A PRESSURE GRADIENT, TMB Report 752, May 1951, 40 pp.

BD6 Golovato, P., PREDICTIONS AND MEASUREMENTS OF THE BOUNDARY LAYER AT THE STERN OF THE USS GRAMPUS (GUPPY-TYPE SUBMARINE), TMB Report C-485, February 1952, CONFIDENTIAL.

See also BA2, BB15 and BB16.

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BE. BODIES, EFFECT OF SHAPE

BE1 Young, A.D. and Owen, P.R., A SIMPLIFIED THEORY FOR STREAMLINE BODIES OF REVOLUTION AND ITS APPLICATION TO THE DEVELOPMENT OF HIGH-SPEED LOW-DRAG SHAPES, ARC R & M 2071, July 1943.

A method is presented for determining a streamline body of revolution which yields a velocity distribution approximate to a specified type.

BE2 Munzer, H. and Reichardt, H., ROTATIONALLY SYMMETRICAL SOURCE-SINK BODIES WITH PREDOMINATELY CONSTANT PRESSURE DISTRIBUTION, MOS ARE Trans. No. 1/50, 1950, (Trans. of German Report U.M. 6616, 1944.

BE3 Gertler, M., RESISTANCE MEASUREMENTS ON A SYSTEMATIC SERIES OF STREAMLINED BODIES OF REVOLUTION FOR APPLICATION TO THE DESIGN OF HIGH-SPEED SUBMARINES, TMB Report C-297, April 1950, CONFIDENTIAL.

BE4 McNown, J.S. and Hsu, En-Yun, APPROXIMATION OF AXISYMMETRIC BODY FORMS FOR SPECIFIED PRESSURE DISTRIBUTIONS, J. Appl. Phys., July 1951, pp. 864-868.

See also BA9, BB1, BB15, BC3, BC10, D12, and D17.

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BF. BODIES, REYNOLDS NUMBER EFFECTS

BF1 Albring, W., SIMILARITY CONSIDERATIONS OF FORCES ON SLENDER BODIES OF REVOLUTION, WITHOUT CONTROL SURFACES, SUBJECT TO OBLIQUE FLOW, UWDA Trans. of German Torpedo Document 3306, 1943.

BF2 Abbott, Ira H., AIRSHIP MODEL TESTS IN THE VARIABLE-DENSITY WIND TUNNEL, NACA TR 394, 1931.

See also ADa4, BB15, and BC17.

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BG- BODIES, MACH NUMBER EFFECTS

BG1 Göthert, B., PLANE AND THREE-DIMENSIONAL FLOW AT HIGH SUBSONIC SPEEDS, NACA TM 1105, Oct. 1946, (Trans. of Lilienthal Gesellschaft Report 127).

A simple relation is given for determining, as a first approximation, the influence of compressibility on the velocities and pressures in two- and three-dimensional flow. Calculations are given for the critical Mach number of slender elliptic cylinders and ellipsoids of revolution. Theory indicates that the increase in wing lift with Mach number is strongly dependent on the Mach number.

BG2 Lees, L., A DISCUSSION OF THE APPLICATION OF THE PRANDTL-GLAUERT METHOD TO SUBSONIC COMPRESSIBLE FLOW OVER A SLENDER BODY OF REVOLUTION, NACA TN 1127, 1946.

BG3 Young, A.D. and Kirkby, S., APPLICATION OF THE LINEAR PERTURBATION THEORY TO COMPRESSIBLE FLOW ABOUT BODIES OF REVOLUTION, College of Aeronautics, Cranfield, England, Report No. 11, Sept. 1947.

BG4 Dorrance, W.H., ON THE CONPRESSIBILITY CORRECTION FACTOR FOR AXIALLY SYMMETRIC BODIES, J. Aero. Sci., Vol. 16, No. 7, July 1949, pp. 443-444.

BG5 Young, A.D., ON THE COMPRESSIBILITY CORRECTION FACTOR FOR AXIALLY SYMMETRIC BODIES, J. Aero. Sci., Vol. 16, No. 11, Nov. 1949, p. 703.

BG6 Hess, R.V. and Gardner, C.S., STUDY BY THE PRANDTL-GLAUERT METHOD OF COMPRESSIBILITY EFFECTS AND CRITICAL MACH NUMBER FOR ELLIPSOIDS OF VARIOUS ASPECT RATIOS AND THICKNESS RATIOS, NACA TN 1792, 1949.

By the use of a form of the Prandtl-Glauert method that is valid for three-dimensional flow problems, the value of the maximum incremental velocity for compressible flow about thin ellipsoids at zero angle of attack is calculated as a function of Mach number for various aspect ratios and thickness ratios; triaxial as well as rotational ellipsoids are considered. The critical Mach numbers (within the accuracy of the Prandtl-Glauert method) of the various ellipsoids are also determined. Results indicate an increase in critical Mach number with decrease in aspect ratio which is large enough to explain the experimental results on low aspect-ratio wings at zero lift.

BG7 Oswatitsch, K., THE EFFECT OF COMPRESSIBILITY ON THE FLOW AROUND SLENDER BODIES OF REVOLUTION, K. Tekn. Högsk., TN12, 1950.

BG8 Boltz, F.W. and Beam, B.H., EFFECT OF COMPRESSIBILITY ON THE PRESSURE ON A BODY OF REVOLUTION AND ON THE AERODYNAMIC CHARACTERISTICS OF A WING-NACELLE COMBINATION CONSISTING OF THE BODY OF REVOLUTION MOUNTED ON A SWEPTBACK WING, NACA RM A50E09, July 1950, RESTRICTED.

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BG9 Rabineau, B.A., COMPRESSIBILITY CORRECTIONS FOR BODIES OF REVOLUTION, J. Aero. Sci., Vol. 19, No. 3, March 1952.

An approximate formula is derived for a compressibility correction on bodies of revolution at 0 deg. angle of attack. Results give good agreement with more exact methods.

See also ADa4, AH1, BA12, BB11, BB16, BB18, BC11, BC13, BC19, and DA10.

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C. COMPONENTS IN COMBINATION (INCLUDING MUTUAL INTERFERENCE EFFECTS)

C1 Abbott, I.A., THE DRAG OF TWO STREAMLINE BODIES AS AFFECTED BY PROTUBERANCES AND APPENDAGES, NACA TR 451, 1931.

C2 Schlichting, H., AERODYNAMICS OF MUTUAL INTERFERENCE OF AIRCRAFT PARTS, RAE Trans. No. 275, Volkenrode R & T No. 171 (GDC/137), Aug. 1946.

A survey of theoretical and experimental research in Germany during the preceding eight years is presented, with special emphasis on the aerodynamic forces due to mutual interference between separate parts of an aircraft. The theoretical investigations deal particularly with the interference between wing and fuselage (pressure distribution, pitching moment, rolling moment due to sideslip) and between wing-fuselage and tail surface (downwash and induced sidewash). The experimental investigations are mainly six-component measurements on idealized aircraft models consisting of wing-fuselage combinations and of wing fuselage and tail unit combinations with different shapes of wing and fuselage combined as low-, medium-, and high-wing combinations.

C3 Tulin, M.P., THE NATURE OF BOUNDARY LAYER INTERFERENCE PHENOMENA AT THE JUNCTURE OF INTERSECTING BODIES, TMB Report C-390, April 1951, CONFIDENTIAL.

See also A13, AAa7, AAa14, BA11, BA13, BB7, BC10, and CB1.

