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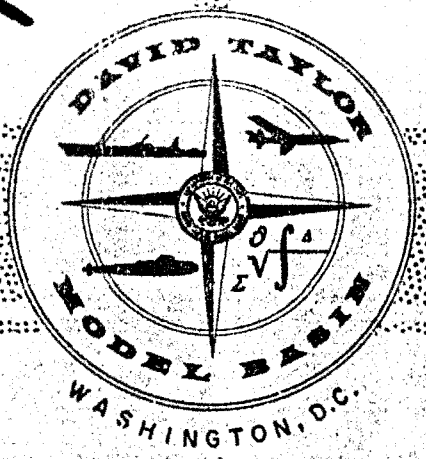

DEPARTMENT OF THE NAVY

LITERATURE SEARCH AND COMPREHENSIVE BIBLIOGRAPHY OF WINGS IN GROUND EFFECT AND RELATED PHENOMENA

by

William F. Foshag

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SUMMARY

A comprehensive survey and literature search is made of the general field of wings operating in ground effect and related phenomena. Comments are included of some of the papers published, to present a sketch of the methods of approach of a number of authors. The bibliography presents sources which consider the problem from the theoretical, experimental, and/or applications point of view. Tables are included which provide a convenient breakdown of the various sources, for a quicker method of locating specific references dealing with an area of special interest to the reader.

INTRODUCTION

The application of the ground effect phenomenon to over-surface high-speed transportation has created a new technology. A winged system flying in close proximity to the surface is considered one of the group or family commonly called ground effect machines (GEM's) or air cushion vehicles. It may be considered that this new technology is at about the same level of inquiry as the early aircraft industry was in 1910. Further, it may be considered that the application of the wing-in-ground-effect (hereafter called WIG) principle at the time of this writing (1965) has been reduced to a practical craft in only a few instances. Therefore, it was felt that all sources should be included in a literature review which might provide an understanding of this phenomenon and/or its applications. The selection of sources was made primarily on the basis of direct interest to the aerodynamicist and practicing engineer. Nevertheless, the inclusion of entries such as popular articles, patent descriptions, early reports, and unusual comments is intended for general background and as assistance to patent attorneys, aeronautical historians, naval architects, and other interested individuals. Generally, it may be said that it is the intent of this bibliography to suggest or support initial inquiry or investigation into the phenomenon of wings in ground effect.

The bibliography therefore includes a comprehensive collection of material which covers the theoretical and experimental aspects of the WIG. The search was extended to include references which show application

of the phenomenon to practice. This extension gives a liberal interpretation of the WIG phenomena, in an attempt to suggest possible extension of past engineering concepts to potential future applications.

A comprehensive understanding of the WIG would not be complete without an accounting for the practice of nature in this area. One cannot avoid realizing that the flying fish and certain seabirds take advantage of the surface effect of the ocean. Their performance may arouse our interest and perhaps indicate methods of near-surface flight maneuver and control.

SCOPE OF THE SURVEY

An outline of the scope of this bibliography is in order here. Generally, it may be considered that reference made to any form of sustaining fixed surface (airfoil or wing system) which receives or augments its lift by reason of its forward motion over a proximate surface will be included here. Also, it is considered that this wing lift may be further supplemented by the use of air-jet sealing curtains, which may be considered to operate continually or partially during the flight over the surface.

The bibliography therefore contains a comprehensive collection of references of the following air-jet systems only when they are in proximity to the ground and in forward motion: Jet Flap, GETOL, and Channel Flow Wing (side jet curtains).

A review of naval engineering literature reveals that the utilization of aerodynamic lift to displacement and planing craft is not unknown. Those sources and descriptions of naval craft and boats in which definite aerodynamic lifting shapes or surfaces are present to assist in the reduction of hull resistance are included in this report.

There are a few inclusions in this report of references on the resistance and/or stability of wheeled vehicles moving over a land surface. These few references are included because of their description of related problems, especially in wind-tunnel testing techniques over a ground board.

Also searched and included in this report is a full listing of sources covering the testing and application of sponsons or stub wings to flying boat hulls. The stub wing may well be considered an aerodynamic

lifting surface when clear of the water. An extension of this system, in which a wing may be aided in leaving the water surface by the use of the seaplane planing hull, will suggest further applications for practical ram wings.

A system related to the stub wing is included. This system has been called by NASA the "float wing" or integrated planing hull. This arrangement, which is well adaptable to ram wing vehicles, is one in which the flying boat planing hull is faired directly into the complete wing. The wing, which is somewhat awash when the craft is at rest, serves as the lateral stabilizer for the craft when at rest and when taking off. More generally, the hydrodynamic considerations of the WIG when taking off or landing on the water have yet to be fully explored.

A recent development (which utilizes sidewalls submerged in water) is the captured air bubble (CAB) type GEM. Although it is not sustained over the surface as a pure wing, it may, during high-speed cruise, be lifted by the ram pressure as it enters a forward-facing opening, or door. The border line between a WIG and a CAB can, at times, be thin. This report omits coverage of the CAB, since this development is still quite new and would best be included among works pertaining to GEM's which utilize systems of air-moving machinery for the prime source of lift.

A patent search was made to uncover references which would indicate the application of the WIG and related devices to patent disclosure. Here some latitude was given as to what might be considered a WIG in that many boats and craft with air-displacing or lifting features were included. Generally, only those patents are included in which the inventor states in some manner that his invention may be fully or partially airborne due to certain shapings of the hull or winged surfaces. Certain boating or flying systems have been listed which this author feels indicate distinct means for accomplishing close surface flight or transport. The collection of patents cited here should not be regarded as a substitute for final or professional patent search, however.

Because of the large number of references listed, it was felt that the reader might have difficulty selecting the references of interest to him. Therefore, a supplementary bibliography (Appendix A) has been prepared, the references of which are themselves bibliographies or reports of special importance, arranged by subject matter. This appendix should be

considered as an extension of the theme of this bibliography and should direct the reader to related areas of interest.

These areas of extended interest are described herewith:

1. Aerodynamics and Hydrodynamics of Seaplanes

If one considers the ram wing operating from the water surface as a special case of the seaplane, then many of the hydrodynamic performance reports and information may be of immediate value.

2. VTOL/STOL Aircraft

The bibliographies list many references for ducted fan, deflected slipstream, fan-in-wing, etc., all of which are aircraft operating in ground effect. The ability of most of these aircraft to hover excludes their reference from the body of this bibliography.

3. Ground Effect Machines

As the WIG may certainly be considered to be one of the family of GEM's, then many of the problems and comparisons associated with other GEM systems may have application to the WIG.

4. Hydrofoils

Bibliographies are, in part, included here for their general interest; but more in particular, for certain theoretical considerations in which the hydrofoil operating in the proximity of the free air or water surface may represent applicable problems as encountered also by the WIG when operating close to a free surface.

5. Interface Meteorology and the Katzmayer Effect

The operational domain of the applied WIG will, in all probability, be over the water. This surface is seldom smooth. The effect of the wind is to produce waves; and hence, the medium (interface) in which the WIG will operate is not stable or rigid, but subject to irregular motion and oscillation. Hence, it will become necessary to understand the effect of this disturbance on the aerodynamics of the WIG. To this end, there are included several references with bibliographies on wind-wave studies and also references on the Betz-Knoller or Katzmayer effect. These latter effects concern the apparent change of lift and drag of an airfoil when impressed in such a fluctuating airstream.

6. Automobile Wind Tunnel Air Resistance Testing

References are included in the supplementary bibliography for those interested in problems which are suggested by the aerodynamic characteristics of wheeled vehicles moving over the ground surface.

7. Raimondi Effect

A primary source with references is included in Appendix A covering the Raimondi Effect. This effect explains the attraction of a circulation towards a boundary or surface and this material may complement certain theoretical considerations of the WIG.

8. Miscellaneous

PRESENTATION OF RESULTS

The references are arranged in an alphabetical order by the principal author's last name. In the case of more than one entry by an author, it will be found that his earliest contribution will appear first in the listing. In the instance where a group or company is responsible for the authorship of a publication, then the known name of the organization will be alphabetically placed. References consisting of comments or photographs are entered into the listing alphabetically, usually by subject matter or description.

A series of tables is included which provide an insight into the references. With these tables it becomes possible to search out a combination of subjects or interests to a number of specific sources. By scanning across the appropriate columns of descriptors, the scope of a particular reference may be quickly revealed and understood.

Table 5 describes the structure or presentation of a reference. This usually will be found helpful in assessing the extent of detail presented and the availability of the source. Note that there is one category in which the references may be cited as generally unavailable. This category is intended to single out references which have security classification or are generally considered to contain material proprietary to a particular company. This group also covers papers that are currently unpublished for one reason or another; but which probably could be obtained by some effort. Another category is cited in which the references were not examined by the author because of their immediate unavailability

and the lack of time required to search them out. The reader may therefore only know of their existence, sense their content from the title and hope to have better access to sources in this last category.

CONCLUDING REMARKS

Upon reviewing the bibliography, it was decided that the tabulated reference listing against descriptors was an excellent means to understand the content of a source which dealt with matters of experiment and application and, generally, for most works of a theoretical nature. The review of experimental work on wings in ground effect from the initial tests by A. Betz (1912) to the present date reflects only a few narrow avenues of interest in spite of the bulk of material available. Generally, the experimental data available fall into these groups:

1. Exploratory tests.
2. Tests made to substantiate theoretical investigations.
3. Forces and moments on aircraft wings during landing and taking off.
4. Renewed investigations in the light of current applied ram-wing interest.

However, many of the theoretical works were felt to be of such a basic and often unique nature that the tabulation often could not express the intent or method of the author. To clarify the theoretical background and to suggest a directed evolution of WIG theory, it was decided to abstract, at this point, all theoretical and truly contributory papers available in a chronological manner. Those theoretical papers concerned with the wind-tunnel ground interference correction have not been abstracted here.

A review in Appendix B of the theoretical treatment of WIG's indicates that the authors working in the last ten years apparently were not aware of the magnitude of the field as reported here. Now that the present review is available, it could prove the basis for much fruitful work, resulting from the cross-fertilization of individual ideas presented herein.

A synthesis of the available information on WIG's should be made. In particular, it is important to make an assessment of the ranges of

the ground distance parameter h/C for which each three-dimensional theory holds. The closer to the ground one wishes to consider, the more singularities are required. Also, very close to the ground, linearization is not permissible, whereas this is permissible for the unbounded case.

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BIBLIOGRAPHY

1. Ackermann, U. and G. Bock. Betrachtungen zu einem Zwei-Wirbel-Flügelmodell. Zeitschrift für Flugwissenschaften (Brunswick, Ger.), v. 9, Apr/May 1961, p. 100-104.

2. Across the Mississippi. Flight International (London), v. 82, 19 Jul 1962. Air-Cushion Vehicles Supplement, v. 1, no. 1, p. 3-4 (bound in).

   Bertelsen ram wing.

3. Adelmann, William and others. Boat. Wash., Dec 1929. 6 p. (Patent Office. 1,738,979)

4. Aeromobilia. Hovering Craft & Hydrofoil (London), v. 1, Dec 1961, p. 9-11.

   Bertelsen ram wing.

5. Ahlborn, Friedrich. Der Flug der Fische. Hamburg, 1895. 35 p. (Real-gymnasium des Johanneums)

6. Air-Cushioned, This Lockheed "Winged-Hull" ...Japanese Ram-Wing. Flight International (London), v. 82, 25 Oct 1962. Air-Cushion Vehicles Supplement, v. 1, no. 4, p. 71, 70 (bound in).

7. Albritton, J. P. and F. J. A. Huber. Wall Corrections for a Wing Near a Ground Plate in a Circular Cross Section Wind Tunnel. Dayton, Jun 1955. 20 p. (Wright Air Development Center. Tech. Rpt. 55-280)

8. Alexander, A. J. Experiments on a Jet-Flap Delta Wing in Ground Effect. Cranfield, 16 p. (Cranfield, Eng. College of Aeronautics. Rpt. 164)

9. Allied LRA-1 Amphibious Glider. In Jane's All the World's Aircraft, 1943/1944. New York, Macmillan, 1945, p. 158c.

10. Allison, John M. Tank Tests of a Model of the Hull of the Boeing 314 Flying Boat (NACA Tank Model 72). Wash., Sep 1936. (Nat. Advisory Com. for Aeronautics. Memo. Rpt.)

11. Ando, Shigenori. Japan's Ram-Wing Research. Flight International (London), v. 85, 28 May 1964. Air-Cushion Vehicles Supplement, v. 4, no. 23, p. 72 (bound in).

12. Ando, Shigenori and Jun-ichi Miyashita. Comments on Aerodynamic Drag of Ground Effect Machines. Aerospace Engineering (New York), v. 20, Nov 1961, p. 24-25, 79, 81-83.

13. Ando, Shigenori, Jun-ichi Miyashita, and K. Teraj. Summary of the Model Tests for Simple Ram Wing KAG-3. Hovering Craft & Hydrofoil (London), v. 3, Aug/Sep 1964, p. 38-50.

14. Andrews, Solomon. Form. Wash., Jun 1850. 1 p. (Patent Office. 7449)

15. Aoyagi, Kiyoshi and David H. Hickey. Large-Scale Wind-Tunnel Test in Ground Effect of a 35° Sweptback Wing Jet Transport Model Equipped With Blowing Boundary-Layer-Control Trailing and Leading-Edge Flaps. Wash., May 1963. 53 p. (Nat. Aeronautics & Space Adm. Tech. Note D-1884)

16. Armfield, William J., IV and others. Air Cushion Vehicles; Transportation of the Future. New York, Transportation Research Associates, 1962. p. 1, 2, 26-27, 43-45.

17. Ashill, P. R. Kawasaki KAG-3. Flight International (London), v. 85, 27 Feb 1964. Air-Cushion Vehicles Supplement, v. 4, no. 20, p. 29-30, 17 (bound in).

18. Ashill, P. R. The State of the Art of Ram Wing Research. Hovering Craft & Hydrofoil (London), v. 2, May 1963, p. 18-20,22.

Also issued as Cranfield, Eng. College of Aeronautics. Note 159. Nov 1963. 14 p.

19. Auld, Charles D. and Richard M. Hartley. Wind-Tunnel Test of a Model of the XP5M-1 Airplane. Pt. 3: Ground Effects on the Longitudinal Characteristics of a 0.0625-Scale Powered Model. Wash., Mar 1949. 5 l. 11 plates. (David Taylor Model Basin. Rpt. C-206. Aero Rpt. 763 Pt. 3)

20. Babcock, Vearne C. Boat Hull. Wash., Jan 1954. 7 p. (Patent Office. 2,666,406)

21. Bäuerle, Hans. Six Component Measurements on a Model of the Seaplane HA-139 Over a Plane Representing the Water Surface (Sechskomponenten Messungen an einem Modell des Seeflugzeuges Ha-139 über einer den Wasserspiegel darstellenden Platte). Wash., 1948? 12 l. (handwritten). (David Taylor Model Basin. Aerodynamics Laboratory) (Unrevised partial translation of: Germany. Zentrale für Wissenschaftliches Berichtswesen ... Forschungsbericht 945. Berlin-Adlershof, Jun 1938. 17 p.) Ger. text appended.

Also in Jahrbuch 1939 der Deutschen Luftfahrtforschung. Munich, R. Oldenbourg, 1939. p. I-377 - I-382. Ger. text. Title varies.

22. Bagley, J. A. Low-Speed Tunnel Tests on a Two-Dimensional Aerofoil With Split Flap Near the Ground. Farnborough, Mar 1961. 15 p. (Gt. Brit. Royal Aircraft Est. Tech. Note Aero 2636)

23. Bagley, J. A. The Pressure Distribution on Two-Dimensional Wings Near the Ground. London, H. M. Stationery Off., 1961. 40 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 3238. 22,060. Feb 1960) (Gt. Brit. Royal Aircraft Est. Rpt. Aero 2625. Feb 1960)

24. Bairstow, Leonard. Applied Aerodynamics. New York, Longmans, Green, 1939. p. 410-413.

25. Bamberger, Julien G. Catamaran Type Boat. Wash., Feb 1963. 4 p. (Patent Office. 3,077,851)

26. Bamberger, Julien G. Hydroplane. Wash., Jul 1931. 5 p. (Patent Office. 2,422,818)

27. Barlow, Gerald R. and R. G. Huntington. Preliminary Study of Hover Performance of a Ram-Wing GEM. Wash., Oct 1962. 39 p. (David Taylor Model Basin. Rpt. 1662. Aero Rpt. 1015)

28. Bell, Joe W. and James M. Benson. Tank Tests of the Martin No. 156 Flying-Boat Model (NACA Tank Model 70). Wash., Aug 1936. (Nat. Advisory Com. for Aeronautics. Memo. Rpt.)

29. Bertelsen, William R. The Arcopter GEM Project. Hovering Craft & Hydrofoil (London), v. 1, Jul 1962, p. 21-23.

30. Betz, Albert. Applied Airfoil Theory. In Durand, William F. Aerodynamic Theory. New York, Dover Publications, 1963. v. 4, p. 94.

31. Betz, Albert. Die Gegenseitige Beeinflussung zweier Tragflächen. Zeitschrift für Flugtechnik and Motorluftschiffahrt (Munich), v. 5, 17 Oct 1914, p. 253-258.

32. Betz, Albert. The Lift and Drag of a Wing in Proximity to the Ground (Auftrieb and Widerstand einer Tragfläche in der Nähe einer horizontalen Ebene (Erdboden). Dayton, 1925. (Air Force. Air Materiel Command. Memorandum Rpt. 167)(Translation from Zeitschrift für Flugtechnik und Motorluftschiffahrt (Munich), v. 3, 14 Sep 1912, p. 217-220)

Issued while the Engineering Division of the Air Materiel Command was part of the War Dept. Air Service. This Division was later merged with other groups as the Wright Air Development Center. The latter became part of the Aeronautical Systems Div. of the Air Force Systems Command.

33. Blaisdell, Allen H. Making Use of Ground Effect. Aviation (New York), v. 38, Sep 1939, p. 32-33, 77-78.

34. Boehler, Gabriel D. Basic Principles of Ground Cushion Devices. Jan 1960. (Society of Automotive Engineers. Preprint 133A. p. 5, 7-8, 18-20)

35. Bonder, Julian. Ruch Dwóch Walców w Cieczy Doskonalej Wraz Z Zastosowaniem do Lotu w Bliskości Ziemi. Warsaw, A. Michalski, 1925. (Warszawskie Towarzytstwo Politechniczne. Sprawozdania i Prace, v. 4, no. 9, 1925, p. 1-80)

Abstracted in Zeitschrift für angewandte Mathematik und Mechanik (Berlin), v. 9, Jun 1929, p. 242-245.

36. Borgenstam, Curt. Hovering Craft; Their Future Use and Development. Hovering Craft & Hydrofoil (London), v. 2, Oct 1962, p. 9, 11.

37. Bradfield, F. B., ed. Notes on the Technique Employed at the R.A.E. in Low-Speed Wind-Tunnel Tests in the Period 1939-1945. London, H. M. Stationery Off., 1952. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 2556, Oct 1947, p. 4)

38. Braunss, Günter and Wolfgang Lincke. Die Auftriebsverteilung einer ebenen Platte in Bodennähe. Zeitschrift für Flugwissenschaften (Brunswick, Ger.), v. 10, Jul 1962, p. 282-285.

39. Braunss, Günter and Wolfgang Lincke. Einfluss der Bodennähe auf die Auftriebsverteilung einer ebenen Platte in ebener inkompressibler Strömung. Darmstadt, 1960. (Darmstadt. Technische Hochschule. Institut für Luftfahrttechnik. Bericht)

40. Breder, C. M., Jr. Field Observations on Flying Fishes; a Suggestion of Methods. Zoologica (New York), v. 9, 1929, p. 295-312.

41. Breder, C. M., Jr. On the Structural Specialization of Flying Fishes From the Standpoint of Aerodynamics. Copeia (Northridge, Calif.), no. 4, 31 Dec 1930, p. 114-121.

42. Brown, W. S. Wind Tunnel Corrections on Ground Effect. London, H. M. Stationery Off., Jul 1938. 32 p. (Gt. Brit. Aeronautical Research Council. Rpt. & Memo. 1865)

43. Brownback, Henry L. Speedboat and Hull. Wash., Jan 1945. 6 p. (Patent Office. 2,366,590)

44. Buell, Donald A. and Bruce E. Tinling. Ground Effects on the Longitudinal Characteristics of Two Models With Wings Having Low Aspect Ratio and Pointed Tips. Wash., Jul 1957. 48 p. (Nat. Advisory Com. for Aeronautics. Tech. Note 4044)

45. Buell, Donald A. and Bruce E. Tinling. The Static Longitudinal Stability and Control Characteristics in the Presence of the Ground of a Model Having Triangular Wing and Canard. Wash., Mar 1959. 32 p. (Nat. Aeronautics and Space Admin. Memo. 3-4-59A)

46. Bukowski, Jerzy. Technika Laboratoryjna Pomiarów Aerodynamiczynch. Warsaw, 1933. p. 45. (Warsaw. Instytut Aerodynamiczny)

47. Bureau d'Analyse et de Recherche Appliquées (France). Theoretical Analysis of Air Flow Around Wings Located in the Vicinity of the Ground. Issy-Les-Moulineaux, France, 1962. 8 p. (U. S. Army Contract DA 91-591-EUC 1758. Final Rpt. 1 Mar-30 May 1962)

48. Burke Walter F. Design Information on Seawings. Baltimore, Md., Mar 1941. (Martin Co. Eng. Rpt. 1429).
Issued under former name: Glenn L. Martin Co.

49. Bush, R. G. Lateral Water Stability Model 314 Dynamic Model. Seattle, Oct 1940. (Boeing Co. Document D-2870).
Issued under former name: Boeing Aircraft Co.

50. Butler, Sidney F. J. and B. A. Moy. Interim Report on Six-Component Low-Speed Tunnel Tests of the Effect of Ground Proximity on an Aspect-Ratio 9 Jet Flap Complete Model. Farnborough, Jul 1960. 8 p. (Gt. Brit. Royal Aircraft Est. Tech. Note Aero 2692)

51 Butler, Sidney F. J., M. B. Guyett and B. A. Moy. Six-Component Low-Speed Tunnel Tests of Jet-Flap Complete Models With Variation of Aspect Ratio, Dihedral, and Sweepback, Including the Influence of Ground Proximity. Farnborough, Jun 1961. (Gt. Brit. Royal Aircraft Est. Rpt. Aero 2652, p. 13-15)

52. Carafoli, Elie. Aérodynamique des Ailes d'Avion. Influence des Parois et des Surfaces Libres. Paris, Librairie Aéronautique, 1928. p. 94-96.

Also in Revue Générále de l'Aéronautique, no. 10, 1929, p. 94-103.

53. Carafoli, Elie. Aerodinamica. Bucharest, Editura Tehnica, 1951. p. 463-466.

54. Carmichael, Bruce H., Frank A. Dobson and William L. Rawlings. State of the Art Summary; Air-Cushion Vehicles. Newport Beach, Calif., Jun 1960. (Aeronutronic Publ. U-926. p. 6.1-6.12)

Revised as: Army. Transportation Research Command. TCREC Tech. Rpt. 61-108. See Item 265 by Rawlings and others.

55. Carroll, Edward R. Amphibian Aeroplane Without Boat-Shaped Pontoons. Wash., Mar 1929. 3 p. (Patent Office. 1,704,076)

56. Carter, Arthur W. Effect of Ground Proximity on the Aerodynamic Characteristics of Aspect-Ratio-1 Airfoils With and Without End Plates. Wash., Oct 1961. 27 p. (Nat. Aeronautics and Space Adm. Tech. Note D-970)

57. Catamaran Flying Ships; an Air/Sea Compromise for Trans-Ocean Travel? Flight International (London), v. 63, 2 Jan 1953, p. 8.

Martin Development Co.

58. Causing a Mild Sensation on the Connecticut River From Essex South to Long Island Sound is a 26 ft. Ram-Wing Boat Designed by Norman Dickinson...In People and Projects. Hovering Craft & Hydrofoil (London), v. 2, Sep 1963, p. 4.

59. Cesare, Cremona. Esperienze Sistematiche Sugli Scafi G.I.S. 27, 28, 29 e 30. Rome, 1940. (Italy. Atti di Guidonia, v. 2, p. 205-232. No. 31, Aug 1940)

Abstracted in: Luftwissen (Berlin), v. 8, Feb 1941, p. 62.

60. Chaffois, J. Aérodynamique de l'Avion. Paris, Dunod, 1962. v. 1, p. 63-65.

61. Chaplin, Harvey R. Ground Effect Machine Research and Development in the United States. Wash., Dec 1960. (David Taylor Model Basin. Rpt. 1463. Aero Rpt. 994. p. 14-16)

62. Chaplin, Harvey R. Integrated Propulsion System for Ram Wing Aircraft. Wash., Jun 1964. 6 p. (Patent Office. 3,135,480)

63. Chaplin, Harvey R. and Lewis W. Masters. Rheoelectric Measurements of Some Theoretical Effects of Ground Proximity on Wings. Wash., Jan 1964. 13 p. (David Taylor Model Basin. Aero Rpt. 1068)

64. Cid, Arthur V. Neue Forschungsergebnisse auf dem Wege zur Entwicklung eines hochseetüchtigen Wasser-Segelflugzeuges. Munich, R. Oldenbourg. (Internationale Studienkommission für den Motorlosen Flug. Mitteilungsblatt no. 5, Dec 1937. p. 108-120)

65. Clark, K. W. and W. D. Tye. Some Measurements of Ground Effect in the Seaplane Tank. (Gt. Brit. Aeronautical Research Council. 3263. Aug 1937)(Gt. Brit. Royal Aircraft Est. Rpt. BA 1421. Aug 1937)

Unpublished.

66. Cleveland Firm Developing Duckling Personal Amphib. Aviation (New York), v. 45, Oct 1946, p. 84.

International Aviation Corp. amphibian.
Also described in Aviation, v. 46, Mar 1947 (Yearbook Issue), p. 71 as "International Aviation."

67. Collins, J. S. Perservance in Miniature. Flight International (London), v. 83, 27 Jun 1963. Air-Cushion Vehicles Supplement, v. 2, no. 12, p. 101-102 (bound in).

68. Collins Radio Co. Research on the Aerofoil Boat Concept; Engineering Proposal. Cedar Rapids, Iowa, Jan 1964. 9 p.

69. Coombes, L. P. The Effect of Various Type of Lateral Stabilizers on the Take-off of a Flying Boat. London, H. M. Stationery Off., Oct 1930. 5 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 1411)

70. Coombes, L. P. and D. W. Bottle. Notes on Stubs for Seaplanes. London, H. M. Stationery Off., Sep 1935. 32 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 1755)

71. Corbett, W. E. P. The Soaring Flight of the Albatross. Sailplane and Glider (London), v. 14, Jul 1946, p. 7-8.

72. Coward, K. S. Direct Ascent Aircraft Employing the Deflected Slipstream Principle; Summary Report (U). San Diego, Apr 1956. 44 p. (Ryan Aeronautical Co. Rpt. 8818-3) CONFIDENTIAL Rpt. Group 4.

73. Cowley, W. L. and C. N. H. Lock. Cushioning Effect on Aeroplanes Close to the Ground. London, H. M. Stationery Off., Jul 1920. 10 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 754)

74. Cowley, W. L. and G. A. McMillan. Interference Effect of Surface of Sea on a Flying Boat. London, H. M. Stationery Off., May 1934. 15 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 1626)

75. Cox, Harold Roxbee and L. P. Coombes. The Hull-less Flying-Boat. Aeroplane (London), v. 53, 1 Dec 1937, p. 677-680.

76. Cram, R. L. Hull Model Towing Tests; Model 314. Seattle, Nov 1938. (Boeing Co. Rpt. D-1604 Revised)

Issued under former name: Boeing Aircraft Co.

77. Crook, Louis H. Warner Jet Propelled Compression Plane. Wash., Jun 1943. 6 p. (Crook (L. H.) Aerodynamic Laboratory. Aeronautical Rpt. 560)

78. Dätwyler, Gottfried. Untersuchungen über das Verhalten von Tragflügelprofilen sehr nahe am Boden. Zürich, Verlag Leemann, 1934. 109 p. (Zürich. Eidgenössische Technische Hochschule. Institut für Aerodynamik. Mitteilungen 1. Promotionarbeit 773)

-- English abstract in Aircraft Engineering (London), v. 7, Jan 1935, p. 24.

79. Daněk, Milan. Aerodynamika a Mechanika Letu pro Piloty a Techniky. Prague, Naše Vojsko, 1958. p. 62-63.

80. Daniels, Charles J. Tank Test of 1/10 Full-Size Model of Allied Aviation Corporation's 12-Place Float-Wing-Glider; NACA Model 140. Wash., Jul 1942. (Nat. Advisory Com. for Aeronautics. Memo. Rpt.)

Work done for the Bureau of Aeronautics.

81. Daniels, Charles J. Tank Tests of 1/10-Full-Size Model of Navy XLRQ-1 12-Place Float-Wing Seaplane Glider; NACA Model 133. Wash., Jun 1942. (Nat. Advisory Com. for Aeronautics. Memo. Rpt.)

Work done for the Bureau of Aeronautics.

82. Daniels, Charles J. Tests of a Model of a Flying-Boat Hull Incorporating D. K. Warner's "Compression-Plane" Principle; NACA 171. Wash., 1944. (Nat. Advisory Com. for Aeronautics. Memo. Rpt. L4F24)

83. Dau, Karl. Characteristics of a Rectangular Wing With a Peripheral Jet in Ground Effect. Pt. 1. Toronto, Sep 1961. 23 p. [56] plates. (Toronto, Univ. Institute for Aerospace Studies. Tech. Note 56)

Issued under former name: Institute of Aerophysics.
Pt. 2 issued as Tech. Note 59. See Item 89 by Davis.

84. David Taylor Model Basin. GEM Planning Committee. Advance Planning Report. Wash., 1961. 14 p.

Unpublished.

85. David Taylor Model Basin. Air Force and Moment on NAF Float-Wing Glider. Wash., Aug 1942. 5[1] l. 19 plates. (Aerodynamics Lab. Aero Rpt. 636)

Issued under former name: Aerodynamical Laboratory. Navy Yard, Wash.
Allied LRA-1 Amphibious Glider.

86. David Taylor Model Basin. F4U Airplane With Jet Propulsion Unit. Wash., Jan 1943. 8[2] l. 21 plates. (Aerodynamics Lab. Aero Rpt. 655)

Issued under former name: Aerodynamical Laboratory. Navy Yard, Wash.

87. Davidson, I. M. The Jet Flap. Royal Aeronautical Soc. Jour. (London), v. 60, Jan 1956, p. 30, 32.

88. Davidson, I. M. and B. S. Stratford. An Introduction to the Jet Flap. Pyestock, Jun 1954. (Gt. Brit. Nat. Gas Turbine Est. Rpt. R.155. p. 34)

89. Davis, James M. Characteristics of a Rectangular Wing With a Peripheral Jet in Ground Effect. Pt. 2. Toronto, May 1962. 30 p. [111] plates. (Toronto, Univ. Institute for Aerospace Studies. Tech. Note 59)

Issued under former name: Institute of Aerophysics.
Pt. 1 issued as Tech. Note 56. See Item 83 by Dau.

90. DiBartola, P. E. and R. J. Bulinski. Home is Anywhere for GETOL Airplane. S.A.E. Jour. (New York), v. 70, Jan 1962, p. 76-78.

Issued also as Society of Automotive Engineers Paper 428C. Abstracted with comments as "Ground Effect to Aid Take-Off" in The Aeroplane, v. 102, 8 Feb 1962, p. 134-135.

91. Diehl, Walter S. Engineering Aerodynamics. Rev. ed., New York, Ronald Press Co., 1936. p. 58-60, 445, 446.

92. Dimmock, N. A. An Experimental Introduction to the Jet Flap. Pyestock, Jul 1955. (Gt. Brit. Nat. Gas Turbine Est. Rpt. R.175. p. 20-21)

93. Dimmock, N. A. Some Further Jet Flap Experiments. Pyestock, May 1955. (Gt. Brit. Nat. Gas Turbine Est. Memo M.255. p. 13)

94. Doetsch, H. Sechskomponenten-Messungen an zwei Tragflügeln und an einem Flugbootmodell. Munich, R. Oldenbourg, 1939. (Jahrbuch 1939 der Deutschen Luftfahrtforschung. p. I243-I253)

95. Doetsch, K. H., G. C. Howell and W.F.W. Urich. The Landing Flare of a Gothic-Wing Aircraft of Aspect Ratio 1.0 Taking Account of the Aerodynamic Ground Effect. Farnborough, Jan 1960. 7 p. (Gt. Brit. Royal Aircraft Est. Tech. Note Aero 2600, Rev.)

96. Dornier, Claudius. Flying boat. Wash., Jul 1926. 4 p. (Patent Office. 1,591,475)

97. Dornier, Claudius. Flying-Boat's Hull. Wash., Dec 1924. 4 p. (Patent Office. 1,518,640)

98. Dornier, Claudius. Vorträge und Abhandlungen aus dem Gebiete des Flugzeugbaues und Luftschiffbaues, 1914-1930. Friedrichshafen, Ger., Jan 1930. 145 p.

99. Dornier, Peter, Eugen Jager and Karl Wiedemer. Airplane Adapted to Start and Land on an Air Cushion. Wash., Dec 1962. 3 p. (Patent Office. 3,070,327)

100. Dowd, R. E. The Aeronautics of the Flying Fish. Aerial Age Weekly (New York), v. 12, 10 Jan 1921, p. 464-465.

101. Dugdale, L. Deep Water Birds and Gust Soaring. Sailplane and Glider (London), v. 13, Feb 1945, p. 6-7, 11.

102. Dunham, William H. Aerodynamically Designed Amphibious Vehicle. Wash., Feb 1963. 18 p. (Patent Office. 3,077,321)

103. Dunham, William H. Preliminary Results of Wind-Tunnel Tests of the HS-2 Hydroskimmer. Wash., Oct 1961. 34 p. (David Taylor Model Basin. Rpt. 1571)

104. Dwinnell, James H. Principles of Aerodynamics. 1st ed. New York, McGraw-Hill, 1949. p. 136, 337.

105. Earl, T. D. Ground Effect Machines. Paris, Jan 1962. (NATO. Advisory Group for Aeronautical Research and Development. AGARDograph 37. p. 34)

106. Emery, E. G., Jr. Hydrodynamic Stability Study. Seattle, May 1939. (Boeing Co. Rpt. D-2220)

Issued under former name: Boeing Aircraft Co.

107. Ennakkoluulot Ovat Estennä Keksintöjen Toteuttamiselle (Prejudices are Hinderance to Exploitation of Discovery). Uusi Suomi (Helsinki), no. 175, 1959, p. 5.

Translated title of this Finnish newspaper is: New Finland. Article treats Kaario ram wing.

108. Entwistle, F. The Meteorological Problem of the North Atlantic. Royal Aeronautical Soc. Jour. (London), v. 43, Feb 1939, p. 92, 100, 103.