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CA. COMPONENTS IN COMBINATION, WING-WING

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CB. COMPONENTS IN COMBINATION, WING-BODY

CB1 Spreiter, J.R., AERODYNAMIC PROPERTIES OF SLENDER WING-BODY COMBINATIONS AT SUBSONIC, TRANSONIC, AND SUPERSONIC SPEEDS, NACA TN 1662, July 1948.

A method based on assumptions similar to those of Munk's airship theory and R.T. Jones' low-aspect-ratio pointed wing theory has been derived and expressions have been obtained for the load distribution, lift, and moment of inclined slender wing-body configurations having flat-plate wings and circular fuselage sections. The results apply to subsonic and transonic speeds and to supersonic speeds as well provided that the entire wing-body combination lies near the center of the Mach cone.

CB2 Ross, L.M., LOW-SPEED INVESTIGATION OF A SMALL TRIANGULAR WING OF ASPECT RATIO 2.0 - I. THE EFFECT OF COMBINATION WITH A BODY OF REVOLUTION AND HEIGHT ABOVE A GROUND PLANE, NACA RM A7K03, August 1948, RESTRICTED.

This report describes wind-tunnel tests of a triangular wing of aspect ratio 2.0, with symmetrical double-wedge section with a maximum thickness of 5 percent of the chord. The results are presented for the wing alone and in two locations on a body of fineness ratio 12.5. Further data are presented for wings at several heights above a ground plane.

CB3 McCormack, G.M. and Walling, W.C., AERODYNAMIC STUDY OF A WING-FUSELAGE COMBINATION EMPLOYING A WING SWEPT BACK 63 DEG. - INVESTIGATION OF A LARGE-SCALE MODEL AT LOW SPEED, NACA RM A8D02, Jan. 21, 1949, CONFIDENTIAL.

CB4 Smith, C.B., WIND-TUNNEL WALL CORRECTIONS FOR WING-BODY COMBINATION, J. Aero. Sci., Vol. 16, No. 4, April 1949.

CB5 Spreiter, J.R., AERODYNAMIC PROPERTIES OF CRUCIFORM-WING AND BODY COMBINATIONS AT SUBSONIC, TRANSONIC AND SUPERSONIC SPEEDS, NACA TN 1897, 1949.

CB6 Spreiter, J.R., THE AERODYNAMIC FORCES ON SLENDER PLANE- AND CRUCIFORM-WING AND BODY COMBINATIONS, NACA TR 962, 1950.

A theoretical method is given for determining the forces and moments on inclined slender-wing-body combinations consisting of a slender body of revolution and either a plane or cruciform arrangement of low-aspect-ratio pointed wings.

CB7 Jacobs, W., LIFT AND MOMENT CHANGES DUE THE FUSELAGE FOR A YAWED AIRPLANE WITH UNSWEPT AND SWEPT WINGS, FFA MED 34, 1950.

CB8 Stocker, P.M., SUPERSONIC FLOW PAST BODIES OF REVOLUTION WITH THIN WINGS OF SMALL ASPECT RATIO, Aero. Quart., Vol. 3, pp. 61-79, May 1951.

CB9 Low, L. and Stone, H.N., THE SUBSONIC AERODYNAMIC CHARACTERISTICS OF WINGS IN COMBINATION WITH SLENDER BODIES OF REVOLUTION, Cornell Aero. Lab. Inc. Report No. CAL/CM-679, July 1951.

A method is presented for determining the lift and pitching moment coefficients of combinations of wings with slender bodies of revolution typical of missile-booster-fin configurations. The method is compared with experimental results and with the theories of Spreiter and Lennertz. Comparisons are

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also made between the measured characteristics of slender bodies of revolution and the predictions of Flax and Lawrence and Allen.

CB10 Hopkins, E.J. and Carel, H.C., EXPERIMENTAL AND THEORETICAL STUDY OF THE EFFECTS OF BODY SIZE ON THE AERODYNAMIC CHARACTERISTICS OF AN ASPECT RATIO 3 WING-BODY COMBINATION, NACA RM A51G24, October 1951, CONFIDENTIAL.

Measurements of force and moment were made for a wing of aspect ratio 3.0 for three geometrically similar bodies of revolution (fineness ratio 12.5) for the wings in the presence of each of the bodies and for the wing combined with each. The ratios of body diameter to wing span were 0.196, 0.259, and 0.343. Good agreement was obtained between the experimental and calculated results by including velocity induced by body on wing and velocity induced by wing on body in the theoretical analysis.

CB11 Miles, J.W., ON SLENDER WING-BODY THEORY, J. Aero. Sci., Vol. 19, No. 2, February 1952, p. 140.

This is a letter criticizing the Spreiter analysis of the slender wing-body problem.

CB12 Zlotnick, M. and Diederick, F.W., THEORETICAL CALCULATION OF THE EFFECT OF THE FUSELAGE ON THE SPANWISE LIFT DISTRIBUTION ON A WING, NACA RM L51J19, March 3, 1952, RESTRICTED.

A method is presented for calculating the effect of the fuselage on the spanwise lift distribution on a wing by an application of a conformal-mapping procedure to the simplified lifting-surface theory. This method is said to be applicable to any symmetrical wing-fuselage configuration. At low angles of attack the method is shown to approach the theoretically correct limit for wing-fuselage combinations having a wing of vanishingly small aspect ratio and for those having a wing of infinite aspect ratio. Some calculations made by this method are compared with experimental data. A computing scheme is given in which the calculation for the infinitely long fuselage and the correction for the finite fuselage length are made separately; a numerical example is given.

CB13 Smith, D.W., Shibata, H.H. and Selan, R., LIFT, DRAG AND PITCHING MOMENT OF LOW-ASPECT-RATIO WINGS AT SUBSONIC AND SUPERSONIC SPEEDS - AN INVESTIGATION AT LARGE REYNOLDS NUMBERS OF THE LOW-SPEED CHARACTERISTICS OF SEVERAL WING-BODY COMBINATIONS, NACA RM A51K28, Feb. 1952, CONFIDENTIAL.

See also A12, AAa7, AAa14, AAb39, AAb55, AC2, AD1, AD14, ADa4, ADb18, ADb22, ADb26, AEa2, AEa7, AEa9, AF8, AFa16, AG3, AH3, BA12, BA13, BB7, BG8, C1, C3, CC2, CC7, D7, and DA11.

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CC. COMPONENTS IN COMBINATION, WING-BODY-TAIL

CC1 Sherman, A., INTERFERENCE OF TAIL SURFACES AND WING AND FUSELAGE FROM TESTS OF 17 COMBINATIONS IN THE NACA VARIABLE DENSITY TUNNEL, NACA TR 678, 1939.

This describes an investigation of the interference associated with tail surfaces added to wing-fuselage combinations.

CC2 Schlichting, H. and Frenz, W., CONCERNING THE INFLUENCE OF WING AND BODY ON THE VERTICAL TAIL SURFACE (Über den Einfluss von Flügel und Rumpf auf das Seitenleitwerk), Jahrb. d.D.L., 1941, pp. I300-I314.

Results are given of systematic six-component measurements on aircraft models with different wing-fuselage configurations (low, mid and high-wing) and with single and double vertical tail surfaces. From these it was concluded that the contribution of the vertical tail surfaces to directional stability is strongly dependent on the wing-body configuration and the position of the vertical tail surface.