109. Etkin, Bernard. Dynamics of Flight. New York, Wiley, 1959. p. 76-77, 475-477.

110. Fairchild Stratos Corp. Aircraft & Missile Div. A Concept for a Transoceanic Logistic Carrier. Rev. Hagerstown, Md., Mar 1960. 60 l. (Rpt. MR-75)

111. Fairchild Stratos Corp. Aircraft & Missile Div. A Proposal to Study Certain Aspects of Airplane in Ground Effect. Hagerstown, Md., Nov 1960. 32 p. (Rpt MR-94)

112. Fick, Roderich. Lilienthal Effekt and Dynamisches Segeln. Zeitschrift für Flugtechnik und Motorluftschiffahrt (Munich), v. 15, 28 Nov & 13 Dec 1924, p. 244-246 & 258-260, respectively.

113. Fink, Marvin P. and James L. Lastinger. Aerodynamic Characteristics of Low-Aspect-Ratio Wings in Close Proximity to the Ground. Wash., Jul 1961. 37 p. (Nat. Aeronautics and Space Adm. Tech. Note D-926)

114. Fitz Patrick, James L. G. Natural Flight and Related Aeronautics. New York, Jun 1952. 118 p. Bibliog. (American Institute of Aeronautics and Astronautics. Sherman M. Fairchild Publication Fund Paper FF-7)

Issued under former name: Institute of the Aeronautical Sciences.

115. Fontaine, Maurice. Quand les Poissons Quittent Leur Domaine Aquatique. Science et Vie (Paris), v. 82, Jul 1952, p. 25-30.

116. Foshag, William F. Design and Fabrication of Two "Hydro-Skimmer" Models. Wash., Jan 1961. 10 p. (Aerophysics Co. Proposal AP-28)

117. Fujikawa, Hiroomi. The Lift on the Symmetrical Joukowski Aerofoil in a Stream Bounded by a Plane Wall. Physical Soc. of Japan Jour. (Tokyo), v. 9, Mar/Apr 1954, p. 233-239.

118. Fujikawa, Hiroomi. Note on the Lift Acting on a Circular-Arc Aerofoil in a Stream Bounded by a Plane Wall. Physical Soc. of Japan. Jour. (Tokyo), v. 9, Mar/Apr 1954, p. 240-243.

119. Furlong, G. Chester and T. V. Bollech. Effect of Ground-Interference on the Aerodynamic and Flow Characteristics at a 42° Swept-back Wing at Reynolds Numbers up to 6.8×10^6. Wash., Govt. Print. Off., 1955. 60 p. (Nat. Advisory Com. for Aeronautics. Rpt. 1218)

120. Garber, J. R. and J. Deneguolo. Watercraft. Wash., Dec 1943, 3 p. (Patent Office. 2,336,987)

121. Garmont, Harry H. Hull Construction. Wash., Nov 1949. 6 p. (Patent Office. 2,488,183)

122. Gar Wood Predicts Boats That Fly. Modern Mechanics and Inventions (Minneapolis), v. 4, Aug 1930, p. 51.

123. General Dynamics/Convair. GETOL Research Program; Final Report. Ft. Eustis, Va., Aug 1963. 165 p. (GDC-62-370. Contract DA 44-177-TC-722)(Army. Transportation Research Command. Tech. Rpt. 63-1)

124. Giles, Harry L., Jr. Theoretical Ground Plane Effects on Span Loading for Wings Having No Sweep. Seattle, 1955. 66 p. (Washington. Univ. Thesis (M.S. Aero))

125. Glauert, Hermann. Wind Tunnel Interference on Wings, Bodies and Airscrews. London, H. M. Stationery Off., 1933. 75 p. [223] plates. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 1566. Sep 1933)

126. Goranson, Fabian R. A Method for Predicting the Elevator Deflection Required to Land. Wash., Sep 1944. 17 p. (Nat. Advisory Com. for Aeronautics. Wartime Rpt. L-95. Advanced Restricted Rpt. L4I16)

127. Green, A. E. The Forces Acting on a Circular-Arc Aerofoil in a Stream Bounded by a Plane Wall. London Mathematical Soc. Proceedings, 2nd ser., pt. 1, v. 46, 14 Nov 1939, p. 19-54.

128. Green, A. E. The Two-Dimensional Aerofoil in a Bounded Stream. Quarterly Jour. of Mathematics (London), v. 18, Sep 1947, p. 167-177.

129. Greenberg, Mayo J. Some Considerations of an Airfoil in an Oscillating Stream. Wash., Aug 1947. 38 p. (Nat. Advisory Com. for Aeronautics. Tech. Note 1372)

130. Greif, Richard K., Mark W. Kelley and William H. Tolhurst, Jr. Wind-Tunnel Tests of a Circular Wing With an Annular Nozzle in Proximity to the Ground. Wash., May 1960. 37 p. (Nat. Aeronautics and Space Adm. Tech. Note D-317)

131. Ground Effect; the Whys and Wherefores. Flight International (London), v. 82, 20 Dec 1962. Air-Cushion Vehicles Supplement, v. 1, no. 6, p. 117 (bound in).

Dornier DO-X.

132. Haller, Pierre de. La Portance et la Trainée Induite Minimum d'une Aile au Voisinage du Sol. Zürich, Verlag Leemann, 1936. (Zürich. Eidgenössische Technische Hochschule. Institut für Aerodynamik. Mitteilungen 5)

133. Hancock, G. J. The Ground Effect on a Two-Dimensional Jet-Flapped Aerofoil. London, Jun 1958. 12 p. 6 plates. (Gt. Brit. Aeronautical Research Council. 20,251. FM 2692. S&C 3289)

134. Hankin, E. H. Animal Flight; a Record of Observation. London, Iliffe and Sons, 1914. 405 p.

135. Hankin, E. H. Observations on the Flight of Flying Fishes. Zoological Soc. of London. Proceedings, no. 2, 1920, p. 467-474.

136. Havelock, T. H. The Lift and Moment on a Flat Plate in a Stream of Finite Width. Royal Soc. of London. Proceedings. Ser. A, v. 166, no. 925, 19 May 1938, p. 178-196.

137. Hayward, L. H. The History of Air-Cushion Vehicles. Hovering Craft & Hydrofoil (London), v. 2, Dec 1962, p. 12-17 & Jan 1963, p. 12-18.

Also issued as monograph by Kalerghi-McLeavy Publications, London.

138. Heald, Roy H. Comparison of the Ground-Plane and Image Methods for Representing Ground Effect in Tests on Vehicle Models. Jour. of Research of the Nat. Bureau of Standards (Wash.), v. 13, Dec 1934, p. 863-870.

139. Heinkel, Ernst. German Patent 558802. 12 Sep 1932. Flugsport (Frankfurt), v. 24, 1932. Patentsammlung des Flugsport, v. 4, no. 34, 1932, p. 133.

140. Heyson, Harry H. Tables of Interference Factors for Use in Wind-Tunnel and Ground-Effect Calculations for VTOL-STOL Aircraft. Pt. 1: Wind Tunnels Having Width-Height Ratio of 2.0. Wash., Jan 1962. 208 p. (Nat. Aeronautics & Space Adm. Tech. Note D-933)

141. Heyson, Harry H. Tables of Interference Factors for Use in Wind Tunnel and Ground-Effect Calculations for VTOL-STOL Aircraft. Pt. 2: Wind Tunnels Having Width-Height Ratio at 1.5. Wash., Jan 1962. 201 p. (Nat. Aeronautics & Space Adm. Tech. Note D-934)

142. Heyson, Harry H. Tables of Interference Factors for Use in Wind Tunnel and Ground-Effect Calculations for VTOL-STOL Aircraft. Pt. 3: Wind Tunnels Having Width-Height Ratio of 1.0. Wash., Jan 1962. 202 p. (Nat. Aeronautics & Space Adm. Tech Note D-935)

143. Heyson, Harry H. Tables of Interference Factors for Use in Wind-Tunnel and Ground-Effect Calculations for VTOL-STOL Aircraft. Pt. 4: Wind Tunnels Having Width-Height Ratio of .5. Wash., Jan 1962. 201 p. (Nat. Aeronautics & Space Adm. Tech Note D-936)

144. Heyson, Harry H. Wind-Tunnel Wall Interference and Ground Effect for VTOL-STOL Aircraft. American Helicopter Soc. Jour. (New York), v. 6, Jan 1960, p. 1-9.

145. Hoerner, Sighard F. Fluid-Dynamic Drag; Practical Information on Aerodynamic Drag and Hydrodynamic Resistance. 2nd ed. Midland Park, N. J., 1958. p. 7-13 - 7-14.

146. Houghton, Edward L. and Alan E. Brock. Aerodynamics for Engineering Students. London, Edward Arnold, 1960. p. 372-374.

147. Hubbs, Carl L. The Flight of the California Flying Fish. Copeia (Northridge, Calif.) no. 62, 1918, p. 85-88.

148. Hubbs, Carl L. Further Observations and Statistics on the Flight of Fishes. Michigan Academy of Science, Arts and Letters. Papers, v. 22, 1937, p. 641.

149. Hubbs, Carl L. Nature's Own Seaplanes. Wash., 1933. (Smithsonian Institution. Annual Rpt. p. 333-348)

150. Hubbs, Carl L. Observations on the Flight of Fishes, With a Statistical Study of the Flight of the Cypselurinae and Remarks on the Evolution of the Flight of Fishes. Michigan Academy of Sciences, Arts and Letters. Papers, v. 17, 1932, p. 575-611.

151. Huber, L. Strömungsbilder zum Bodeneinfluss. Verein Deutscher Ingenieure. Zeitschrift (Berlin) v. 84, 20 Jul 1940, p. 522-523.

152. Hudimoto, Busuke. The Lift on an Aerofoil With a Circular Arc Section Placed Near the Ground. Kyoto. Imperial Univ. College of Engineering. Memoirs, v. 8, Mar 1934, p. 36-41.

153. Huggett, D. J. An Approach to the Theoretical Study of the Ground Effect on a Jet Flap. London, Jun 1958. 7 p. (Gt. Brit. Aeronautical Research Council, 20,279)(AD 209,713)

Also as: Southampton, Eng. Univ. Rpt. 112. 1959.

154. Huggett, D. J. The Ground Effect on the Jet Flap in Two Dimensions. [Pt. 1]. London, Dec 1957. 6 p. (Gt. Brit. Aeronautical Research Council. 19,713)

Also in Aeronautical Quarterly (London), v. 10, Feb 1959, p. 28-46.

155. Huggett, D. J. and A. J. Wilson. The Ground Effect on the Jet Flap in Two Dimensions. Pt. 2: Pitching Moment and Downwash Changes on a 58° Flap and Further Experiments, Including Pitching Moment Changes on a 31° Flap. London, Feb 1958. 4 p. [4] plates. (Gt. Brit. Aeronautical Research Council. 19,906. S&C 3251)

156. Hugh, Alastair. Background to Hovercraft. Flight International, v. 75, 19 Jun 1959, p. 825-826.

157. Hutchinson, J. L. Further Measurements of Ground Interference on the Lift of a Southampton Flying Boat. London, H. M. Stationery Off., n.d. 5 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 1747. Nov 1935)

158. Hutchinson, J. L. Note on Tokyo Imperial University Report 156. Mar 1938. (Gt. Brit. Marine Aircraft Experimental Est. Rpt. F/Res/114)(Gt. Brit. Aeronautical Research Council. 3376a. Ae. Techl. 1351a)

Unpublished.

159. Idrac, Pierre. Etudes Experimentales sur le Vol à Voile. Paris, Librairie des Science Aéronautiques, 1931. 75 p.

German ed.: Experimentelle Untersuchungen über den Segelflug ... Munich, R. Oldenbourg, 1932. 81 p.

160. Ingalls, Albert G. Ashore and afloat. Scientific American (New York), v. 136, Mar 1927, p. 195.

161. Japanese Ram-Wing. Flight International (London), v. 82, 25 Oct 1962. Air-Cushion Vehicles Supplement, v. 1, no. 4. p. 70 (bound in).

162. Jones, Bradley. Elements of Practical Aerodynamics. 4th ed. New York, Wiley, 1950. p. 190-193.

163. Jones, R. Lindbergh and Ground Effect. Flight International (London), v. 83, 28 Mar 1963. Air-Cushion Vehicles Supplement v. 2, no. 9, p. 50 (bound in).

164. Kaario, Toivo J. Ilman Kantama Pintakulkuneuvo [Air Cushioned Surface Vehicle]. Teknillen Aikakauslehti (Helsinki), v. 32, Feb 1942, p. 43-47.

Translated in Aerophysics Co. Rpt. AR-595, p. 6-15. See Item 166 by Kaario.

165. Kaario, Toivo J. The Principles of Ground Effect Vehicles. In Princeton Univ. Symposium on Ground Effect Phenomena; a Compilation of the Papers Presented Oct 21, 22, 23, 1959. Princeton, Mar 1960. p. 253-262.

166. Kaario, Toivo J. Translations From the Finnish of Two Patents and One Paper Describing T. J. Kaario's Early Work on Air-Cushion Vehicles (1932-1949). Wash., Nov 1959. 15 l. (Aerophysics Co. Rpt. AR-595)

167. Kahl, John F. Flying-Machine. Wash., Mar 1919. 5 p. (Patent Office. 1,296,089)

168. Kangas, Jussi. Lentävä Siipi; Tulevaisuuden Kulkuneuvo? [Flying Wing; Vehicle of the Future?] Kansan Kuvalehti (Helsinki), no. 22, 1950, p. 6.

169. Katzoff, Samuel and Harold H. Sweberg. Ground Effect on Downwash Angles and Wake Location. Wash., Govt. Print. Off., 1943. 12 p. (Nat. Advisory Com. for Aeronautics. Rpt. 738)

Also in: Nat. Advisory Com. for Aeronautics. Twenty-Eighth Annual Report...1942. Wash., Govt. Print. Off., 1946, p. 159-170.

170. Kawasaki's Ram Wing. Flight International (London), v. 82, 22 Nov 1962. Air-Cushion Vehicles Supplement, v. 1, no. 5, p. 88 (bound in).

171. Kensche, Heinz. Dynamic Soaring. Sailplane and Glider (London), v. 19, Nov 1951, p. 249-250. (Translation from Thermik; Zeitschrift für die gesamte Luftfahrt, Jan/Feb 1951)

172. Kirkham "Air Boat." In Jane's All the World's Aircraft. London, S. Low, Marston and Co., 1926. p. 267b-268b.

173. Kirschbaum, N. and J. Helgesen. Supplementary Lift for Air Cushioned Vehicles. Vol. 1: Data Report. Bethpage, L. I., 1962. 1 v. (Grumman Aircraft Engineering Corp. Contract DA 44-177-TC-708. Final Rpt.) (Army. Transportation Research Command. TR 62-98)

This volume issued only by Grumman with TRECOM report number affixed.

174. Kirschbaum, N. and J. Helgesen. Supplementary Lift for Air Cushioned Vehicles, Vol. 2: Data Analysis. Ft. Eustis, Va., Jun 1962. 164 p. (Grumman Aircraft Engineering Corp. Contract DA 44-177-TC-708. Final Rpt.)(Army. Transportation Research Command. TREC Tech. Rpt. 62-50)

175. Kirschbaum, N. and J. Helgesen. Supplementary Lift for Air Cushioned Vehicles, Vol 3: Performance Analysis. Ft. Eustis, Va., Jun 1962. 78 p. (Grumman Aircraft Engineering Corp. Contract DA 44-177-TC-708. Final Rpt.)(Army. Transportation Research Command. TREC Tech. Rpt. 62-51)

176. Klemin, Alexander. A Belt Method of Representing the Ground. Jour. of the Aeronautical Sciences (New York), v. 1, Oct 1934, p. 198-199.

177. Kloen, Max. Hydro-speed Ship. Wash., Jul 1931, 5 p. (Patent Office. 1,815,303)

178. Knoller, Richard. Die Gesetze des Luftwiderstandes. Flug- und Motortechnik (Vienna), v. 3, 25 Jul 1909, p. 1-6.

179. Knowlton, M. P. and D. Summers. Stability and Performance Characteristics of a Cruciform Getol. Princeton, Dec 1961. 10 p. 18 plates. (Princeton Univ. Dept of Aeronautical Engineering. Rpt. 580)

180. Koenig, David G., James A. Brady and Robert V. Page. Large-Scale Wind-Tunnel Tests at Low Speed of a Delta Winged Supersonic Transport Model in the Presence of the Ground. Wash., Jan 1962. 28 p. (Nat. Aeronautics and Space Adm. Tech. Memo. X-644)

181. Kohler, M. Luftkräfte und Luftkraftemomente an einem Seeflugzeug auf dem Wasser. Zeitschrift für Flugtechnik und Motorluftschiffahrt (Munich), v. 24, 28 Aug 1933. p. 442-446.

182. Koriagin, Usevolod. Aero-Glide Boat. Wash., Jan 1964. (Patent Office. 3,118,411)

183. Krejci-Graf, Karl. Beobachtungen über den Flug fliegender Fische. Natur und Volk (Frankfurt), v. 66, 1 Dec 1936, p. 623-625.

184. Kubota, Toshi. Theoretical Study of the Influence of Bleed Area on Aerodynamic Ground-Interference Phenomena. China Lake, Calif., Mar 1959. 91 p. (AER, Inc. Tech. Rpt. 115 (114-9-1). Contract N123(60530)14510A)(Naval Ordnance Test Station. Tech. Publication 2324)(NAVORD Rpt. 6592)

185. Küchemann, Dietrich. Remarks on the Betz-Knoller Effect. Wash., Joint Intelligence Objectives Agency. Jun 1946. 5 p. (British Interrogation of German Scientists. 23)(Gt. Brit. Ministry of Aircraft Production. Rpt. and Trans. 46)

186. Lachmann, Gustav V. Boundary Layer and Flow Control. v. 1. London, Pergamon Press, 1961. p. 68-71, 96, 397, 522-524.

187. Langley, Marcus. Ground Effect; Some Thoughts Inspired by Early Data. Flight International (London), v. 83, 28 Mar 1963. Air Cushion Vehicles Supplement, v. 2, no. 9, p. 47-48 (bound in).

188. Langley, Marcus. Over the Waves. Flight International (London), v. 83, 25 Apr 1963. Air Cushion Vehicles Supplement, v. 2, no. 10, p. 67 (bound in).

189. Latimer-Needham, C. H. The Aerodynamics of the Flight of Flying-Fishes. The Sailplane and Glider (London), v. 4, 11 Aug 1933, p. 174-175.

Issued under former name: The Sailplane.
Abstracted by Klemin, Alexander. Scientific American (New York), v. 150, Jan 1934, p. 37.

190. Latimer-Needham, C. H. Flying-Fish Aerodynamics. Flight International (London), v. 60, 25 Oct 1951, p. 535-536.

191. Le Sueur, Maurice. Ground Effect on the Take-Off and Landing of Airplanes (L'Influence du Voisinage du Sol sur l'Envol et l'Atterrissage des Avions). [illegible]h., Jul 1935. 32 l. 11 plates. (Nat. Advisory Com. for Aeronautics. Tech. Memo. 771) (Translation from La Science Aérienne (Paris), v. 3, Jan-Feb 1934, p. 60-93)

192. Levey, Harris C. The "Ground" Interference of a Carrier Deck. Royal Aeronautical Soc. Jour. (London), v. 61, Apr 1957, p. 276-278. p. 276-278.

193. Licher, Rose M. Increase in Lift for Two and Three Dimensional Wings Near the Ground. Santa Monica, Oct 1956. 46 p. (Douglas Aircraft Co. Rpt. SM-22615)

194. Liiva, Jaan. A Facility for Dynamic Testing of Models of Airborne Vehicles With Ground Effect. Toronto, Oct 1961. 20 p. 17 plates. (Toronto. Univ. Institute for Aerospace Studies. Tech. Note 53)

Issued under former name: Institute of Aerophysics.

195. Lilienthal, Gustav. Die Biotechnik des Fliegens. Leipzig, R. Voigtländer Verlag, 1925. p. 18-21.

196. Lockheed-California Co. A Design Study "Winged Hull" Vehicles Configured for Transoceanic Logistics. Burbank, Jul 1962. 110 p. (Rpt. 16027)

197. Lockheed-California Co. Low-Speed Wind Tunnel Tests of the Winged Hull. Phase 1. Burbank, Aug 1961. (Rpt. LFL L-47-1)

198. Lockheed-California Co. Low-Speed Wind Tunnel Tests of a Winged Hull Configuration. Burbank, Jan 1963. (Rpt. LFL L-50)

199. Lockheed-California Co. Proposal for Evaluation of the Effects of Surface Waves on the Performance of a "Winged Hull" Test Vehicle. Burbank, Mar 1962. 18 1. (Rpt. 15785)

200. Lockheed-California Co. Quick Response Logistics Vehicle Design Study. Burbank, May 1963. 184 p. (Rpt. 16811)

201. Lockheed-California Co. Research Proposal of Response of Aerodynamic Lifting Surface in Ground Effect to Passage Over Sinusoidal Surface. Burbank, Mar 1962. 12 1. (Rpt. 15778)

202. Lockheed-California Co. Technical Proposal for a Stability and Control Study of Winged-Hull Vehicles. Burbank, Nov 1962. 25 p. (Rpt. 16429)

203. Lockwood, Vernard E. Effect of Groundboard Height on the Aerodynamic Characteristics of a Lifting Circular Cylinder Using Tangential Blowing From Surface Slots for Lift Generation. Wash., Oct 1961. 23 p. (Nat. Aeronautics and Space Adm. Tech. Note D-969)

204. Lueders, Dennis H. Aerodynamic and Hydrodynamic Tests of a 1/17-Scale Model of BuAer Design DR-136 With New Horizontal Stabilizer Configurations. Hoboken, N. J., Mar 1958. 59 1. incl. illus. (Stevens Inst. of Tech. Experimental Towing Tank. Rpt. 679. p. 17-19, 57-59. Contract NOa(s)56-568-c)

205. Lyon, M. A. and J. E. Adamson. The Effect of Ground Interference on the Trim of a Low-Wing Monoplane. London, H. M. Stationery Off. n.d. 30 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 1861. 3737. Oct 1938)

206. Magnan, Antoine. Le Vol à Voile, Avec Contribution à l'Étude Expérimentale de la Physique et de la Mécanique des Fluides. Paris, Editions G. Roche d'Estrez, 1925. 253 p.

207. Malavard, Lucien. Ground Effect on Airfoils; Rheoelectric Analog Study of Theoretical Flows. Issy-les-Moulineaux, Apr 1961. 30 p. (France. Bureau d'Analyse et de Recherche Appliquées. Contract DA 91-591-EUC-1397)

208. Malavard, Lucien. Remarque sur les Propriétés Aérodynamiques Théoriques des Profils d'Ailes en Présence du Sol.

Presented at Day of Studies on the Ground Effect Machine, Paris, 27 Feb 1961.

209. Malavard, Lucien and M. J. Pérès. Étude de Quelques Problèmes Techniques Relevant de la Théorie des Ailes. Paris, 1939. (France. Ministère de l'Air. Publications Scientifiques et Techniques. 153. p. 129-138) (Paris. Univ. Thesis)

210. Mankuta, Harry. Ground Effect Machines Morphology Study. Buffalo, Jan 1961. (Bell Aerosystems Co. Rpt. 2017-945002. p. 34-36)

211. Manning, W. O. The Ayr Flying Boat. Aeroplane (London), v. 48, 24 Apr 1935, p. 474-475.

212. Markowski, W. Zasady Lotu Sámolotów Szybkich. Warsaw, Wydawnictwo Ministerstwa Obrony Narodowej, 1959. p. 161-165.

213. Marks, Murray. Ground Effect. Shell Aviation News (London), No. 228, Jun 1957, p. 10-11.

214. Martin, Edward T. Ground Effect on the Power-Required Curve. Skyways (New York), v. 13, Jun 1954, p. 15, 56-58.

215. Martin, Glenn L. Aircraft Construction. Wash., Feb 1939, 8 p. (Patent Off. 2,147,795)

216. Martin, James V. Wave Riding Speed Vessel. Wash., Dec 1944. 13 p. (Patent Off. 2,365,205)

217. Martin, Ogden L. Land, Water & Air Vehicle. Wash., Apr 1962. (Patent Off. 3,029,042)

218. Melbourne, W. H. Experiments on a Delta Wing With Jet-Assisted Lift. London, H. M. Stationery Off., 1962. 48 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo 3288. 21,968. May 1960) (London. Imperial College of Science and Technology. Aeronautics Dept. Rpt. 101, Feb 1960)

219. Merrill, Albert A. Variation in Resultant Pressure Upon Landing due to Proximity of the Earth. Ace (Glendale, Calif.), v. 2, Dec 1920, p. 19.

220. Millikan, Clark B. Aerodynamics of the Aeroplane. New York, Wiley, 1941. p. 81-84.

221. Mills, Sidney. Boat. Wash., Aug 1961. 5 p. (Patent Off. 2,995,104)

222. Mitchell, R. J. Tank Tests With Seaplane Models. Aircraft Engineering (London), v. 2, Oct 1930, p. 255-259.

223. Mitchell, R. J. and A. N. Clifton. Experiments in a Model Tank as a Basis for the Design of Floats and Flying Boats. In International Congress of Aerial Navigation. 5th, The Hague, 1930. Report, v. 1. p. 606-633.

224. A model of a new British hydrofoil has been tested at speed in rough water. The craft, designed by Mr. Philip Castle and Major Michael Trasenter, incorporates a delta aerodynamic hull of shallow "V" section and narrow sharply swept fully submerged main foils ...Hovering Craft & Hydrofoil (London), v. 3, Apr 1964, p. 4-5.

225. Morrison, M. E., Jr. and H. Reynolds. Stability and Control; Low Speed Wind Tunnel Tests on a Convair Type P6Y Seaplane Model With a Combined Suction-Blowing BLC System in Combination With Propeller Slipstream in and out of Ground Effect; Phase B & C Report. San Diego, May 1960. 2 v. (CONVAIR. Rpt. CVAL 267D & E)

226. Mottard, Elmo J. and Robert D. Ruggles. Tank Tests of a Powered Model of a Compression Plane; NACA Model 171A-2. Wash., Jul 1948. 12 p. (Nat. Advisory Comm. for Aeronautics. Research Memo. SL8G02)

227. Müller, Wilhelm. Abbildungstheoretische Grundlangen für das Problem des Tragflügels in Erdbodennähe. Zeitschrift für angewandte Mathematik und Mechanik (Berlin), v. 11, Jun 1931, p. 231-236.

228. Müller, Wilhelm. Systeme von Doppelquellen in der ebenen Strömung, insbesondere die Strömung un zwei Kreiszylinder. Zusammenhang mit dem Problem der Tragflügelströmung in Erdbodennähe. Zeitschrift für angewandte Mathematik und Mechanik (Berlin), v. 9, Jun 1929, p. 208-209.

229. Munk, Max M. The Principles of Aerodynamics. Wash., The author, 1933. p. 91-92.

230. Nederlandsche Vliegtuigenfabriek Fokker. Door een enkel Dragvlak Gevormde Vliegboot. The Hague, Aug 1926. 3 p. incl. illus. (Netherlands. Bureau voor de Industriele Eigendom. 15077, Class 62, Groop 8a)

Issued under former name: Nederlandsche Vliegtuigenfabriek.

231. Nenadović, Miroslav. Osnovi Aerodinamičkih Konstrukcija. Aeroprofili, v. 1., Belgrade, Izdavačko Preduzeće Narodne Republike Srbije, 1948. p. 341-344.

232. New Canoe has Wings. Mechanics and Handicratt (New York), v. 3, Oct 1936, p. 27.
Crook ram wing (?).

233. A New Idea for Flying-Boats. Aeroplane (London), v. 57, 14 Sep 1939, p. 370.

Dornier patent described.

234. New Type "Cat" Hull. Motor Boating (New York), v. 105, Jan 1960. Mitchell Boat Co.

235. Newman, J. Nicholas and Frances A. P. Poole. The Wave Resistance of a Moving Pressure Distribution in a Canal. Wash., Mar 1962. 8 p. 2 plates. (David Taylor Model Basin. Rpt. 1619)(Reissue of paper from Schiffstechnik (Hamburg), v. 9, Jan 1962, p. 21-26)

236. Nichols, J. T. and C. M. Breder, Jr. About Flying Fishes. Natural History (New York), v. 28, Jan-Feb 1928, p. 64-77.

237. Nowak, Roman. Marine Propulsion. Wash., Oct 1949. 6 p. (Patent Off. 2,483,663)

238. Nutt, A. E. Woodward and G. J. Richards. Cine-Photographic Measurement of Speed and Attitude of Southampton Aircraft When Taking Off and Alighting. London, H. M. Stationery Off., 1935. 13 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 1621) (Gt. Brit. Marine Aircraft Experimental Est., Dec 1933)

239. Ono, Masami. On the Representation of a Ground in the Wind Tunnel. Journal of the Aeronautical Sciences (New York), v. 3, Nov 1935, p. 40-42.

240. Onspaugh, Carl M. Wind Tunnel Investigation of Single and Tandem Low-Aspect-Ratio Wings in Ground Effect. Burbank, May 1963. 1 v. (Lockheed-California Co. Rpt. LFL L-53)

Analysis of data given in Lockheed California Co. Rpt. 16906, see item 303.

241. Owen, P. R. and H. Hogg. Ground Effect on Downwash With Slipstream. London, H. M. Stationery Off., 1952. 12 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 2449. 7590, Jan 1944) (Gt. Brit. Royal Aircraft Est. Rpt. Aero 1901, Jan 1944)

242. Ower, E., R. Warden and W. S. Brown. An Investigation of Ground Effect With a Model of a Mid-Wing Monoplane. London, H. M. Stationery Off., May 1938. 30 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 1847. 3569)

243. Pankhurst, R. C. and Douglas W. Holder. Wind-Tunnel Technique; an Account of Experimental Methods in Low-and High-Speed Wind Tunnels. London, Pitman, 1952. p. 555-556.

244. Park, Ford. Near-Surface Vehicles. International Science and Technology (New York), Feb 1962, p. 14, 15.

245. Parkinson, John B. Tank Tests of a Model of the Hull of a Flying Boat for C. L. Ofenstein. Wash., Jun 1937. (Nat. Advisory Comm. for Aeronautics. Memo. Rpt.)

246. Paterson, J. H. The Ground Effect on Jet-Flap Wings. Marietta, Ga., 1956. (Lockheed Aircraft Corp. ER-2515)

247. Peckham, D. H. Ground Effect on a Gothic Wing of Aspect Ratio 1.0. (Gt. Brit. Royal Aircraft Est.)

Unpublished.

248. Pérez, Marc. I'Influence du Voisinage du Sol sur les Ailes d'Avion. ENSA; Revue Technique de l'Association des Ingénieurs de l'Aéronautique (Paris), no. 4, Jul-Aug 1937, p. 17-29 and no. 5, Sep-Oct 1937, p. 25-41.

249. Perkins, Courtland D. and Robert E. Hage. Airplane Performance Stability and Control. New York, Wiley, 1949. p. 256-259.

250. Phillips, Bryan. Southampton Symposium. Pt. 2: Further Papers From the Univer[illegible]S Meeting. Flight International (London), v. 83, 23 May 1963. Air Cushion Vehicles Supplement, v. 2, no. 11, p. 79-80 (bound in).

251. Pintaliitimeni Aikata Ulu. Tekniikan Maailma (Helsinki), v. 15, Aug 1959, p. 10-11.

Kaario ram wing.

252. Piper, R. W. Note on the Downwash at the Tail of a High-Lift Monoplane Near the Ground. Farnborough, Sep 1940. 5 p. 4 plates. (Gt. Brit. Royal Aircraft Est. Rpt. B.A. 1629)

253. Piper, R. W. and H. Davies. Note on the Factors Affecting Trim at Take-off and Landing. (Gt. Brit. Ministry of Supply, Oct 1941)

Unpublished.

254. Pistolesi, Enrico. Ground Effect; Theory and Practice (Teorie ed Esperienze sul Problema dell'Ala in Vicinanza del Suolo). Wash., Jun 1937. 35 p. 5 plates. (Nat. Advisory Com. for Aeronautics. Tech. Memo. 828) (Translation from Pisa. Scuola d'Ingegneria. Pubblicazioni, Ser 6, no. 261, Jul 1935, p. 1-25)

Also published in L'Aerotecnica (Rome), v. 15, Apr 1935, p. 393-418.

255. Pistolesi, Enrico. L'Influsso della Limitazione della Corrente sulle Caratteristiche dei Modelli di Ali. Pt. 1-2. L'Aerotecnica (Rome), v. 15, Jul-Aug 1935, p. 697-734, 845-846 and v. 16, Jan 1936, p. 1-73.

Pt. 1 appendix in English: p. 845-846.

256. Pistolesi, Enrico. Il Problema dell'Ala in Vicinanza del Suolo. L'Aerotecnica (Rome), v. 13, Apr 1933, p. 351-360, 501-502.

English abstract: p. 501-502.
Also published in Pisa. Scuola d'Ingegneria. Pubblicazioni. No. 218-219, May 1933.

257. Poisson-Quinton, Philippe. Influence de la Proximité du Sol sur les Caractéristiques Aérodynamiques d'Avions V/STOL Utilisant des Jets. In NATO. Advisory Group for Aeronautical Research and Development. Symposium on Vertical/Short Takeoff and Landing Aircraft, Paris, Jun 1960. Pt. 2. Paris, 1961. p. 427-436. (AGARDograph 46, Pt. 2)

Also issued as France. Office National d'Études et de Recherches Aéronautiques. Note Tech. 1/2449 A, 1960.

258. Poisson-Quinton, Philippe. Two-dimensional studies of a Ground Effect Platform. In Princeton Univ. Symposium on Ground Effect Phenomena; a Compilation of the Papers Presented October 21, 22, 23, 1959. Princeton, N. J., Mar 1960. p. 1-22.

259. Poisson-Quinton, Philippe and Amédée Bévert. Some Aerodynamic Aspects of the Ground Effect, New York, Apr 1962. 6 p. (Society of Automotive Engineers. Preprint 508A)

260. Poisson-Quinton, Philippe and L. Lepage. Caractéristiques des Ailes á Jet à 1'Approche su Sol.

Presented at Day of Studies on the Ground Effect Machine, Paris, 27 Feb 1961.

261. Pope, Alan. Wind-Tunnel Testing. 2d ed. New York, Wiley, 1954. p. 261-263.

262. Potter, W. T. Air-Riders in the United States. Hovering Craft & Hydrofoil (London), v. 1, Aug-Sep 1962, p. 9-10.

263. Prandtl, Ludwig. Applications of Modern Hydrodynamics to Aeronautics. Wash., Govt. Print. Off., 1921. In Nat. Advisory Com. for Aeronautics. Seventh Annual Report...1921. Rpt. 116, p. 183-184.

264. Prosnak, W. J. and P. Kucharczyk. The influence of the Ground on the Aerodynamic Properties of an Airfoil With Jet Flap. Archiwum Mechaniki Stosowanej (Warsaw), v. 11, no. 4, 1959, p. 475-509.