CC3 Bird, J.D., Lichtenstein, J.H., and Jaquet, B.M., INVESTIGATION OF THE INFLUENCE OF FUSELAGE AND TAIL SURFACES ON LOW-SPEED STATIC STABILITY AND ROLLING CHARACTERISTICS OF A SWEPT-WING MODEL, NACA RM L7H15, Oct. 15, 1947, RESTRICTED.

A wind-tunnel investigation was made to determine the influence of the fuselage and tail surfaces on the static stability and rotary derivatives in roll of a transonic airplane configuration which had 45 deg. swept back wing and tail surfaces.

CC4 Jacobs, W., THE INFLUENCE OF THE INDUCED SIDEWIND ON THE EFFICIENCY OF THE VERTICAL TAIL. A SIMPLIFIED METHOD OF CALCULATION, FFA MED 35, 1950.

A theoretical investigation is presented of the influence of the induced sidewind on vertical tail effectiveness.

CC5 Mayer, J.P. and Gillis, C.L., DIVISION OF LOAD AMONG THE WING, FUSELAGE AND TAIL OF AIRCRAFT, NACA RM L51E14a, May 29, 1951, CONFIDENTIAL.

Data are presented for the apportionment of load among the wing, fuselage, and tail for several aircraft configurations having wings of relatively low aspect ratio, at subsonic and supersonic speeds (Mach numbers 0.25 - 1.5). These data were obtained on full-scale airplane, rocket-propelled model and in low-speed wind-tunnel tests. The data indicate that the component of total load carried by the wing does not vary appreciably with Mach number for full-scale aircraft. The present assumption that the fuselage carries a load proportional to the area of wing blanketed by the fuselage is shown to be roughly correct at low speeds and at supersonic speeds for the configurations tested. It was shown that wing incidence does not materially affect the component of additional load carried by the wing or fuselage. The fuselage component of load becomes more predominant at high angles of attack.

CC6 Stephanson, J.D. and Selan, R., THE STATIC LONGITUDINAL CHARACTERISTICS AT MACH NUMBERS UP TO 0.95 OF A TRIANGULAR WING CANARD MODEL HAVING A TRIANGULAR CONTROL, NACA RM A51107, Dec. 1951, CONFIDENTIAL.

This report presents and analyzes results of tests to assess longitudinal characteristics of a canard-type model with a triangular wing of aspect ratio 2 and NACA 0008-63 sections. The horizontal canard surface had a plan form identical to the wing and a NACA 0005-63 section. Tests were performed at Mach 0.25 to 0.95 at Reynolds numbers of 8×10^6 and 3×10^6. The model was tested with horizontal

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control surface at various fixed angles of incidence and with surface unrestrained so that it could pivot about an axis at 30 percent of its mean aerodynamic chord.

CC7 Graham, D. and Koenig, D.G., TESTS IN THE AMES 40- BY 80-FT. WIND TUNNEL OF AN AIRPLANE CONFIGURATION WITH AN ASPECT RATIO 2 TRIANGULAR WING AND AN ALL MOVABLE HORIZONTAL TAIL-LATERAL CHARACTERISTICS, NACA RM A51L03, Feb. 1952, CONFIDENTIAL

Results of an investigation to determine the low-speed lateral characteristics of a triangular-wing airplane model are described. Tests were made with the wing alone, wing-fuselage and wing-fuselage-vertical tail configurations in addition to the tests of a complete model.

See also A5, AF4, C2, DA6, DA10, DA16, DA17, DA18, DA19, DB1, DB4, DB5, DC3, DC5, and DC7.

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CD. COMPONENTS IN COMBINATION, TAIL BODY

CD1 Englehardt, H., SUPPLEMENTARY REPORT ON MEASUREMENTS OF THE INFLUENCE OF THE FUSELAGE ON TAIL-SURFACE EFFECTIVENESS, Technische Hochschule, Muenchen, April 1943, CADO, Wright Field, Dayton, Ohio, ZWB-THM-1-43/R3957-F687962/13082.

CD2 Koloska, RESULTS OF WIND-TUNNEL MEASUREMENTS ON ARRANGEMENTS OF ELEVATOR, FUSELAGE AND RUDDER, MOS GDC 17/1T, Jan. 1944.

See also ADb16, C3, CC4, D18, DA3, DC1, DC6, and DC7.

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D. STABILITY AND CONTROL

D1 Arnstein, K. and Klemperer, W., PERFORMANCE OF AIRSHIPS, Aerodynamic Theory, Vol. VI, Durand, W.F., Ed., Durand Reprinting Committee, California Institute of Technology, 1943 (Reprint of 1934 Edition).

D2 Albring, W., SUMMARY REPORT OF EXPERIMENTAL AND MATHEMATICAL METHODS FOR THE DETERMINATION OF COEFFICIENTS OF TURNING OF BODIES OF REVOLUTION, BuShips Trans. No. 90, Nov. 1945.

D3 Albring, W., STABILITY AND MANEUVERABILITY OF BODIES WITH CONTROL SURFACES, SIT Translation, ETT Note 38, 1946.

D4 Davidson, K.S.M. and Schiff, L.I., TURNING AND COURSE-KEEPING QUALITIES, SNAME Trans., 1946.

D5 Ribner, H.S., THE STABILITY DERIVATIVES OF LOW-ASPECT-RATIO TRIANGULAR WINGS AT SUBSONIC AND SUPERSONIC SPEEDS, NACA TN 1423, 1947.

D6 McKinney, M.O., and Drake, H.M., FLIGHT CHARACTERISTICS AT LOW SPEED OF DELTA-WING MODELS, NACA RM L7K07, Jan. 13, 1948, RESTRICTED.

D7 Toll, T.A. and Queijo, M.J., APPROXIMATE RELATIONS AND CHARTS FOR LOW-SPEED STABILITY DERIVATIVES OF SWEPT WINGS, NACA TN 1581, 1948.

The derivations given are based on simple airfoil theory of approximate relations for low-speed stability derivatives of swept wings. The method accounts for the effect of sweep, aspect ratio, wing location and, in most cases, taper ratio. Charts based on the derived relations are presented for stability derivatives of untapered swept wings. Calculated values of the derivatives are compared with experimental results.

D8 Jaquet, B.M. and Brewer, J.D., LOW-SPEED STATIC STABILITY AND ROLLING CHARACTERISTICS OF LOW-ASPECT-RATIO WINGS OF TRIANGULAR AND MODIFIED TRIANGULAR PLAN FORMS, NACA RM L8L29, 1949.

D9 Gimprich, M. and Jacobs, W.R., THE EFFECT OF FINS ON THE BEHAVIOR OF FREE BODIES, SIT ETT Report 361, Feb. 1950, CONFIDENTIAL.

D10 Landweber, L. and Abkowitz, M.A., NOMENCLATURE FOR TREATING THE MOTION OF A SUBMERGED BODY THROUGH A FLUID, SNAME Tech. and Res. Bull. No. 1 - 5, Apr. 1950.

D11 Wolhart, W.D., and Michael, W.H., WIND-TUNNEL INVESTIGATION OF THE LOW-SPEED LONGITUDINAL AND LATERAL CONTROL CHARACTERISTICS OF A TRIANGULAR-WING MODEL OF ASPECT RATIO 2.31 HAVING CONSTANT-CHORD CONTROL SURFACES, NACA RM L50G17, Sept. 6, 1950, RESTRICTED.