265. Rawlings, William L. and Donald H. Seiveno. State-of-the-Art Summary; Air-Cushion Vehicles. Revision 1. Ft. Eustis, Va., Aug 1961. (Army. Transportation Research Command. TCREC Tech. Rpt. 61-108. p. 6.1-7.1)(Aeronutronic. Publication U-926-RV 1)

266. Raymond, Arthur E. Ground Influence on Aerofoils. Wash., Dec 1921. 8 p. (Nat. Advisory Com. for Aeronautics. Tech. Note 67)

267. Recant, Isidore G. Wind-Tunnel Investigation of Ground Effect on Wings With Flaps. Wash., May 1939. 17 p. (Nat. Advisory Com. for Aeronautics. Tech. Note 705)

268. Recant, Isidore G. and A. R. Wallace. Effect of Ground on Characteristics of Model of a Low-Wing Airplane With Full-Span Slotted Flap With and Without Power. Wash., Sep 1942. 12 p. 18 plates. (Nat. Advisory Com. for Aeronautics. Wartime Rpt. L-335. Advanced Restricted Rpt)

269. Reeder, Walter D. and Raymond W. McDonald. GETOL Aircraft; a Research Status Report. New York, Jun 1962. 18 p. (American Institute of Aeronautics and Astronautics. Paper 62-182)

Presented at IAS Nat. Summer Meeting, Los Angeles, 19-22 Jun 1962.

270. Reid, Elliott G. An Analysis of Airplane Landing Speeds. Aviation (New York), v. 27, 20 Jul 1929, p. 192-194.

271. Reid, Elliott G. Applied Wing Theory. 1st ed. New York, McGraw-Hill, 1932. p. 174-176.

272. Reid, Elliott G. A Full-Scale Investigation of Ground Effect. Wash., Govt. Print. Off., 1927. (Nat. Advisory Com. for Aeronautics. Rpt. 265. p. 233-237)

273. Reid, Elliott G. and Thomas Carroll. A Warning Concerning the Take-Off With Heavy Load. Wash., Jul 1927. 6 p. (Nat. Advisory Com. for Aeronautics. Tech. Note 258)

274. Rethorst, Scott. The 100-Knot Columbia. Flight International (London), v. 82, 25 Oct 1962. Air Cushion Vehicles Supplement, v. 1, no. 4, p. 73-76 (bound in).

275. Rethorst, Scott. VRC Surface Effect Ship Columbia. In Institute of the Aeronautical Sciences. Proceedings of the National Meeting on Hydrofoils and Air Cushion Vehicles, Washington, D. C., September 17-18, 1962. New York, IAS, 1962. p. 135-140.
IAS later merged with Amer. Rocket Soc. to become American Institute of Aeronautics & Astronautics.
Abstracted in: Hovering Craft & Hydrofoil (London), v. 2, Oct 1962, p. 22-23.
Meeting co-sponsored by U. S. Navy.

276. Rethorst, Scott and W. T. Potter. Maritime Administration Surface Effect Ship. New York, Apr 1963. 6 p. (Society of Automotive Engineers. Preprint 697D)

Presented at SAE-ASNE National Aero-Nautical Meeting, Wash., 8-11 Apr 1963.

277. Ridley, Kenneth F. An Investigation of Airplane Landing Speeds. Wash., Sep 1930. 39 p. (Nat. Advisory Com. for Aeronautics. Tech. Note 349)

278. Rippen, Nicholas. Airplane. Wash., Sep 1933. 6 p. (Patent Off. 1,928,317)

279. Rosenhead, L. The Lift on a Flat Plate Between Parallel Walls. Royal Society of London. Proceedings, (London), Ser. A, v. 132, 2 Jul 1931, p. 127-152.

280. Royal Aeronautical Society. Data sheets. Aerodynamics, v. 3: Aircraft. Ground Effect on Lift and Drag. 13th issue. London, Dec 1962. (Sheet. 01.01.01, Mar 1958. 2 p.)

281. Royce, Winston W. and Scott Rethorst. Translational Characteristics of Ground Effect Machines. Wash., Jan 1961. 24 p. (American Institute of Aeronautics and Astronautics. Paper 61-79)

Presented at IAS 29th Annual Meeting, New York, 23-25 Jan 1961.

282. Sanders, J. Wind Tunnel Corrections in Ground-Effect Tests. Ottawa, 1948. 26 p. (Canada. National Research Council. Aeronautical Rpt. AR-5. 1821. Rpt MA-194, May 1947)

283. Sasaki, Tatudiro. Change in Lift of a Wing Placed Near the Ground. Journal of Applied Physics, Japan (Tokyo), v. 2, 1933, p. 211.

In Japanese.

284. Saunders, G. H. Aerodynamic Characteristics of Wings in Ground Proximity. Canadian Aeronautics and Space Journal (Ottawa), v. 11, June 1965, p. 185-192.

285. Schaufele, Roger D. An Experimental Investigation Into the Effect of the Ground on the Maximum Lift and Static Longitudinal Stability of a Low Wing Monoplane Equipped With Flaps. Troy, New York, Jan 1949. 50 p. (Rensselaer Polytechnic Institute)(DDC ATI 66,781)

286. Schmitt, Henry. Motor Boat. Wash., Jul 1928. 3 p. (Patent Off. 1,677,495)

287. Schwartzberg, Milton A. and Theodore E. Challberg. Analysis of Wind Tunnel Results Obtained for a Propeller-Powered Model With Flap Blowing. Baltimore, Md., Aug 1957. (Martin Co. Eng. Rpt. 9429. p. 31-32, 135, 136)

Issued under former name: Glenn L. Martin Co.

288. Sears, William R. Ground Effect With Special Reference to Pitching Moments. Journal of the Aeronautical Sciences (New York), v. 5, May 1938, p. 281-285.

289. Serebrisky, Y. M. Experimental Investigation of the Vertical Approach of a Plate and the Inclined Approach of a Wing to the Ground. Moscow, 1939. 12 p. (Moscow. Central Aero-Hydrodynamical Institute. Transactions 422)

290. Serebrisky, Y. M. Ground Effect on the Aerodynamical Characteristics of an Aeroplane. Moscow, 1936. 37 p. (Moscow. Central Aero-Hydrodynamical Institute. Transactions 267)

In Russian with English summary.

291. Serebrisky, Y. M. and S. A. Biachuev. Wind-Tunnel Investigation of the Horizontal Motion of a Wing Near the Ground. Wash.,Sep 1946. 19 l. 13 plates. (Nat. Advisory Com. for Aeronautics. Tech. Memo. 1095) (Translation from Moscow. Central Aero-Hydrodynamical Institute. Transactions 437, 1939)

292. Shepheard, F. W. Analysis of Powered Model Wind Tunnel Tests on 1/10 Scale Grumman Design 117, DTMB Series II. Pt. 5: Groundboard Effects (Title Unclassified). Bethpage, L. I., N.Y., Feb 1957. 66 p. (Grumman Aircraft Engineering Corp. Rpt XA117-B-4.7-V)

CONFIDENTIAL Rpt. Group 4.

Analysis of data presented in David Taylor Model Basin. Aero Rpt. 924, Pt. 5, Feb 1958.

293. Sherwood, Wiley A. Aerodynamics. New York, McGraw-Hill, 1946. p. 92-93.

294. Shouletkin, Was. Airdynamics of the Flying Fish. Internationale Revue der gesamten Hydrobiologie und Hydrographie (Leipzig) v. 22, no. 1/2, 1929, p. 102-110.

295. Spence, A. and D. Lean. Some Low-Speed Problems of High-Speed Aircraft. Paris, Apr 1961. (NATO. Advisory Group for Aeronautical Research and Development. Rpt. 357. p. 7-8)

296. Stalker, Edward A. Principles of Flight. New York, Ronald Press, 1931. p. 94-95.

297. Stalker, Edward A. A Reflection Plate Representing the Ground. Journal of the Aeronautical Sciences (New York), v. 1, Jul 1934, p. 151-152.

298. Stanton-Jones, Richard. The Jet-Flap With Ground Effect. Burbank, Calif., Jul 1956. 4 p. (Lockheed Aircraft Corp. MISC 749, NEGS 249)

299. Stepniewski, Wieslaw Z. Performance Possibilities of Subsonic Airplanes Taking-Off and Landing on the Ground Cushion. In Princeton Univ. Symposium on Ground Effect Phenomena; a Compilation of the Papers Presented October 21, 22, 23, 1959. Princeton, N. J., Mar 1960. p. 285-301.

300. Stepniewski, Wieslaw Z. Possibilities and Problems of GETOL Aircraft. 16 p.
Presented at Day of Studies on the Ground Effect Machine, Paris, 27 Feb 1961.

301. Stepniewski, Wieslaw Z. and others. Research Program to Determine the Feasibility and Potential of the Ground Effect Take-Off and Landing (GETOL) Configuration. Ft. Eustis, Va., Mar 1962. 2 v. (Army. Transportation Research Command. TCREC Tech. Rpt. 62-63) (Vertol Rpt. R276)

302. Stevens, William P. Feasibility Study of a Dynamic Interface Vehicle Configured for an Amphibious Assault Mission. Burbank, Feb 1962. 16 p. (Lockheed-California Co. Rpt. 15736)

303. Stevens, William P. and Samuel G. Hansen. Wind Tunnel Investigation of Single and Tandem Low-Aspect-Ratio Wings in Ground Effect. Burbank, May 1963. 27 p. (Lockheed-California Co. Rpt 16906)

Basic wind tunnel data given in Lockheed-California Co. Rpt. LFL L-53, see Item 240.

304. Strand, Torstein. The Jet Flap; Review and Extension. San Diego, 1956. (CONVAIR. Rpt. ZA-255)

305. Strand, Torstein. 150 Knot GEM Cruise. In Institute of the Aerospace Sciences. Proceedings of the Ground Effect Machines Form...January 22-24, 1962. New York, 1962. p. 32-37. (American Institute of Aeronautics and Astronautics. Sherman M. Fairchild Publication Fund Paper FF-32)

Also published in Aerospace Engineering (New York), v. 21, Apr 1962, p. 38-44.

306. Strand, Torstein and Scott Rethorst. Interim Report on VRC Channel GEM Concept. Pasadena, Nov 1960. 20 l. 13 plates. (Vehicle Research Corp.)

Presented at ONR/TRECOM GEM Conference, Ft. Myer, Va., 16-18 Nov 1960.

307. Strand, Torstein, Roy G. Fowler and Hideo Yoshihara. Increased Increased Airplane Endurance Through Employment of Wing End Plates in Ground Proximity. San Diego, Dec 1962. 14 p. (Air Vehicle Corp.)

308. Strand, Torstein, Winston W. Royce and Toshie Fujita. Performance Theory for High Speed Ground Effect Machines. Pasadena, Jun 1961. 23 p. (Vehicle Research Corp. Rpt. 11)

309. Strawn, Theodore R. Amphibian Aircraft. Wash., 13 Dec 1960. 6 p. (Patent Off. 2,964,271)

310. Suomalainen lentävä Lautanen Patentoitu jo Ennen Talvistotaa. Suomen Kuvalehti (Helsinki), no. 28, 1959, p. 16-17.

Kaario ram wing.

311. Tani, Itiro. On the Effect of the Ground Upon the Lift of a Monoplane Wing. Tokyo. Imperial Univ. Aeronautical Research Inst. Journal, no. 96, Aug 1932, p. 684-689.

In Japanese.

312. Tani, Itiro, Hideo Itokawa and Masuo Taima. Further Studies of the Ground Effect on the Aerodynamic Characteristics of an Aeroplane, With Special Reference to Tail Moment. Tokyo, Nov 1937. (Tokyo. Imperial Univ. Aeronautical Research Inst. Rpt. 158, v. 13, p. 117-145)

313. Tani, Itiro, Masuo Taima and Sodi Simidu. The Effect of Ground on the Aerodynamic Characteristics of a Monoplane Wing. Tokyo, Sep 1937. (Tokyo. Imperial Univ. Aeronautical Research Inst. Rpt. 156, v. 13, p. 23-76)

For note on above report see Marine Aircraft Exp. Est. (Gt. Brit.). Rpt. F/Res/114, Item 158.
Also issued as Gt. Brit. Aeronautical Research Council. 3376, Feb 1938.

314. Taverne, Gaspard L. Aviation Naturelle; Études sur la Mécanique Animale en Vue d'Applications aux Machines Locomotrices et Spécialement à l'Aéroplane. Paris, Doin & Cie, 1931. p. 89.

315. Thomas, Fred. Aerodynamische Eigenschaften von pfeilund Deltaflügeln in Bodennähe. Wissenschaftliche Gesellschaft für Luftfahrt. Jahrbuch (Brunswick, Ger.), 1958, p. 53-61.

316. Tinson, Clifford W. Ground Effect. Flight International (London), v. 83, 24 Jan 1963. Air Cushion Vehicles Supplement, v. 2, no. 7, p. 14 (bound in).

317. Tönnies, E. Effect of the Ground on an Airplane Flying Close to it. (Der Boden-Effekt beim Fluge in Erdnähe). Wash., Jun 1932. 16 p. (Nat. Advisory Com. for Aeronautics. Tech. Memo. 674) (Translation from Zeitschrift für Flugtechnik und Motorluftschiffahrt (Munich), v. 23, 29 Mar 1932, p. 157-164)

318. Tolman, Scott H. Hydroaeroplane. Wash., Aug 1919. 6 p. (Patent Off. 1,314,227)

319. Tomotika, Susumu. Further Studies on the Effect of the Ground Upon the Lift of a Monoplane Aerofoil. Tokyo, Apr 1935. (Tokyo. Imperial Univ. Aeronautical Research Inst. Rpt. 120, v. 10, p. 25-44)

320. Tomotika, Susumu. The Lift Acting on a Flat Plate in a Stream Bounded by an Infinite Plane Wall. Tokyo, Jan 1934. (Tokyo. Imperial Univ. Aeronautical Research Inst. Rpt. 100, v. 8, p. 115-156)

321. Tomotika, Susumu and Isao Imai. The Interference Effect of the Surface of the Sea on the Lift of a Seaplane. Tokyo, Feb 1937. (Tokyo. Imperial Univ. Aeronautical Research Inst. Rpt. 146, v. 12, p. 69-128)

322. Tomotika, Susumu and Isao Imai. The Moment of the Fluid Pressure Acting on a Flat Plate in a Semi-Infinite Stream Bounded by a Plane Wall. Pt. 1: Case of Lower Boundary (the Ground Effect). Tokyo, Jun 1937. (Tokyo. Imperial Univ. Aeronautical Research Inst. Rpt. 152, v. 12, p. 421-471)

323. Tomotika, Susumu and Isao Imai. Note on the Lift and Moment of a Circular-Arc Aerofoil Which Touches the Ground With its Trailing Edge. Physico-Mathematical Society of Japan. Proceedings (Tokyo), v. 20, Jan 1938, p. 15-32.

324. Tomotika, Susumu and Isao Imai. Notes on the Lift and Moment of a Plane Aerofoil Which Touches the Ground With its Trailing Edge. Tokyo, Jul 1937. (Tokyo. Imperial Univ. Aeronautical Research Inst. Rpt. 154, v. 12, p. 519-571)

325. Tomotika, Susumu, Ziro Hasimoto and Kaoru Urano. The Force Acting on an Aerofoil of Approximate Joukowski Type in a Stream Bounded by a Plane Wall. The Quarterly Journal of Mechanics and Applied Mathematics (Oxford), v. 4, Sep 1951, p. 289-307.

326. Tomotika, Susumu, Takeo Nagamiya and Ysoitada Takenouti. The Lift on a Flat Plate Placed Near a Plane Wall, With Special Reference to the Effect of the Ground Upon the Lift of a Monoplane Aerofoil. Tokyo, Aug 1933. 60 p. (Tokyo. Imperial Univ. Aeronautical Research Inst. Rpt. 97, v. 8)

327. Tomotika, Susumu, Ko Tamada and Yukimasa Saito. Note on the Effect of Boundary Walls of a Stream Upon the Circulation Round a Plane Aerofoil. Tokyo, Aug 1939. (Tokyo. Imperial Univ. Aeronautical Research Inst. Rpt. 182, v. 14, p. 363-394)

328. Tomotika, Susumu, Ko Tamada and H. Umemoto. The Lift and Moment Acting on a Circular-Arc Aerofoil in a Stream Bounded by a Plane Wall. The Quarterly Journal of Mechanics and Applied Mathematics (Oxford), v. 4, Mar 1951, p. 1-22.

329. Tomotika, Susumu, Kaoru Urano and Ziro Hasimoto. Further Studies on the Lift and Moment of a Circular-Arc Aerofoil Which Touches the Ground With its Trailing Edge. Physico-Mathematical Society of Japan. Proceedings (Tokyo), v. 23, Sep 1941, p. 713-724.

330. Toronto. Univ. Institute for Aerospace Studies. Annual Progress Report, 1963. Toronto, Oct 1963. p. 53-54.

Issued under its former name: Institute of Aerophysics.

331. Toronto. Univ. Institute for Aerospace Studies. Bulletin and Annual Progress Report, 1960. Toronto, Oct 1960. p. 49-50, 140-142.

Issued under its former name: Institute of Aerophysics.

332. Toussaint, Albert. Contribution à l'Étude de l'Interaction-Sol pour des Ailes Sustentatrices. Académie des Sciences. Comptes Rendus (Paris), v. 199, 19 Nov 1934, p. 1095-1096.

333. Toussaint, Albert. Contribution à l'Étude Expérimentale des Lois de Similitude en Aérodynamique. Paris, Jan 1924. 101 p. (Paris. Univ. Thesis (B.S.))