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D12 Gimprich, M., A SIMPLIFIED STUDY OF THE EFFECT OF LENGTH-DIAMETER RATIO ON THE STEADY TURNING AND DYNAMIC STABILITY OF A BODY MOVING IN A FLUID, SIT ETT Report 406, Jan. 1951.

D13 Stanford University, SHIP STABILIZATION PROGRAM FOR YEAR OCT. '50 TO SEPT. '51, Stan. Univ. Div. of Eng. Mech., Tech. Memo No. 2, Contract N6-ONR-25129, Mar. 1951.

This is a brief presentation of the theory of ship stabilization by the use of servo-controlled oscillating fins.

D14 Lange, R.H. and Fink, M.P., EFFECT OF A DEFLECTABLE WING-TIP CONTROL ON THE LOW-SPEED LATERAL AND LONGITUDINAL CHARACTERISTICS OF A LARGE-SCALE WING WITH THE LEADING EDGE SWEPT BACK 47.5 DEG., NACA RM L51C07, April 26, 1951.

D15 Chadwick, J.H., PHYSICAL PHENOMENA AFFECTING THE DYNAMIC BEHAVIOR OF FINS, Stan. Univ. Div. of Eng. Mech., Tech. Memo No. 3, Contract N6-ONR-25129, May 9, 1951.

D16 Schuldenfrei, M., Comisarow, P. and Goodson, K.W., STABILITY AND CONTROL CHARACTERISTICS OF A COMPLETE AIRPLANE MODEL HAVING A WING WITH QUARTER-CHORD LINE SWEPT BACK 40 DEG., NACA TN 2482, Dec. 1951.

D17 Johnson, J.L., THE STATIC STABILITY DERIVATIVES OF A SERIES OF RELATED BODIES OF REVOLUTION, TMB Report C-383, March 1951, CONFIDENTIAL.

D18 Landweber, L. and Johnson, J.L., PREDICTION OF DYNAMIC STABILITY DERIVATIVES OF AN ELONGATED BODY OF REVOLUTION, TMB Report C-359, May 1951, CONFIDENTIAL.

See also A9, A10, AB9, ADa2, ADa3, ADa5, ADb16, ADb21, ADd1, ADd2, AF5, AFa9, BA7, BB3, BB4, CD1, CD2, E16, and E17.

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DA. STABILITY AND CONTROL, LONGITUDINAL

DA1 Göthert, R., MEASUREMENTS ON HORIZONTAL TAIL SURFACES (Hohenleitwerksmesungen), Ringbuch d. LFF, Bd. 1, IA13, 8 May 1940.

DA2 Martinov, A. and Kolosov, E., SOME DATA ON THE STATIC LONGITUDINAL STABILITY AND CONTROL OF AIRPLANES, NACA TM 941, 1940.

This report considers criteria for design of tail surfaces to obtain required stability of an airplane. It concerns problems related to choice of servo control and location of airplane center of gravity.

DA3 Scholkemeier, F.W., MEASUREMENTS OF LIFT AND HINGE MOMENTS ON TWO COMPLETE TAIL UNITS WITH SWEPT-BACK ELEVATORS OF DIFFERENT TAPER RATIOS, MOS R & T 490, April 1944.

Measurements were obtained on two tail units differing in the tapering of thin elevator units. The tail units were mounted on a fuselage stump. The tests were performed at a dynamic pressure of 100 kg/m^2, which is equivalent to a Reynolds number of 1.3×10^6, based on the mean chord of the tail.

DA4 Shortal, J.A. and Maggin, B., EFFECT OF SWEEPBACK AND ASPECT RATIO ON LONGITUDINAL STABILITY CHARACTERISTICS OF WINGS AT LOW SPEEDS, NACA TN 1093, 1946.

DA5 Lowry, J.G. and Schneiter, L., INVESTIGATIONS AT LOW SPEED OF THE LONGITUDINAL STABILITY CHARACTERISTICS OF A 60 DEG. SWEPTBACK TAPERED LOW DRAG WING, NACA TN 1284, 1946.

DA6 Schuldenfrei, M., Comisarov, P. and Goodson, K.M., STABILITY AND CONTROL CHARACTERISTICS OF AN AIRPLANE MODEL HAVING 45.1 DEG. SWEPTBACK WING WITH ASPECT RATIO 2.50 AND TAPER RATIO 0.42 AND 42.8 DEG. SWEPTBACK HORIZONTAL TAIL WITH ASPECT RATIO 3.87 AND TAPER RATIO 0.49, NACA RM L7B25, May 8, 1947.

Tests were conducted on an airplane model with 45.1 deg. sweptback wing to determine the low-speed stability and control characteristics. The test Reynolds number was 2.87×10^6 based on a mean aerodynamic chord of 2.47 ft., except for some series of the aileron tests which were made at a Reynolds number of 2.05×10^6.

DA7 Hoyt, E.D. and Imlay, F.H., THE INFLUENCE OF METACENTRIC STABILITY ON THE DYNAMIC LONGITUDINAL STABILITY OF A SUBMARINE, TMB Report C-158, Oct. 1948, CONFIDENTIAL.

DA8 Fitzpatrick, J.E. and Foster, G.V., STATIC LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF A 52 DEG. SWEPTBACK WING OF ASPECT RATIO 2.88 AT REYNOLDS NUMBERS FROM 2,000,000 TO 11,000,000, NACA RM L8H25, 1948.

DA9 Foster, G.V. and Fitzpatrick, J.E., LONGITUDINAL STABILITY INVESTIGATION OF HIGH-LIFT AND STALL-CONTROL DEVICES ON A 52 DEG. SWEPTBACK WING WITH AND WITHOUT FUSELAGE AND HORIZONTAL TAIL AT A REYNOLDS NUMBER OF 6.8×10^6, NACA RM L8I08, 1948.

[redacted]

DA10 Johnson, B.H. and Rollins, F.W., INVESTIGATION OF A THIN WING OF ASPECT RATIO 4 IN THE AMES 12-FT PRESSURE WIND TUNNEL - V-STATIC LONGITUDINAL STABILITY AND CONTROL THROUGHOUT THE SUBSONIC SPEED RANGE OF A SEMISPAN MODEL OF A SUPERSONIC AIRPLANE, NACA RM A9I01, Dec.8, 1949, CONFIDENTIAL.

Results are reported of wind-tunnel tests of a semispan model of a hypothetical supersonic airplane to determine the static longitudinal stability and control characteristics of the airplane throughout the Mach number range 0.20 to 0.95 and at Reynolds numbers up to 10^7. The semispan model had a long slender fuselage and a wing and horizontal tail of aspect ratio 4 and taper ratio 0.5. The profile of the wing and tail was a sharp-edged, faired, symmetrical double wedge with a thickness-chord ratio of 0.042.

DA11 Weiberg, J.A. and Carel, H.C., WIND-TUNNEL INVESTIGATION AT LOW SPEED OF A WING SWEPTBACK 63 DEG. AND TWISTED AND CAMBERED FOR A UNIFORM LOAD AT A LIFT COEFFICIENT OF 0.5, NACA RM A50A23, May 9, 1950, 53 pp., CONFIDENTIAL.

DA12 Fischel, J. and O'Hare, W.M., LOW-SPEED INVESTIGATION OF DEFLECTABLE WING-TIP ELEVATORS ON A LOW-ASPECT RATIO UNTAPERED 45 DEG. SWEPTBACK SEMISPAN WING WITH AND WITHOUT AN END PLATE, NACA RM L50D19, June 1, 1950, CONFIDENTIAL.