334. Toussaint, Albert. Cours de Technique Aéronautique; Conservatoire National des Arts et Métiers, First Year. v. 2. Paris, Editions Scientifiques Riber, 1942, p. 102-112.

335. Trouncer, J. and G. F. Moss. Low-Speed Wind-Tunnel Tests on a Model of a Jet Tailless Aircraft. London, H. M. Stationery Off., 1956. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 2843, p. 3, 6, 17, 33. 10,616. Jan 1947) (Gt. Brit. Royal Aircraft Est. Rpt. Aero. 2181, Jan 1947)

336. Turner, Thomas R. Ground Influence on a Model Airfoil With a Jet-Augmented Flap as Determined by Two Techniques. Wash., Feb 1961. 18 p. (Nat. Aeronautics and Space Adm. Tech. Note D-658)

337. Ushakov, B. A. Effect of Nearness to the Ground on the Aerodynamic Characteristics of the Wing. Moscow, 1935. (Moscow. Central Aero-Hydrodynamical Institute. Tech. Note 47)

338. Viaud, Louis. Étude en Soufflèrie des Caractéristiques Aérodynamiques de Quelques Dispositifs Hypersustentateurs Placés au Voisinage du Sol. Academie des Sciences. Comptes Rendus (Paris), v. 206, 20 Jun 1938, p. 1877-1880 and v. 207, 4 Jul 1938, p. 37-39.

339. Viaud, Louis. Méthode Expérimentale pour l'Étude en Soufflèrie de l'Interaction au Sol. Académie des Sciences. Comptes Rendus (Paris) v. 206, 14 Mar 1938, p. 817-819.

340. Vogler, Raymond D. and Thomas R. Turner. Wind-Tunnel Investigations at Low Speeds to Determine Flow-Field Characteristics and Ground Influence on a Model With Jet-Augmented Flaps. Wash., Sep 1957. 48 p. (Nat. Advisory Com. for Aeronautics. Tech. Note 4116)

341. Von Kármán, Theodore and Johannes M. Burgers. General Aerodynamic Theory; Perfect Fluids. In Durand, William Frederick, ed. Aerodynamic Theory, v. 2, Div. E. New York, Dover, 1963. p. 236-247.

Reprint of 1935 edition.

342. Walters, Donald E., E. G. Stout, T. P. Higgins, Jr. and J. R. Brown. The Dynamic Interface Vehicle. New York, Jun 1962. 8 p. (American Institute of Aeronautics and Astronautics. Paper 62-140)

Presented at IAS Nat. Summer Meeting, Los Angeles, 19-22 Jun 1962.

343. Ward, Kenneth E. and Roland E. Olson. Dynamic Tests of a Model of the Boeing 314 Flying Boat, NACA Model 108. Wash., May 1940. (Nat. Advisory Com. for Aeronautics. Memo. Rpt.)

344. Warner, Douglas K. Compression Airplane. Wash., Dec 1944. 11 p. (Patent Off. 2,364,677)

345. Warner, Douglas K. Hydrofoil Stabilization of a Ground Effect Machine. Wash., Jan 1964. (Patent Off. 3,117,545)

346. Warner, Douglas K. Skimming and Flying Vehicle. Wash., Dec 1944. 9 p. (Patent Off. 2,364,676)

347. Water "Wind Tunnel." Flight International (London), v. 84, 25 Jul 1963. Air Cushion Vehicles Supplement, v. 3, no. 13, p. 3 (bound in).

Lockheed ram wing.

348. Welkoborsky, Norbert. Fliegende Fische. Flugsport (Frankfurt am Main), v. 25, 8 Nov 1933, p. 497-498.

349. Werlé, Henri. Simulation de l'Effect de Sol au Tunnel Hydrodynamique. La Recherche Aérospatiale (Paris), no. 95, Jul-Aug 1963, p. 7-15.

Reprinted as: France. Office National d'Études et de Recherches Aérospatiales. TP 63. 1963.

350. Wetmore, J. W. and L. I. Turner, Jr. Determination of Ground Effect From Tests of a Glider in Towed Flight. Wash., Govt. Print. Off., 1940. 13 p. (Nat. Advisory Com. for Aeronautics. Rpt. 695)

351. White, Herbert E. Wind-Tunnel Tests of a Low-Aspect-Ratio Wing in Close Proximity to the Ground. Wash., Jun 1963. [3] 25 p. incl. illus. (David Taylor Model Basin. Aero Rpt. 1056)

352. Wieselsberger, Carl. Wing Resistance Near the Ground (Über den Flügelwiderstand in der Nähe des Bodens). Wash., Apr 1922. 7 p. (Nat. Advisory Com. for Aeronautics. Tech Memo. 77) (Translation from Zeitschrift für Flugtechnik und Motorluftschiffahrt (Munich), v. 12, 31 May 1921, p. 145-147)

Abridged as "Der Einfluss der Erdbodennähe suf den Flügelwiderstand" in Göttingen. Aerodynamische Versuchsanstalt. Ergebnisse, Pt. 2. München, Oldenbourg, 1923. p. 41-42.

353. Wiio, Osmo A. Lentävä Lautanen 27 Vuotta Vanha Suomalainen Keksinto. Suomen Kuvalehti (Helsinki), no. 26, 1959, p. 10-14.

354. Williams, John and Sidney F. J. Butler. Further Development in Low-Speed Wind-Tunnel Technique for VSTOL and High-Lift Model Testing. In American Institute of Aeronautics and Astronautics. AIAA Aerodynamic Testing Conference, Washington, D. C., Mar 9-10, 1964; Proceedings. New York, 1964. p. 17-32.

355. Williams, John, Sidney F. J. Butler and M. N. Wood. The Aerodynamics of Jet Flaps. London, H. M. Stationery Off., 1963. 32 p. (Gt. Brit. Aeronautical Research Council. Rpt. and Memo. 3304. 22,823, Jan 1961)(Gt. Brit. Royal Aircraft Est. Rpt. Aero. 2646, Jan 1961)

Amplified version in International Congress for the Aeronautical Sciences. 2d, Zurich, 1960. Advances in Aeronautical Sciences, v. 4; Proceedings...New York, Macmillan, 1962. p. 619-656.

356. Williams, P. G. A Note on the Lift of a Jet-Flap Aerofoil Near the Ground. London, May 1962. 8 p. (Gt. Brit. Aeronautical Research Council. 23,821. FM 3195. Perf. 2110)

357. Willoughby, Robert L. and Frank B. Seaman. Evaluation of the "T" Effect Phenomenon. Wright-Patterson AFB, Ohio, Sep 1958. 6 p. (Wright Air Development Ctr. Tech. Note 58-250)

358. With the Outboarders. Motor Boating (New York), v. 108, Aug 1961, p. 32, 54.

Swietzer Bros. ram wing.

359. Wood, Garfield A. Boat. Wash., Mar 1949. 5 p. (Patent Off. 2,464,957)

360. Wood, Karl D. Technical Aerodynamics. 2d ed. New York, McGraw-Hill, 1947. p. 186-187.

361. Wood, M. N. and W. J. G. Trebble. Low Speed Tunnel Measurements of the Ground Effect on a 1/5th Scale Model of the Swift. London, H. M. Stationery Off., 1959. 37 p. (Gt. Brit. Aeronautical Research Council. Current Paper 458)

362. You can Fly This $300 Boat! Mechanix Illustrated (New York), v. 58, Feb 1962, p. 65-67 & cover.

Armstrong ram wing hydroplane.

363. Young, A. D. A Note on Ground Effect on the Lift due to a Jet Flap. London, Mar 1958. 5 p. (Gt. Brit. Aeronautical Research Council. 19,971)

364. Zahm, Albert F. and R. M. Bear. Ground-Plane Influence on Airplane Wings. Wash., Feb 1921. 6 p. 10 plates. (David Taylor Model Basin. Aero Rpt. 173)

Issued under its former name: Construction Dept., Navy Yard, Wash.

Abridged in:

Franklin Inst. Journal, v. 191, May 1921, p. 687-693.

Aviation and Aircraft Jour. (New York), v. 10, 27 Jun 1921, p. 807-808.

Zahm, Albert F. Aeronautical Papers, 1885-1945. v.2. Notre Dame, Ind., Univ. of Notre Dame, 1950, p. 625-628.

365. Zwieback, Edgar L. Trailing Vortices of Jet Transport Aircraft During Takeoff and Landing. New York, Jul 1964. 3 p. (American Institute of Aeronautics and Astronautics. Paper 64-325)

Presented at 1st AIAA Annual Meeting and Technical Display, Wash., 29 Jun-2 Jul 1964.

APPENDIX A
SUPPLEMENTARY BIBLIOGRAPHY

1. Aerodynamics and Hydrodynamics of Seaplanes

   a. Benson, James M. and Jerold M. Bidwell. Bibliography and Review of Information Relating to the Hydrodynamics of Seaplanes. Wash., Sep 1945. 83 p. (Nat. Advisory Com. for Aeronautics. Wartime Rpt. L-230. Advance Confidential Rpt. L5G28)

   b. Bidwell, Jerold M. and Douglas A. King. Abstracts Pertaining to Seaplanes. Wash., Jun 1947. 272 p. (Nat. Advisory Com. for Aeronautics. Research Memo. L6I13)

   c. Bidwell, Jerold M. and Douglas A. King. Additional Abstracts Pertaining to Seaplanes. Wash. [1947?]. 274 p. (Nat. Advisory Com. for Aeronautics. Research Memo. L7J14)

   d. Works Progress Administration. Bibliography of Aeronautics. Pt. 5: Seaplanes, Pt. 6: Flying Boats, Pt. 7: Amphibians. [Wash. ?] 1938. 201 p.

2. VTOL/STOL Aircraft

   a. Bock, G. and H. Spintzyk. VTOL-STOL Aircraft. Rev. ed. Paris, Mar 1961. 161 p. (Advisory Group for Aerospace Research and Development. Bibliography 2)

   b. Bock, G., H. G. Klug and H. Spintzyk. VTOL/STOL Aircraft. First Supplement 1961/62. Jun 1963. 98 p. (Advisory Group for Aerospace Research and Development. Bibliography 2, Supplement 1)

   c. Adler, A. C. and S. A. Harrington. Review of VTOL Design Studies. Buffalo, Aug 1960. 132 p. incl. illus. (Cornell Aeronautical Lab., Inc. Rpt. BB-1367-H-1) (DDC AD-246 160L)

3. Ground Effect Machines (GEM's)

a. Liberatore, E. K. GEM Activities and Bibliography. Revision 2. Buffalo, Apr 1961. 39 p. (Bell Aerosystems Co.)

b. Smith, Maurice H. and Mary Lee. Bibliography on Ground Effects. Princeton, Oct 1959. 9 p. (Princeton Univ. James Forrestal Research Center. Library. Literature Research 15)

4. Hydrofoils

a. Armed Services Technical Information Agency. Hydrofoils; an ASTIA Report Bibliography. Dec 1961. (DDC AD 268 500L)

b. Armed Services Technical Information Agency. Hydrofoils; an ASTIA Report Bibliography (U). Dec 1961. (DDC AD 327 000L)

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5. Interface Meteorology and Katzmayer Effect

a. FitzPatrick, James L. G. Natural Flight and Related Aeronautics. New York, Jun 1952. 118 p. (American Institute of Aeronautics and Astronautics. Sherman M. Fairchild Publication Fund Paper FF-7)

Issued under former name: Institute of the Aeronautical Sciences.

b. Miles, John W. On the Generation of Surface Waves by Shear Flows. Pts. 1-4. Journal of Fluid Mechanics (London). v. 3, Nov 1957, p. 185-204; v. 6, Nov 1959, p. 568-582, 583-598; v. 13, Jul 1962, p. 433-448.

c. Miles, John W. On the Generation of Surface Waves by Turbulent Shear Flows. Journal of Fluid Mechanics (London) v. 7, Mar 1960, p. 469-478.

d. Phillips, O. M. On the Generation of Waves by Turbulent Wind. Journal of Fluid Mechanics (London) v. 2, Jul 1957, p. 417-445.

6. Automobile Wind Tunnel Air Resistance Testing

a. Schmid, C. Luftwidustand an Kraftfahrzeugen, Versuche am Fahrzeug und Modell. Deutsche Kraftfahrtforschung (Berlin) v. 1, 1938, p. 1-56

b. Sawatki, E. Einfluss der Luftkräfte auf die Stabilität des Kraftfahrzeugs. Deutsche Kraftfahrtforschung (Berlin) Technischer Forschungsbericht. Zwischenbericht 70, 1939, 19 p.

c. Reid, Elliot G. Farewell to the Horseless Carriage. S.A.E. Journal (New York), v. 36, May 1935, p. 180-189

d. Lay, W. E. Is 50 Miles per Gallon Possible With Correct Streamlining. S.A.E. Journal (New York) v. 32, Apr 1933, p. 144-156 and v. 32, May 1933, p. 177-186.

7. Raimondi Effect

a. Raimondi, Emanuele G. A. Risultati Sperimentali Relative ad un Nuovo Fenomento di Aerodinamica. Notiziario Tecnico di Aeronautica (Rome) v. 6, Oct 1930, p. 1-19

8. Miscellaneous

a. Pocock, P. J. Non-Aeronautical Applications of Low-Speed Wind Tunnel Techniques. Paris, 1960. 95 p. incl. illus. (Advisory Group for Aerospace Research and Development. Rpt. 313) (Canada. National Research Council. MA 243)

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APPENDIX B

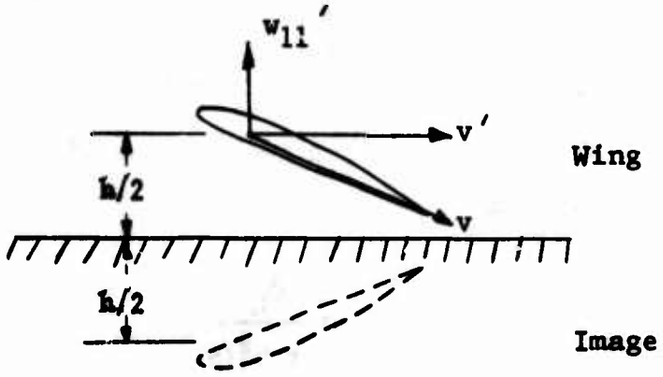
SURVEY OF THEORETICAL PAPERS

Selected theoretical papers listed in the main bibliography are discussed briefly. Only the number of the entry and the author's name are used to identify each paper.

[32] Betz - In many bibliographies, this paper is credited as being the first "theoretical" study of airfoils in ground effect. This is not the case; the paper is limited to reporting experimental results of drag reduction and lift increase associated with the ground effect. It is, in fact, the first experimental report on the subject.

[31] Betz - In this paper, the analogy between a wing in ground effect, which can be replaced by a wing and the image wing with respect to the ground, and a biplane wing is recognized. The paper has, otherwise, only historical interest, since it precedes the publication of Prandtl's lifting-line wing theory by five years.

[352] Wieselsberger - This is the classical elementary treatment of the effect of the ground on a wing of finite span which can be found in most books on aerodynamics. One replaces the ground by an image wing, symmetrical to the true wing with respect to the ground, and then calculates the interaction of the image wing and the actual wing by means of Prandtl's lifting-line theory. The calculation is similar to that used to determine the drag of a biplane from the drag of a monoplane.



The resulting direction of the flow on the wing (indicated by v′) is found by the geometric addition of the original direction of the velocity v and the vertical velocity w_{11}' due to the image wing. The induced drag near the ground is smaller than at a higher altitude, since w_{11}' increases to a maximum from a value of zero far from the ground.

The change in drag due to the ground is given by:

$$W' = -\int_{-b/2}^{b/2} \frac{w_{11}'}{v} \, dA \quad ,$$

where w_{11}' is given, from Prandtl's theory, by:

$$w_{11}' = \frac{2A}{\pi \rho v b^2} \cdot z$$

where A is the lift, v is the velocity, b is the span, and z is the distance between the two wings, which is related to h/b.

The value of the above integral can be determined numerically for different values of h/b and the result expressed by the influence coefficient σ , such that

$$\Delta C_D = -\sigma \frac{C_L^2}{b^2/S}$$

where S is the wing area and C_L and C_D are the lift and drag coefficients, respectively.

The change of angle of attack of the wing, due to the ground, can be expressed as

$$\Delta\alpha = -\sigma \frac{C_L}{\pi \, b^2/S}$$

Therefore, the influence of the ground on the wing of finite span is equivalent to an increase in aspect ratio. Calling AR' the aspect ratio near the ground and AR that far from the ground, one has:

$$AR' = \frac{AR}{1-\sigma}$$

Later investigators have devised other empirical formulas relating σ to h/b; for example,

$$\sigma = \frac{1}{1 + 5.3\,\frac{h}{b}} \quad , \quad \text{for } \frac{1}{15} < \frac{h}{b} < \frac{1}{4}$$

[125] Glauert - Glauert modifies Wieselsberger's theory by assuming that the velocity induced by the image wing on the real wing must be measured at the center of the wing, but locates the bound vortex of the image wing at the center of pressure of the wing. There results a correction term on the circulation as compared with Wieselsberger's case.

[35] Bonder - This is the first sophisticated theoretical investigation of flight near the ground. It makes a conformal transformation of two opposite wing profiles separated by a plane of symmetry (the ground) into two adjacent cylinders. The calculations are complicated and do not lead to practical numerical expressions. A similar technique was used later on by Müller (Reference 227) and Tomotika (Reference 325).

[227] Müller - A series of lenticular or airfoil shapes, symmetrical with respect to a plane simulating the ground, are transformed into circular cylinders, as was done in Reference 35 by Bonder, using two successive conformal transformations (the conformal mapping theory of Ferrari). The lift over the airfoil is calculated and leads to results apparently difficult to reconcile with experiments; e.g., that the lift decreases when the airfoil is close to the ground.