DA13 Griner, R.F. and Foster, G.V., LOW-SPEED LONGITUDINAL AND WAKE AIR FLOW CHARACTERISTICS AT A REYNOLDS NUMBER OF 6.0 X 10^6 OF A 52 DEG. SWEPT BACK WING EQUIPPED WITH VARIOUS SPANS OF LEADING EDGE AND TRAILING EDGE FLAPS, A FUSELAGE, AND A HORIZONTAL TAIL AT VARIOUS VERTICAL POSITIONS, NACA RM L50K29, Feb. 28, 1951, RESTRICTED.

An investigation was conducted in the Langley 19-ft. pressure tunnel to determine the effect of extensible leading edge flaps on the low-speed static longitudinal stability characteristics of a 52 deg. sweptback wing which had NACA 64_1-112 airfoil section and an aspect ratio of 2.88. Leading-edge flap spans of 25, 35, 40, and 45 percent of the wing semispan were investigated and some of the more satisfactory configurations were further investigated with various combinations of trailing edge flaps for the wing combined with fuselage and horizontal tail. Surveys of the air flow behind the wing at approximately the location of the horizontal tail were made for the wing-fuselage combinations both with and without 0.40 semispan leading-edge and trailing-edge flaps. Tests were made at a Reynolds number of 6.0 x 10^6 and a Mach number of 0.12.

DA14 Heep, H., FUNDAMENTALS OF DYNAMIC DEPTH CONTROL OF HIGH-SPEED SUBMARINES, EES, Mar. 1951.

DA15 Fisher, L.R., LOW-SPEED STATIC LONGITUDINAL AND LATERAL STABILITY CHARACTERISTICS OF TWO LOW-ASPECT-RATIO WINGS CAMBERED AND TWISTED TO PROVIDE A UNIFORM LOAD AT A SUPERSONIC FLIGHT CONDITION, NACA RM L51C20, June 6, 1951, RESTRICTED.

A delta wing and a tapered sweptback wing of aspect ratio 1.56 and 2.00, respectively, both of which were cambered and twisted to provide a uniform load distribution for supersonic flight conditions, were tested in combination with a fuselage at a Reynolds number of 384,000 - 1,550,000 in order to determine the low-speed lift-drag and static stability characteristics of such wings.

DA16 Lichtenstein, J.H., EFFECT OF HORIZONTAL TAIL LOCATION ON LOW-SPEED STATIC LONGITUDINAL STABILITY AND DAMPING IN PITCH OF A MODEL HAVING 45 DEG. SWEPTBACK WING AND TAIL SURFACES, NACA TN 2381, June 1951.

DA17 Lichtenstein, J.H., EFFECT OF HORIZONTAL TAIL SIZE AND TAIL LENGTH ON LOW-SPEED STATIC LONGITUDINAL STABILITY AND DAMPING IN PITCH OF A MODEL HAVING 45 DEG. SWEPTBACK WING AND TAIL SURFACE, NACA TN 2382, June 1951.

A complete model with wing and tail surface, quarter-chord line swept back 45 deg. and an aspect ratio of 4 was investigated in the Langley stability tunnel to determine the effect of varying size and tail length on low-speed static longitudinal stability and on steady-state rotary damping in pitch.

DA18 Queijo, M.J. and Wolhart, W.D., WIND-TUNNEL INVESTIGATION OF THE EFFECT OF HORIZONTAL TAIL POSITION ON LOW-SPEED LONGITUDINAL STABILITY CHARACTERISTICS OF AN AIRPLANE MODEL WITH A 35 DEG. SWEPTBACK WING EQUIPPED WITH CHORDWISE FENCES, NACA RM L51H17, Nov. 5, 1951, RESTRICTED.

An experimental investigation was undertaken in the Langley stability tunnel to determine whether the low-speed longitudinal stability characteristics of a model with 35 deg. sweptback wing could be improved appreciably by lowering the horizontal tail. The investigation included tests of several components of the model and of various model configurations with chordwise fences on the wing. The wing aspect ratio was 3.57 and the taper ratio 0.565. The horizontal tail aspect ratio was 3.59 and the taper ratio 0.50 with 40 deg. sweep at the 0.35-chord line.

DA19 Jaquet, B.M., EFFECTS OF HORIZONTAL-TAIL POSITION, AREA, AND ASPECT RATIO ON LOW-SPEED STATIC LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS OF A 60 DEG. TRIANGULAR WING MODEL HAVING VARIOUS TRIANGULAR ALL MOVABLE HORIZONTAL TAILS, NACA RM L51I06, Dec. 1951, CONFIDENTIAL.

See also A1, A4, A5, A6, A11, AB15, AD10, ADb24, ADb29, ADd3, ADe1, ADh2, AEa4, AEa5, AEa9, AEa10, AF2, AF8, AFa2, AFa5, AFa6, AFa7, AFa16, AG5, AG6, AH3, CB1, CC6, D14, D17, D18, and E1.

DB. STABILITY AND CONTROL, LATERAL

DB1 Shortal, J.A. and Draper, J.W., FREE-FLIGHT TUNNEL INVESTIGATION OF THE EFFECT OF THE FUSELAGE LENGTH AND THE ASPECT-RATIO AND SIZE OF THE VERTICAL TAIL ON LATERAL STABILITY AND CONTROL, NACA ARR 3D17, 1943.

Both fixed and free tests were made in the NACA free-flight tunnel to determine the effect of fuselage length and aspect-ratio and size of the vertical tail on lateral stability and control. Fuselages of two different lengths and various vertical tail surfaces were used on a powered model. Tail aspect ratios of 1.00 and 2.28 were used.

DB2 Toll, T.A., SUMMARY OF LATERAL CONTROL RESEARCH, NACA TN 1245, Mar. 1947.

This is a comprehensive summary of available information on lateral control. Criteria for lateral-control specification, factors involved in obtaining satisfactory control, and methods used in making investigations are presented for surfaces having a large range of aspect ratios. Data on flap-type ailerons with various types of balance are presented in a form suitable for design use.

DB3 Lomax, H. and Heaslet, M.A., DAMPING IN ROLL CALCULATIONS FOR SLENDER SWEPT-BACK WING BODY COMBINATIONS, NACA TN 1950, Sept. 1949.

Damping in roll computations considering compressibility linearization approximation. Method applies at high Mach number or for extremely elongated combinations.

DB4 Bates, W.R.,LOW-SPEED STATIC LATERAL STABILITY CHARACTERISTICS OF A CANARD MODEL HAVING A 60 DEG. TRIANGULAR WING AND HORIZONTAL TAIL, NACA RM L9J12, Nov. 1949, CONFIDENTIAL.

Force tests and flow surveys were made in the Langley free-flight tunnel to determine the stability characteristics of a canard model having 60 deg. triangular planform wing and horizontal tail. Tests were made with the horizontal tail used as a fixed nose elevator or floating freely at varying tab deflection. Various vertical tail configurations also studied. Unusual directional stability characteristics are indicated by the results.

DB5 Brewer, J.D. and Lichtenstein, J.H., EFFECT OF HORIZONTAL TAIL ON LOW-SPEED STATIC LATERAL STABILITY CHARACTERISTICS OF A MODEL HAVING 45 DEG. SWEPTBACK WING AND TAIL SURFACES, NACA TN 2010, Jan. 1950.