[279] Rosenhead - The problem of continuous flow past a flat plate of infinite span between plane parallel walls is solved exactly, using all the mathematical apparatus later used by Tomotika and others in the ground effect problem, in which one of the two parallel walls is removed. The paper is therefore of interest because of its mathematical foundation, not because of its results.

[311] Tani

1. Two-Dimensional Analysis - A plane wing having infinite span and chord c is placed near the ground, at an angle of attack α, free-stream velocity V, and the height of the quarter-chord point H.

The circulation around the wing is given in the form:

$$\Gamma = n \pi V c \sin \alpha_o$$

where n represents the change in circulation compared with that of a wing placed far above the ground.

The chordwise vorticity distribution is assumed (following Birnbaum) to be:

$$\gamma = a_o \sqrt{\frac{1-\xi}{1+\xi}} + a_1 \sqrt{1-\xi^2} + a_2 \xi \sqrt{1-\xi^2}$$

The terms a_o, a_1, a_2 are determined from the assumption that the velocity normal to the chord is zero at three points:

$$\xi = -1, 0, \text{ and } 1$$

To satisfy the boundary condition at the ground plane, an image wing is introduced with vorticity distribution:

$$\gamma' = - a_o \sqrt{\frac{1-\xi'}{1+\xi'}} - a_1 \sqrt{1-\xi'^2} - a_2 \xi' \sqrt{1-\xi'^2}$$

from which n can be calculated as:

$$n = \frac{a_o}{2V \sin \alpha_o} + \frac{a_1}{4V \sin \alpha_o}$$

2. Three-Dimensional Analysis - The velocity on the wing due to the wing itself is calculated assuming an elliptical circulation distribution, while the velocity induced by the image wing is calculated by assuming a uniform circulation distribution across the image wing.

[326] Tomotika - This is the first attempt at a fairly rigorous mathematical treatment of the problem of the calculation of the lift of a flat plate placed in a free stream, in the neighborhood of a wall.

The system of the flat plate at an angle of attack and the ground is transformed by three successive conformal transformations (previously used by Rosenhead (Reference 279) into a ring region, in which an analytic function satisfying the boundary conditions of the problem can be found, using one of Villat's formulas (derived in 1912). The conformal transformations involve: first, the Schwarz-Christoffel method; second, the Weierstrass $\wp$-function; and, third a logarithmic transformation. Once the complex velocity potential is found, the lift is calculated by means of Blasius' formula. The answer is obtained in series form.

[320] Tomotika - The problem treated in this paper is mathematically the same as that of Reference 326; however, the ground is above rather than under the wing. The problem is of some academic interest.

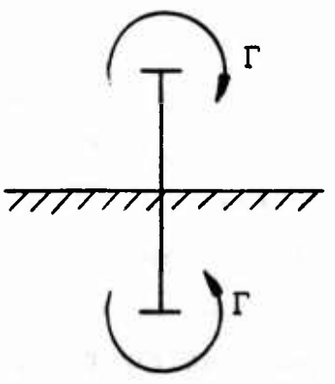
[78] Dätwyler - Dätwyler solves several theoretical problems. One of these is that of the two-dimensional flat plate touching the ground on one side. The solution is obtained by conformal mapping, using the Schwarz-Christoffel method. He calculates the lift on the plate directly, without needing Blasius' formula. Another problem is that of the plate at right angles to the flow with an edge close to the ground. Finally, Dätwyler gives an approximate method of calculation of the lift for a symmetrical wing which uses the image theory.

[319] Tomotika - Following some of Dätwyler's experimental results (Reference 78), Tomotika found it necessary to make additional numerical calculations in the theory of Reference 326, to verify Dätwyler's results. It was found that the Tomotika theory was in agreement with these results.

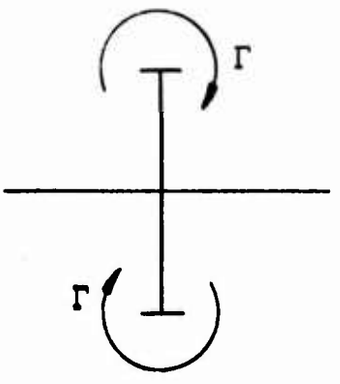
[52] Carafoli - The author uses a simple method (two-dimensional), replacing each wing by a bound vortex and giving the complex potential for the two vortices. The relative flow velocity at the wing can be calculated, showing a decrease in circulation, due to the decrease in velocity at the wing.

This analysis, like Müller's, is contrary to experimental evidence. No change in drag is predicted. Replacement of the airfoil by a line vortex is justified only in the case where the distance between the airfoil and the ground is too large to be of practical interest.

[341] von Kármán and Burgers - The interaction of a single vortex line of infinite extent representing a wing with a free boundary is treated by applying the condition that the pressure at all points of the boundary has the same value. The condition is that W_x, horizontal velocity at the boundary, is equal to zero. This is accomplished by taking the image vortex and changing the direction of its circulation, as compared with the solid boundary case.



Fixed Boundary



Free Boundary

[321] Tomotika and Imai - A rigorous mathematical analysis is developed for the hydrodynamical problem of calculating the lift on a flat plate placed in a two-dimensional continuous stream of fluid which is bounded by a free surface on the lower side of the plate. The conformal mapping formulation of the problem is exactly the same as for the basic problem of Reference 326, since for both a free and a fixed surface the stream function is constant. In the latter case, for further calculations, one uses the fact that the angle between the fixed surface and the direction of the velocity is known. In the former case, it is known that the magnitude of the fluid velocity along the free surface is constant and equal to the free-stream velocity.

Numerical calculations for this problem are very long and tedious. It is shown that, for values of angles of attack from 10° to 15°, the lift is increased a small amount because of the presence of the free surface when the distance of the plate from the surface is of the same order of magnitude as the breadth of the plate.

[322] Tomotika and Imai - The moment of the fluid pressure acting on a plate is calculated when the plate is placed in a semi-infinite stream bounded by an infinite wall on the lower side of the plate. Only the flow with circulation around the plate is considered, and the value of the circulation is so chosen that the flow leaves the trailing edge of the plate smoothly. The conformal mapping calculation is the same as in Reference 326. The moment is calculated using Blasius' formula.

These theoretical results lead us to expect that:

1. The center of pressure of a plane airfoil moves toward its midpoint for any value of the angle of attack as the airfoil approaces the ground.

2. The moment of the resultant pressure about the midpoint of the airfoil decreases because of the interference of the ground when the angle of attack assumes large values; but, on

the contrary, when the angle of attack is small, the moment increases because of the effect of the ground as the airfoil approaches sufficiently near the ground.

[324] Tomotika and Imai - In this paper, Dätwyler's method of calculating the lift and the moment of an airfoil when it touches the ground with its trailing edge is re-derived. It is also shown that Dätwyler's analysis is a limiting case of the analysis of Reference 326.

[313] Tani, Taima and Simidu - This paper is an extension of the work of References 254, 255, and 256. It treats both two- and three-dimensional cases. In the two-dimensional case, a chordwise distribution is assumed, as in References 254, 255, and 256. The aim of the study is to find out (a) the effect of bound vortices of the image wing (these were disregarded in References 311 and 352, for example) and (b) the effect of wing thickness. It is reasoned that the vorticity distribution of Reference 311 is equivalent to the introduction of a point-vortex of circulation Γ and a component doublet of vertical moment $\Gamma \sin \theta$. Therefore, the thickness can be expressed as a component doublet of longitudinal moment $\Gamma \cos \theta$. Further one has:

$$\Gamma \cos \theta = -0.6 \, V \, e \, c^2 \quad ,$$

where e is the maximum thickness in terms of the chord. The thickness effect turns out to correspond to a decrease $-\varkappa e$ in the effective angle of attack. In the three-dimensional case, the effect of the finite length of the trailing vortices of the image wing is considered, as well as that of the bound vortices. A formula is given for summarizing the effect of ground on the effective angle of attack for a wing of finite span.

[327] Tomotika, Tamada, and Saito - This paper is a further exploitation of References 326 and 320, where the attention is focused on the variation of circulation with ground distance rather than on the variation of lift. It is found that the

circulation is greatly affected by the presence of the ground. Comparing the curves for the circulation with the corresponding curves for the lift found in References 326 and 320, it is found that the variation of the lift of the plane airfoil due to the ground is, for the most part, attributable to the variation of the circulation of the airfoil.

[152] Hudimoto - The problem of the effect of ground interference upon an airfoil with a circular-arc section when the circle of this airfoil intersects or touches the surface of the ground is treated. By two successive conformal transformations, involving the Weierstrass $\wp$ and ζ functions, the region outside the circular arc and the straight line is transformed into a rectangle. Then the velocity of the flow of the perfect fluid is determined; and hence, the lift and the moment of the lift acting on the airfoil are calculated by Blasius' formula.

[323] Tomotika and Imai - This paper complements and extends earlier work by de Haller, "La Portance et la Trainée Induite Minimum d'une Aile au Voisinage du Sol" [89].

The problem is the same as that of Reference 152. However, because the trailing edge of the airfoil touches the ground, the conformal transformation is much simpler. One can use the Schwarz-Christoffel method. Thus, the expression for the lift and moment can be found rigorously. By carrying out detailed numerical computations, the effect of camber on the ground effect can be assessed. It is found that the ground effect is not greatly modified by the camber of the airfoil. Hence, the results for plane airfoils seem to be applicable without serious error.

[127] Green - The forces which are acting on a circular-arc airfoil when it is in any position near a plane wall are obtained. This is exactly the same problem as that of Reference 152, except

that Reference 152 is limited to the case when the circle carrying the circular arc intersects the ground plane. (This is the only practical case, anyway.) However, the conformal mapping solution is different, and Green does not refer to Reference 152.

The complex velocity potential is calculated by Green in the same way as in Reference 326; i.e., using the Schwarz-Christoffel method, followed by the application of another transformation involving the Weierstrass $\wp$-function. Green found that additional conformal transformations useful for the problem had been obtained in 1924 by Hodgkinson and Poole. Green is able to solve, analytically, the most general case of the circular airfoil near the ground and to prove that both References 152 and 326 were limiting cases of his general case.

[329] Tomotika, Urano, and Hasimoto - This paper is a follow-on to Reference 323; there is no additional theory. The purpose of the paper is to show that, in Reference 127, Green had arrived at wrong numerical results concerning lift and moment coefficients. It is shown numerically that, for small angles of attack, lift and moment coefficients of a circular airfoil are greater when the airfoil touches the bounding wall than when it is far from it. Green had been claiming the opposite result.

[128] Green - The problem of the fairly general airfoil in the presence of a plane is treated, using the simplest possible approach. The method is original and has been used by many subsequent authors, and will therefore be summarized here.

The airfoil in the complex Z-plane is obtained from a straight line of length 2n in the complex ζ-plane by means of the transformation:

$$Z = e^{-i\zeta} \sum_{n=0}^{\infty} a_n e^{in\zeta}$$

The airfoil is placed in the vicinity of a plane rigid wall. The fluid at infinity flows parallel to the wall with a constant velocity c, and there is a circulation $\varkappa = 2n\, A_o$ around the airfoil.

A suitable complex velocity potential which makes the boundary wall a streamline was found by Green to be:

$$W = cZ + iA_o \{\log Z - \log(Z + 2ib)\}$$

$$+ \left\{ \sum_{n=1}^{\infty} \frac{A_n}{Z^n} + \frac{\bar{A}_n}{(Z + 2ib)^n} \right.$$

where $\bar{A}_n$ denotes the complex conjugate of A_n .

Forces and moments can be computed by Blasius' formulas. The coefficients A_n are determined by satisfying the boundary conditions at the surface of the airfoil. The circulation is determined in the usual way, by assuming a stagnation point at the trailing edge. The circular-arc airfoil is treated as a special case. The numerical solution for the lift on the airfoil is given in the form of a series, for which only the first three terms could be obtained, so that results must be accepted with caution.

[328] Tomotika, Tomada, and Umemoto - The paper is concerned with the same problem as is treated in References 127 and 152: lift and moment of circular airfoil placed in a stream bounded by a plane wall. The study is more thorough than that of Green (Reference 127) and follows the mathematical outline of Hudimoto (Reference 152). It is found that, when the camber of the airfoil is small, the effect of the wall on the lift and moment is similar to that for an airfoil in the form of a flat plate; namely, as the airfoil approaches the wall, the lift and moment coefficients first decrease and then increase to values which are greater than the corresponding values for a circular-arc airfoil in an unlimited stream.

[325] Tomotika, Hasimoto, and Urano - The forces acting on an airfoil of approximate Joukowski-type in a stream bounded by a plane wall are calculated by using the method of images and a conformal transformation technique. The airfoil and its image are transformed into two cylinders, as was previously done by Müller (Reference 227). In other words, the cylinders are transformed into a rectangle by means of the Weierstrass ℘-function.

The paper is more precisely concerned with a study of the changes caused by the thickness of an airfoil on the ground effect than upon its lift. It is found that, at small angles of attack, the lift on the airfoil is generally increased by the presence of the ground, but the rate of increase of the lift with distance above the ground becomes smaller as the thickness of the airfoil increases.

[117] Fujikawa - In this paper, the lift on the symmetrical Joukowski airfoil of small thickness in the presence of a plane rigid wall is obtained in the form of a power series, limited to the first five terms, for the purpose of determining the manner in which the ground effect on the lift of an airfoil is modified by its thickness. The calculation of the lift is carried out, using Green's analysis of Reference 128.

It is found that, at small angles of attack, the wall effect on the lift is quite similar to that in the case of a plane airfoil and further, it is found that, for a given distance of the airfoil from the wall, the wall effect on the lift decreases as the thickness increases, even for small values of the angle of attack.

[118] Fujikawa - Green's method of Reference 128 is applied to the evaluation of the lift acting on a circular-arc airfoil in the presence of an infinite plane rigid wall. The expression for the lift is obtained in the form of a power series. After performing detailed numerical calculations, a discussion is presented on the manner in which the ground effect on the lift of an airfoil is modified by its camber.

It is found that, in accordance with the prediction made by Tomotika (Reference 328), as the arc-airfoil of sufficiently smaller camber approaches the wall, the lift first decreases and then tends to increase to values which are greater than the corresponding values for the same arc-airfoil in an unlimited stream, especially when the angle of attack is small. It is also found that the rate of increase in the lift becomes smaller as the camber of the airfoil increases.

[23] Bagley - A simple method of calculating the pressure distribution in incompressible flow on two-dimensional airfoils of arbitrary section near the ground is developed. The method used is essentially that of Tani (311 and 313); but an extended source distribution is used to represent the airfoil and its image instead of the two doublets used by Tani. A distribution of vortices on two parallel lines is used to represent the airfoil at incidence and its image. The velocity field due to such a distribution has been tabulated by Küchemann and Weber and is also presented in this paper. The closed-form solution of Reference 325 indicates that the velocity distributions agree within about 5 percent. Comparison with a series of experimental measurements on a 10-percent-thick RAE 101 airfoil at distances between 0.5 chord and 0.73 chord from the ground also shows that good agreement is obtained, provided allowance is made for the boundary layers on the airfoil and on the ground board.

[38] Braunss, G. and Lincke, W. - This paper appears to be a summarized version of a publication of the same title prepared in 1960 as a report of the Proceedings of the Aeronautical Institute of Darmstadt [39]. The authors treat the problem of the aerodynamic characteristics of a flat plate near the ground immersed in an incompressible two-dimensional flow. The problem has been treated, using conformal mapping techniques, in References 326, 322, and 324. It is treated here using Munk's classical thin airfoil theory; i.e., distributing singularities, in the form of a vortex distribution of strength $\gamma(x)$ along the flat plate.

The relationship between the induced normal and tangential velocities V_n and V_t at a point x_o on the plate and the vortex strength $\gamma(x)$ is as follows:

$$V_n(x_o) = \frac{1}{2\pi}\int_o^1 \gamma(x)\left[\frac{1}{x_o - x} + \epsilon(x,x_o)\right]dx$$

$$V_t(x_o) = \frac{1}{2\pi}\int_o^1 \gamma(x)\,\tau(x,x_o)\,dx$$

where

$$\epsilon(x,x_o) = \frac{2h_o \sin\alpha - x_o + x\cos 2\alpha}{(2h_o \sin\alpha - x_o + \cos 2\alpha)^2 + (x\sin 2\alpha - 2h_o\cos\alpha)^2}$$

and

$$\tau(x, x_o) = \frac{x\sin 2\alpha - 2\,h_o\cos\alpha}{(2h_o \sin\alpha - x_o + x\cos 2\alpha)^2 + (x\sin 2\alpha - 2h_o\cos\alpha)^2}$$

where the length of the plate is unity. The coordinate along the plate measured from the leading edge is x, the angle of attack is α, and the distance between the ground and the quarter-chord point is h_o.