Results are reported of an investigation in the Langley stability tunnel to determine the effects of changes in horizontal-tail size and location on the static lateral stability characteristics of a complete model with wing and tail surfaces having the quarter-chord line swept back 45 deg. The available procedure, based on analyses of unswept-tail configuration, for predicting the effect of the horizontal tail on the directional stability was found to be unreliable when applied to swept-tail configurations. Wing and horizontal tails were of aspect ratio 4.0, and the vertical tail 1.0; the tests were performed at a Mach number of 0.13 and a Reynolds number of 0.71×10^6 based on the wing mean aerodynamic chord.

DB6 Wolhardt, W.D., INFLUENCE OF WING AND FUSELAGE ON THE VERTICAL TAIL CONTRIBUTION TO THE LOW-SPEED ROLLING DERIVATIVES OF MIDWING AIRPLANE MODELS WITH 45 DEG. SWEPTBACK SURFACES, NACA TN 2587, Dec. 1951.

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See also A12, ADb27, ADb33, ADb35, ADc2, ADd3, ADh2, AEa3, AEa5, AF3, AFa14, AFa15, AFa16, AFa17, AFa19, CC3, CC7, D8, D9, D13, D14, D15, DA6, and DA15.

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DC. STABILITY AND CONTROL, DIRECTIONAL

DC1 Dryden, H.L. and Monish, B.H., THE EFFECT OF AREA AND ASPECT RATIO ON THE YAWING MOMENT OF RUDDERS AT LARGE ANGLES OF PITCH ON THREE FUSELAGES, NACA TR 437, 1932.

The paper reports the measurements of yawing moments produced by deflection of seven rudders, respectively mounted on each of three fuselages over a range of pitch angles.

DC2 Bader, W., THE DIRECTIONAL STABILITY OF AN AIRSHIP IN STRAIGHT FLIGHT (Die Seitenstabilität eines Luftschiffes bei Geradeaus-Fahrt) LFF Bd. 15, Nr. 6, 6 June 1938.

DC3 Pass, H.R., ANALYSIS OF WIND-TUNNEL DATA ON DIRECTIONAL STABILITY AND CONTROL, NACA TN 775, 1940.

DC4 Murray, H.E., WIND-TUNNEL INVESTIGATION OF END-PLATE EFFECTS OF HORIZONTAL TAILS ON A VERTICAL TAIL COMPARED WITH AVAILABLE THEORY, NACA TN 1050, April 1946.

Results of tests of a vertical tail model with stub fuselage in combination with various simulated horizontal tails to determine the effect of horizontal-tail span and location on the aerodynamic characteristics of the vertical tail. Available theoretical data on end-plate effects are collected and presented in a form suitable for design purposes.

DC5 Johnson, H.I., FLIGHT INVESTIGATION OF THE EFFECT OF VARIOUS VERTICAL TAIL MODIFICATIONS ON THE DIRECTIONAL STABILITY AND CONTROL CHARACTERISTICS OF A PROPELLER-DRIVEN FIGHTER AIRPLANE, NACA TR 973, 1950.

This reports the results of a flight investigation undertaken to determine the effect of various vertical-tail modifications and of some combinations of those modifications on the directional stability and control characteristics of a propeller-driven fighter airplane. Six different tail configurations were investigated.

DC6 Fehlner, L.F., THE DESIGN OF CONTROL SURFACES FOR HYDRODYNAMIC APPLICATIONS, TMB Report C-358, Jan. 1951, CONFIDENTIAL.

Design of control surface for maneuvering a vessel is discussed from the hydrodynamic standpoint. Control surfaces are divided into two main categories: (1) flapped and (2) all movable. Recommended flapped designs are restricted to those having "overhang" balance. An example is given which demonstrates remarkable superiority of the all-movable control surface over the flapped. The importance of designing for an elliptical spanwise load distribution is pointed out and means for obtaining it are given.

DC7 Letko, W., EFFECT OF VERTICAL TAIL AREA AND LENGTH ON THE YAWING STABILITY CHARACTERISTICS OF A MODEL HAVING SWEPT BACK WING, NACA TN 2358, May 1951.

An investigation was conducted to determine (1) the contributions of the various airplane components to yawing stability derivatives and (2) the interference between the components of a high-speed airplane configuration having different tail areas and tail lengths. The model wing was of 45 deg. sweepback and aspect ratio 4.

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DC8 Marino, A.A. and Mastrocola, N., WIND-TUNNEL INVESTIGATION OF THE CONTRIBUTION OF A VERTICAL TAIL TO THE DIRECTIONAL STABILITY OF A FIGHTER-TYPE AIRPLANE, NACA TN 2488, Jan. 1952.

The contribution of the vertical tail and fuselage to directional stability are determined from pressure distribution measurements over wide ranges of angle-of-attack and angle-of-yaw with stabilizer in each of three vertical positions, with stabilizer removed, and with both stabilizer and vertical tail removed. The results point out the inadequacies of current design methods and show that more accurate methods must treat separately the contribution of the vertical tail, fuselage area above stabilizer, and fuselage area below stabilizer.

See also A4, A5, ADa2, ADc2, ADd3, ADd4, ADe3, ADh2, AF4, AFa4, AFa8, CC2, and DB1.

[redacted]

E. UNSTEADY FLOW PHENOMENA

E1 Glauert, H., THE LIFT AND PITCHING MOMENT OF AN AEROFOIL DUE TO A UNIFORM ANGULAR VELOCITY OF PITCH, ARC R & M 1216, Nov. 1928.

E2 Jones, R.T., THE UNSTEADY LIFT OF A FINITE WING, NACA TN 682, Jan. 1939.

The unsteady-lift functions for wings of finite aspect ratio have been calculated by approximate methods involving corrections for the aerodynamic inertia and of the angle of the infinite wing. The starting lift of the finite wing is found to be only slightly less than that of the infinite wing, whereas the final lift may be considerably less. The calculations indicate that the distribution of lift near the start is similar to the final distribution. Both the indicial and the oscillating lift function are given. Approximate operational equivalents of the function have been devised to facilitate calculation of lift under various conditions of motion. Coefficients required in the computation have been given for aspect ratios of ∞, 6, and 3.

E3 Sears, W.R. and Kuethe, A.M., THE GROWTH OF THE CIRCULATION OF AN AIRFOIL FLYING THROUGH A GUST, J. Aero. Sci., Vol, 6, No. 9, July 1939, pp. 376-378.

The rate of increase of circulation about the tip of a wing flying through a vertical gust has recently been determined experimentally by Kuethe. In the paper under consideration, the results of these experiments are compared with calculations based on the theories of von Kármán and Sears and R.T. Jones. Results are given for aspect ratios of 3.0 and ∞.

E4 Küessner, H., CONTRIBUTIONS TO THE INSTATIONARY AIRFOIL THEORY (In German) LFF FB 1130/3, 31 Jan. 1940.

E5 Jones, R.T., THE UNSTEADY LIFT OF A WING OF FINITE ASPECT RATIO, NACA TR 681, 1940.

Unsteady-lift functions for wings of finite aspect ratio have been calculated by correcting the aerodynamic inertia and the angle of attack of the infinite wing. The calculations are based on the operational method. The starting lift of the finite wing is found to be only slightly less than that of the infinite wing; whereas the final lift may be considerably less. Theory indicates that the initial lift distribution is similar to the final distribution. Curves are given showing variation of lift after sudden unit change in angle of attack during penetration of a sharp-edge gust and during a continuous oscillation. Function curves are plotted for aspect ratios of ∞, 6, and 3.

E6 Cicala, P., PRESENT STATE OF DEVELOPMENT IN NON-STEADY MOTION OF A LIFTING SURFACE (Translation of article in L'Aeronautica, Vol. 21, No. 9-10, Sept.-Oct. 1941) NACA TM 1277, Oct. 1951.

E7 Biot, M.A. and Boehnlein, C.T., AERODYNAMIC THEORY OF THE OSCILLATING WING OF FINITE SPAN, GALCIT Report No 5 (Flutter Project), Sept. 1942.

E8 Schade, Th. and Krienes, K., THE OSCILLATING CIRCULAR AIRFOIL ON THE BASIS OF POTENTIAL THEORY (Translation of article in LFF, Vol. 17, No. 11-12, Dec. 10, 1940 and Vol. 19, No. 8, August 20, 1942.) NACA TM 1098, Feb. 1947.

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This report, based on Kinners' theoretical investigation of the circular lifting surface, treats the circular airfoil in uniform flow executing small oscillations whose amplitudes correspond to whole functions of the second degree in x and y.

E9 Jones, W.P., THEORETICAL DETERMINATION OF THE PRESSURE DISTRIBUTION ON A FINITE WING IN STEADY MOTION, ARC R & M 2145, May 1943.

E10 Jones, W.P., AERODYNAMIC FORCES ON WINGS IN SIMPLE HARMONIC MOTION, ARC R & M 2026 (8474), 20 Feb., 1945.

A theory for the calculation of the aerodynamic forces acting on wings of finite span and any plan form is developed, and from it an approximate method is derived which reduces the amount of numerical work. Satisfactory agreement with the available experimental evidence is obtained.

E11 Reissner, E., EFFECT OF FINITE SPAN ON THE AIRLOAD DISTRIBUTION FOR OSCILLATING WINGS. I - AERODYNAMIC THEORY OF OSCILLATING WINGS OF FINITE SPAN, NACA TN 1194, Mar. 1947.

A nonuniform lift theory is discussed which applies to aspect ratios at least as small as can be considered by lifting line theory in steady flow.

E12 Reissner, E. and Stevens, J.E., EFFECT OF FINITE SPAN ON THE AIRLOAD DISTRIBUTIONS FOR OSCILLATING WINGS. II - METHODS OF CALCULATION AND EXAMPLES OF APPLICATION, NACA TN 1195, 1947.

E13 Küssner, H.G. and Schade, Th., UNSTEADY PROCESSES. MODERN UNSTEADY AIRFOIL THEORY (MAP Volkenrode Monographs) MOS R & T 1009, Feb. 15, 1948, RESTRICTED.

E14 Küssner, H.G. and Drescher, H., MODERN UNSTEADY AIRFOIL THEORY (MAP Volkenrode AVA Monographs), MOS R & T 1011, Feb. 15, 1948.

E15 Jones, W.P., AIRFOIL OSCILLATIONS AT HIGH MEAN INCIDENCES, ARC 11,502, April 1948, RESTRICTED. (0.724)

E16 Miles, J.W., THE APPLICATION OF UNSTEADY FLOW THEORY TO THE CALCULATION OF DYNAMICAL STABILITY DERIVATIVES., North American Aviation, Inc., Report AL-957, Sept. 8, 1950, 115 pp.

The equations of unsteady flow over thin airfoils and slender bodies of revolution are formulated for dynamic stability situations where all second-order frequency terms may be neglected. This leads to a true first-order (in frequency) theory, which has been used for the calculation of dynamic stability derivatives. Methods of solution are developed for unswept wings in subsonic flow and for wings with supersonic trailing edge in supersonic flow. In the former case, an extension of the Prandtl-Glauert transformation reduces the problem to the equivalent problem in incompressible flow.

E17 Laitone, E.V. and Walters, E.R., THE APPLICATION OF NON-STATIONARY AIRFOIL THEORY TO DYNAMIC STABILITY CALCULATIONS., J. Aero. Sci. Vol. 18, No. 3, Mar. 1951, pp. 214-216.

The two-dimensional nonstationary airfoil theory of Theodorsen is applied to the determination of three-dimensional stability characteristics by an appropriate axis transformation and finite aspect-ratio correction.

E18 Lehrian, D.E., AERODYNAMIC COEFFICIENTS FOR AN OSCILLATING DELTA WING, ARC Report 14,156, July 14, 1951, RESTRICTED.

E19 Cicala, P., PRESENT STATE OF DEVELOPMENT IN NON-STEADY MOTION OF A LIFTING SURFACE, NACA TM 1277, Oct. 1951.

A summary is given of principal results on air forces for wings undergoing unsteady motion in an incompressible fluid and of the methods followed by various investigators as of 1941. Part I contains results for wings of infinite aspect ratio; Part II deals with procedures for wings of finite aspect ratio; Part III contains results for force component in direction of motion (propulsion or drag); and Part IV considers results of some experimental investigation. Each part contains an evaluation of existing publications.

E20 Pierce, H.B. and Johns, S.L., GUST-TUNNEL INVESTIGATION OF DELTA-WING MODEL WITH THE LEADING-EDGE SWEPT-BACK 60 DEG., NACA RM L52B04, April 1952.

E21 Bird, J.D., Fisher, L.R. and Hubbard, S.M., SOME EFFECTS OF FREQUENCY ON THE CONTRIBUTION OF A VERTICAL TAIL TO THE FREE AERODYNAMIC DAMPING OF A MODEL OSCILLATING IN YAW, NACA TN 2657, Apr. 1952.

See also D13 and D15.

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F. SURFACE EFFECTS

See BA1 and Sections FA and FB.

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FA. FREE BOUNDARY

FA1 Weinblum, G., Amtsberg, H., and Bock, W., TESTS ON WAVE RESISTANCE OF IMMERSED BODIES OF REVOLUTION (Versuche Über den Wellenwiderstand Getauchter Rotationskörper, Mitteilungen der Preussischen Versuchsanstalt für Wasserbau und Schiffbau, Berlin, 1936), TMB Translation 234, September 1950.

FA2 • Haskind, M.D., TRANSLATIONAL MOTION OF BODIES UNDER THE FREE SURFACE OF A HEAVY FLUID OF FINITE DEPTH (Trans. from Prikladnaya Matematika i Mekhanika, Vol. 9, No. 1, Sept. 1945, pp. 67-68) NACA TM 1345, June 1952.

FA3 Wigley, W.C.S., THE INERTIA COEFFICIENTS AND COUPLES ON A SUBMERGED SPHEROID, AEW Report 11/49, Mar. 1949, CONFIDENTIAL.

FA4 Sutherland, W.H., TESTS OF A SUBMARINE MODEL TO DETERMINE FORCES ASSOCIATED WITH PROXIMITY TO SURFACE, SIT ETT Report 392, Dec. 1949.

FA5 Wigley, W.C.S., AN APPROXIMATION TO THE COUPLE ON A FINE SUBMERGED SPHEROID WHEN MOVING WITH A SMALL HORIZONTAL YAW IN THE NEIGHBORHOOD OF A FREE SURFACE UNDER GRAVITY, AEW Report 46/49, CONFIDENTIAL.

FA6 Korvin-Kroukovsky, B.V., Chabrow, F.R., Belous, P.M. and Sutherland, W.H., THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE INTERACTION OF A FREE FLUID SURFACE AND A BODY OF REVOLUTION MOVING UNDER IT, SIT ETT Report 390, Jan. 1950, CONFIDENTIAL.

FA7 Sutherland, W.H. and Belous, P.M., TESTS OF A SUBMERGED STREAMLINED MODEL TO DETERMINE FORCES ASSOCIATED WITH PROXIMITY TO SURFACE, SIT ETT Report 393, Jan. 1950, CONFIDENTIAL.

FA8 Havelock, T.H., FORCES ON A SUBMERGED SPHEROID MOVING IN A CIRCULAR PATH, Proc. Roy. Soc., Series A, Vol. 201, No. 1066, Apr. 1950.

FA9 Weinblum, G.P., THE WAVE RESISTANCE OF BODIES OF REVOLUTION, TMB Report 758, May 1951.

FA10 Wigley, W.C.S., THE FORCE AND COUPLE ON A SPHEROID MOVING HORIZONTALLY PARALLEL TO ITS AXIS NEAR THE FREE SURFACE, AEW Report 18/51, May 1951, CONFIDENTIAL.

FA11 Brooks, S., Weinblum, G., and Young, D., FORCES AND MOMENTS EXPERIENCED BY A SPHEROID MOVING UNIFORMLY ON A HORIZONTAL RECTILINEAR PATH AT AND BENEATH THE SURFACE, TMB Report C-384, June 1951, CONFIDENTIAL.

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FA12 Wigley, W.C.S., A NOTE ON A PAPER FORMING REPORT NO. 390 OF THE EXPERIMENTAL TOWING TANK OF THE STEVENS INSTITUTE OF TECHNOLOGY, ENTITLED "THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE INTERACTION OF A FREE FLUID SURFACE AND A BODY OF REVOLUTION MOVING UNDER IT," By B.V. Korvin-Kroukovsky, et. al., AEW Report 31/51, Aug. 14, 1951, CONFIDENTIAL (See FA6 above).

FA13 Haskind, M.D., GENERAL THEORY CONCERNING THE WAVE-MAKING RESISTANCE OF A SOLID IN MOTION THROUGH A FLUID OF FINITE DEPTH, BuShips Trans. 435, Oct. 1951.

FA14 Havelock, T.H., THE WAVE RESISTANCE OF A SPHEROID, Proc. Roy. Soc., Vol. 131 and 132, 1951.

FA15 Korvin-Kroukovsky, B.V., Chabrow, F.R., and Peters, B.H., ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF THE FORCES AND MOMENTS ACTING ON A SUBMARINE MOVING UNDER WAVES, SIT ETT Report 402, Mar. 1952, CONFIDENTIAL.

FA16 Pond, H.L., THE MOMENT ACTING ON A SPHEROID MOVING UNDER A FREE SURFACE, TMB Report C-489, Mar. 1952, CONFIDENTIAL

FA17 Pond, H.L., THE PITCHING MOMENT ACTING ON A BODY OF REVOLUTION MOVING UNDER A FREE SURFACE, TMB Report 819, May 1952.

FA18 Kochin, N.E., THE TWO-DIMENSIONAL PROBLEM OF STEADY OSCILLATIONS OF BODIES UNDER THE FREE SURFACE OF A HEAVY INCOMPRESSIBLE LIQUID, SNAME Tech. and Res. Bull. No. 1-9, 1952.

FA19 Kochin, N.E., THE THEORY OF WAVES GENERATED BY OSCILLATIONS OF A BODY UNDER THE FREE SURFACE OF A HEAVY INCOMPRESSIBLE FLUID, SNAME Tech. and Res. Bull. No. 1-10, 1952.

FA20 Weinblum, G., Brooks, S., and Golovato, P., EXPERIMENTAL INVESTIGATION OF INERTIA AND DAMPING COEFFICIENTS OF A SPHEROID AND SURFACE SHIP IN FREE HEAVE AND PITCH, TMB Report (in preparation) CONFIDENTIAL.

FA21 Havelock, T.H., THE MOMENT ON A SUBMERGED SOLID OF REVOLUTION MOVING HORIZONTALLY, Quart. J. Mech. Appl. Math. (in preparation).

See also ADb25, ADh3, and D13.

FB. RIGID BOUNDARY

FB1 Silverstein, A. and Gulick, B.G., GROUND-HANDLING FORCES ON A 1/40-SCALE MODEL OF THE U.S. AIRSHIP AKRON, NACA TR 566, 1936.

Results of an investigation in the NACA full-scale wind tunnel to determine the ground-handling forces on a 1/40-scale model of the U.S. Airship AKRON. Ground-handling conditions were simulated by establishing a velocity gradient above a special ground board comparable to that encountered over a landing field. The tests were conducted at Reynolds numbers ranging from 5,000,000 to 19,000,000 at each of six angles of yaw between 0 and 180 deg. and at four heights of the model above the ground band.

FB2 Eisenberg, P., AN ASYMPTOTIC SOLUTION FOR THE FLOW ABOUT AN ELLIPSOID NEAR A PLANE WALL, CIT-HL NOrd 9612, Report N-57, Cal. Inst. of Tech., Pasadena, Sept., 1948.

FB3 Eisenberg, P., AN APPROXIMATE SOLUTION FOR INCOMPRESSIBLE FLOW ABOUT AN ELLIPSOID NEAR A PLANE WALL, J. Appl. Mech., Vol. 17, No. 2, June 1950, pp. 154-158.

See also AB8 and CB2.

 [redacted]

G. CAVITATION

In order to make available without delay the information thus far obtained for the preceding sections, the present section on cavitation, a subject on which there appear to be relatively few references related specifically to the effect of aspect ratio, is, for the present, limited to the following references:

G1 Raven, F.A., Feiler, A.M., and Jespersen, A., AN ANNOTATED BIBLIOGRAPHY OF CAVITATION, TMB Report R-81, Dec. 1947, CONFIDENTIAL.

This contains a very comprehensive listing with abstracts of articles on the general subject of cavitation.

G2 Eisenberg, P., ON THE MECHANISM AND PREVENTION OF CAVITATION, TMB Report 712, July 1950.

See also D15.

[redacted]

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74 Experimental Towing Tank, Stevens Institute of Technology, 711 Hudson St., Hoboken, N.J.

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82 Inspector of Naval Material, Baltimore, Md., for Captain W.S. Diehl, USN, Associate Member, Panel on the Hydrodynamics of Submerged Bodies, Bureau of Aeronautics, 4501 Lowell St., N.W., Washington, D.C.

83 - 91 British Joint Services Mission (Navy Staff) P.O. Box 165, Benjamin Franklin Station, Washington, D.C.

92 - 97 Chief of Naval Operations, OP321K, for distribution:

92 Superintendent, Admiralty Research Laboratory, Teddington, Middlesex, England

93-94 Australian Scientific Liaison Office, Washington, D.C.

95-97 Director, Hydrodynamics Laboratory, National Research Council, Ottawa, Canada

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A BIBLIOGRAPHY OF REPORTS ON LOW-ASPECT-RATIO LIFTING SURFACES AND ELONGATED BODIES IN SUBSONIC FLOW, by James L. Johnson, Jr. Washington, November 1952. vi, 91 p. [redacted]

This report presents a survey of the literature dealing with subsonic low-aspect-ratio phenomena, with emphasis on subjects of importance in the design of submarines and undersea weapons.

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2. Flow, Subsonic
3. Lifting-surface theory
I. Johnson, James L., Jr.
II. NS 715-102

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