If V_∞ is the free-stream velocity, the two boundary conditions on the plate can be written as:

$$V_\infty \sin\alpha + V_n(x_o) = 0$$

$$V_\infty \sin\alpha = \frac{1}{2\pi}\int_o^1 \gamma(x)\left[\frac{1}{x_o - x} + \epsilon(x,x_o)\right]dx$$

Letting

$$x = \tfrac{1}{2}(1 - \cos\phi) \quad ; \quad x_o = \tfrac{1}{2}(1 - \cos\psi)$$

the vortex strength is written, classically:

$$\gamma = 2\,V_\infty\left[(A_o + \sin\alpha)\frac{1+\cos\phi}{\sin\phi} + \sum_{\nu=1}^{n} A_\nu \sin\nu\phi\right]$$

Hence, by substitution:

$$A_o \left[1 + Q(\psi)\right] - \sum_{\nu=1}^{n} A_\nu \left[\cos \nu\psi - T_\nu(\psi)\right] = -\sin \alpha \, Q(\psi)$$

where

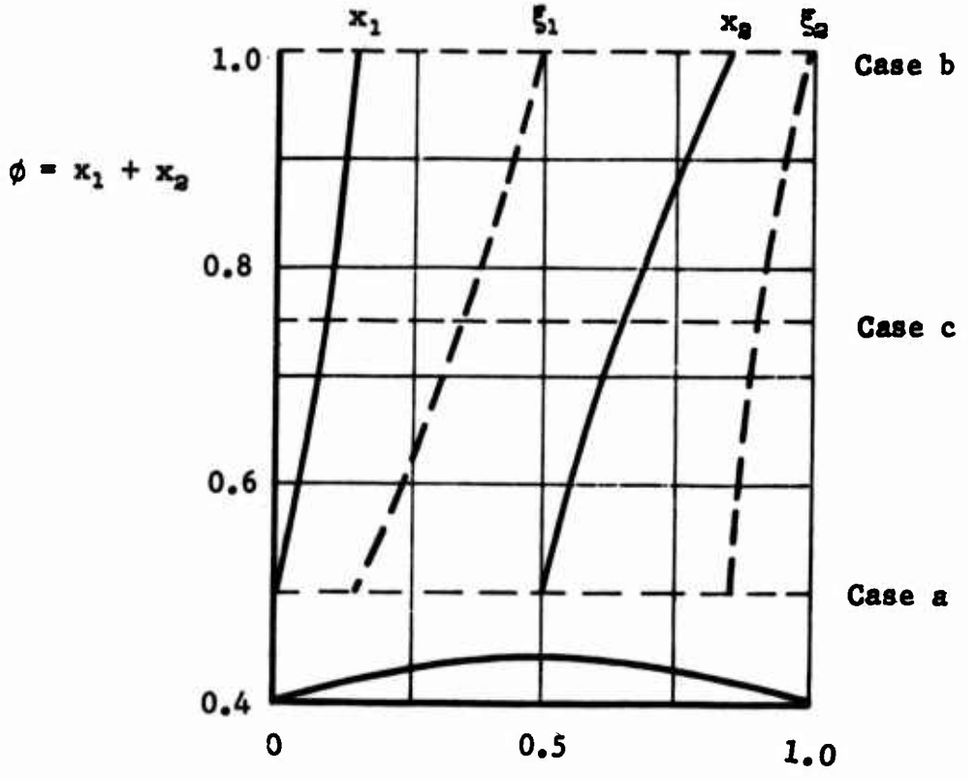
$$Q(\psi) = \int_0^\pi \epsilon(\phi, \psi)(1 + \cos \phi) \, d\phi$$

$$T_\nu(\psi) = \int_0^\pi \epsilon(\phi, \psi) \sin \phi \sin \nu\phi \, d\phi$$

Using the proper approximate expression for $T_\nu(\psi)$, one can calculate the coefficients A_n by Fourier series integration. Computers are useful for numerical solutions.

[1] Ackermann, U, and Bock, G. - In Reference 38, a two-dimensional airfoil near the ground is represented by a continuous vortex distribution. This mathematical representation does not allow for a tractable extension to the three-dimensional case. The purpose of the present paper is, therefore, to simplify as much as possible the representation of an airfoil in ground effect by investigating the correctness of the approximation made in replacing the wing section by a model of two vortices, which gives exactly the lift and the center-of-pressure position of a plate with incidence and parabolic camber in free two-dimensional flow. By means of this simple model, and using classical thin airfoil theory, the flat plate is investigated in two-dimensional flow near the ground. Numerical calculations were made for three different vortex control point locations shown in the figures. Here ξ_1, and ξ_2 are the distances of the control points and x_1 and x_2 are the distances of the vortices from

the leading edge of the airfoil (the chord length is unity). In the three cases, designated a, b, and c, the values of $\phi \equiv x_1 + x_2$ are 0.5, 1.0, and 0.75, respectively.



A comparison between the results of the calculations with those of Reference 326, indicates that the two-vortex approximation using $\phi = 0.75$ is very useful in a wid- domain of applications.

[207] Malavard, L. - Two-dimensional flows around airfoils placed in the immediate vicinity of the ground are analyzed theoretically by means of the electric analogy. The advantage of the electrical analogy method is that is allows - rigorous solution of the problem, which is necessary because Malavard feels that the assumptions of small disturbances in which second-order perturbation terms are disregarded does not hold very near to the

ground. He states that the theory of Reference 305 is not valid for this case. He proves it as follows:

The perturbation velocity along the ground is given by:

$$u_{1g} = -\int_{-\infty}^{+\infty} (V_g - V_\infty)\, dx = \int_{-\infty}^{+\infty} u_g\, dx$$

where

V_∞ free-stream velocity

V_g resultant velocity along the ground

x coordinate parallel to the ground

$$u_g = V_g - V_\infty$$

Now, the lift coefficient on the airfoil is given by:

$$C_L = C_{L_\Gamma} - \int_{-\infty}^{+\infty} \left(\frac{u_{1g}}{V_\infty}\right)^2 d\left(\frac{x}{c}\right)$$

where

$$C_{L_\Gamma} = -\frac{\Gamma}{V_c c}$$

is the circulation lift coefficient.

In classical wing theory, one assumes $C_L = C_{L_\Gamma}$. Malavard calculates the value of the disregarded integral involving u_{1g} in the case of a constant vorticity distribution along a segment of length c, parallel to and a distance h from the ground, as well as for various combinations of source and sink distributions, and shows that this term can reach 20 percent of the C_{L_Γ} term at a height-chord ratio of 0.05.

Different methods of using the rheoelectrical analogy are described, which make it possible to simulate in an electric tank either the velocity potential or the stream function, or the argument-function, or the logarithmic potential of the flow.

Applications to convex-plane airfoils, Clark Y airfoils with or without blowing, and flat plates with flaps are indicated.

The results obtained show that:

a. The lift of airfoils whose lower surface is plane and parallel to the ground generally increase as the distance to the ground becomes smaller.

b. The effect of a light blowing at the trailing edge is likely, owing to the blocking effect it generates, to improve the lift considerably.

c. The effect of the ground on an airfoil with a downwashed flap is obviously adverse.

[193] Licher, R. M. - The effect of the ground on the lift of a wing in ground effect is approximated theoretically by means of a singularity method, using networks of finite-strength bound and trailing vortices. For the two-dimensional flat-plate wing, comparison made with the known exact solution of Reference 326 indicates that a set of finite-strength bound vortices can adequately represent the lift of the wing near the ground; however, the number of vortices used must vary with the distance above the ground, increasing when one comes closer to the ground.

For the cambered two-dimensional wing, two different arrangements of the bound vortices are considered; these are believed to bracket the correct results. This method is similar to that used in Reference 1.

For the three-dimensional wing, several networks of bound and trailing vortices are examined and compared with Tani's method (References 311 and 313). One calculation includes the twist and taper; sweptback and delta wings cannot be analyzed by that method.

[315] Thomas, F. - A method based on the extended lifting-line theory is given, which permits the calculation of the lift distribution near the ground for airfoils of arbitrary planform, particularly

sweptback and delta wings. The report is therefore, for the three-dimensional case, an extension of Reference 193. The ground effect is taken into account by the reflection method. The velocities induced by the reflected airfoil at the actual airfoil considered are calculated in accordance with a method given by K. Gersten (1957 Jahrbuch der Wissenschaftliche Gesellschaft für Luftfahrt, pages 172-190).

The theoretical results are well confirmed by comparative measurements on a sweptback wing and a delta wing in the Brunswick wind tunnel. Theory and experiment indicate an increase in the lift curve slope and a decrease in the induced drag near the ground. Apart from these comparative measurements, ground effects on the position of the aerodynamic center, the maximum lift, and the flap effectiveness are investigated.

[63] Chaplin, H. R. and Masters, L. W. - The induced drag of several types of wings in ground effect is calculated theoretically, in an extension of Wieselsberger's original method (Reference 352), by setting up the potential problem in the Trefftz plane and solving it using the rheoelectrical analogy. The shed vortex system is assumed to trail straight behind the wing, and Teledeltos conductive paper is used as the working medium.

For the case of uniform downwash, span-loading distributions and effective aspect ratio are measured, as functions of height/span ratio, for plane wings, certain end-plated wings, and for a wing of which the lateral cross-section is a circular arc with its center lying at the ground surface. The results indicate that the use of end plates to reduce the ground clearance is relatively ineffective compared with reducing the ground clearance along the whole span, from the standpoint of increase in effective aspect ratio.

[356] Williams, P. G. - The lift of a two-dimensional wing located in ground proximity with a jet flap impinging vertically downward, with a large enough momentum jet coefficient that the deflection of the jet can be disregarded, is solved

mathematically by conformal mapping. The wing is regarded as a thin plate at zero incidence, and the jet as a solid boundary perpendicular to the wing connecting the trailing edge to the ground. This potential flow problem, the flow of an obstacle in the shape of an inverted L projecting from the ground, was solved by Darwin in 1945, in connection with the design of minimum-drag tip fins. The form of the solution follows.

The transformation reads:

$$z = d\,\frac{2K}{\pi}\left[Z(\zeta) - \frac{a\ \mathrm{cn}\ \zeta\ \mathrm{dn}\ \zeta}{1 - a\ \mathrm{sn}\ \zeta}\right]$$

where d is the vertical distance of the wing from the ground, a is a parameter, and standard notation is used for the Jacobian elliptic functions (K is the complete elliptic integral of the first kind and Z the Jacobian Zeta function), z is the complex variable in the physical plane, and ζ is the complex variable in the transformed plane.

The complex potential is:

$$w = -Ud\ .\ \frac{2K}{\pi}(k^2 - a^2)^{\frac{1}{2}}\ (1 - a^2)^{\frac{1}{2}}\ \frac{\mathrm{sn}\ \zeta}{1 - a\ \mathrm{sn}\ \zeta}$$

where U is the free-stream velocity and k is the modulus of the elliptic functions.

Using conventional techniques, the lift can be expressed in terms of tabulated elliptic integrals. The formulas are evaluated to obtain a graph of the pressure lift as a function of height above the ground. These data are compared with previous approximate and experimental results.

[332] Toussaint, A. - Two-dimensional wings in ground effect are studied by replacing the ground by the image wing and considering the system of real wing and image wing as a biplane. The wings are assumed to have thickness and camber, and are at an angle of attack. Aerodynamic forces on the biplane are found by conformal mapping.

The results show that, at zero angle of attack, for a symmetrical airfoil, the wing in ground effect has a negative lift, which depends mostly upon the thickness of the wing. Therefore, the angle of attack corresponding to zero lift is positive in ground effect and decreases to zero outside of ground effect. The second effect of the ground is to increase the slope of the lift curve.

Based on the results of the conformal mapping theory, Toussaint proposes the following formulas to represent the change in zero-lift angle due to ground effect and the lift curve slope, for a symmetrical airfoil, 13 percent thick:

$$100\ \Delta C_{L_{\alpha=0}} = -0.6Z\left(\frac{c}{h}\right)^{2.5}$$

$$\left(\frac{dC_L}{d\alpha}\right)_h = \left(\frac{dC_L}{d\alpha}\right)_\infty + 0.6\left(\frac{c}{h}\right)^2 - 0.025\left(\frac{c}{h}\right)^2 \alpha$$

The expression for the lift is then given by:

$$100\ C_{L_h} = 100\ C_{L_\infty} + \left(\frac{c}{h}\right)^2 \left[0.6\ \alpha - 0.025\ \alpha^2 - 0.62\ \sqrt{\frac{c}{h}}\right]$$

In the above equations, the terms are defined as follows:

c	airfoil chord
h	height above ground (measured from mid-chord)
α	angle of attack, in degrees
C_L	lift coefficient

In a later publication (Reference 334), Toussaint extends the above formulas to any airfoil.

[255], Pistolesi, E.

[256] Two- and three-dimensional cases are treated successively. The three-dimensional method is applied as follows:

a. Calculate the circulation around the wing as a function of the velocity (resultant of the velocity at infinity and the induced velocity) at a distance of one-quarter chord from the trailing edge (point k). The lift is obtained by multiplying the component of velocity normal to the chord line by $\ell\, c'$, where ℓ is the chord length and $c' = \frac{1}{2} \cdot \frac{dC_L}{d\alpha}$. (In practice $c' \approx \pi$.)

b. Replace the wing, for calculating induced effects and lift, by a vortex located at the center of gravity of the circulation; or place the vortex at a distance $\ell/4$ from the leading edge (point I), while adding there the proper doublet. For the flat plate, the doublet strength is zero, and the wing is replaced by a single bound vortex.

To calculate induced effects, one initially disregards angle of attack effects; they can be accounted for, in an approximate manner, later on.

In accordance with the above scheme, one calculates the normal velocity V_n at point k:

$$V_n = V_o \sin \alpha + \frac{\Gamma}{2n} \frac{\ell/2}{4h^2 + \ell^2/4}$$

hence

$$\Gamma = n\, \ell\, V_n\, \alpha = \Gamma_o + \Gamma \frac{\ell^2/4}{4h^2 + \ell^2/4}$$

or

$$\Gamma = \Gamma_o \quad (1 + \ell^2/16h^2)$$

Now the velocity at point I is:

$$V_o = \frac{\Gamma}{4nh}$$

Hence, the lift is given by:

$$L = \rho \Gamma \left(V_o - \frac{\Gamma}{4nh} \right)$$

or

$$L = \rho n \ell V^2 \sin \alpha \left[1 - \frac{\ell}{4h}(1 + \ell^2/16h^2) \sin \alpha \right] \left[1 + \ell^2/16h^2 \right]$$

$$\frac{L}{L_o} = \left[1 - \frac{\ell}{4h}(1 + \ell^2/16h^2) \sin \alpha \right] \left[1 + \ell^2/16h^2 \right]$$

These results compare relatively well with those of Tomotika (Reference 326).

These formulas are extended by Pistolesi to include the effects of angle of attack (in the calculation of V_n) and of airfoil curvature. Better agreement with Tomotika's results is then found.

For the three-dimensional treatment, Pistolesi simplifies the problem by disregarding tip vortices and replacing the wing and its image by a horseshoe vortex distribution, which assumes uniform spanwise lift distribution. He finds qualitative agreement with experiments; in particular, the increase in lift decreases, when the incidence increases, until it becomes zero.

Pistolesi suggests that the method can be improved to represent elliptical spanwise lift distributions by using Ferrari's conformal mapping method.

[308] Strand, T., Royce, W. W., and Fujika, T. - Three problems relating to the aerodynamic lift theory of high-speed air-cushion vehicles are discussed.

a. Two-dimensional airfoil theory

The ground is replaced by the image airfoil (zero angle of attack). The airfoil and its image are replaced by a continuous distribution of sources and vortices extending from

leading to trailing edge along the line $y = \pm h$ (where h is the distance to the ground). The velocity components are calculated in the conventional manner. The boundary condition at the airfoil is expressed as:

$$\left.\frac{dy}{dx}\right|_{y=h} = \frac{v}{V_o + u}$$

where

x	coordinate parallel to the ground
y	airfoil ordinate
u,v	horizontal and vertical components of the velocity
V_o	free-stream velocity

The problem is linearized by assuming that $u(x,h) \ll V_o$ and hence disregarding u in comparison with V_o. As is shown by Malavard in Reference 207, this assumption is not valid very near the ground.

b. Channel Flow

For high-speed ground-effect machines with side jets, operating very close to the ground (channel flow GEM), it is assumed that the lift and pitching moment variation with changes in angle of attack can be represented by assuming one-dimensional channel flow underneath the vehicle and using Bernoulli and continuity equations, with an independent term accounting for the variation of the upper surface lift.

c. Mound Flow

It is assumed that, for a channel-flow GEM, the upper surface flow can be considered separately from the lower surface flow. Treating the upper surface like a mound or bump that the air particle must negotiate introduces the possibility of calculating an upper-surface lift coefficient. This lift coefficient is usually calculated approximately. It is found that quite large lift coefficients can theoretically be obtained from the upper-surface pressure distribution by proper shaping of this surface.

[281] Royce, W. W. and Rethorst, S. - A fundamental analysis is presented of the aerodynamics of a three-dimensional lifting surface translating in proximity to the ground. A mathematical model is formulated on the basis of a set of closed spanwise rectangular vortices representing the lifting surface and its side jets extending to the ground, and the corresponding image below the ground plane.

The finite mass flow through this channel underneath the machine permits a solution by matrix methods for the perturbation flow field generated by this vortex model, thereby providing the pressures, forces, moments, and power required by a GEM in forward flight.

A closed form solution is obtained for the limiting case where the surface approaches the ground. The principal value of a vortex singularity in this limit is obtained, and it is shown that on the upper surface the perturbation velocity, and hence the lift, vanishes; while on the lower surface the vortex strength becomes precisely the perturbation velocity. Thus, in this limit, the flow is reduced to one-dimensional channel flow.

[284] Saunders - The effect of the ground on the aerodynamic characteristics of wings is shown with the aid of a linearized two-dimensional model, followed by a description of a lifting-surface theory for finite wings of arbitrary planform. The effects of ground height, aspect ratio, sweep, taper, and non-planar geometries are investigated. Experimental data are found to compare well with theory.

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Table 1

References Dealing With Theory

References:	1 5	20 23	37 41	44 46	48 49	54 55	63 83	89 107	127 129	130 131	136 152	166 175	197 198	199 216	218 220	239 240	242 249	250 261	262 263	270
Configuration, or Geometry:																				
Two-Dimensional	X X	X X	X		X	X	X		X	X X	X	X	X	X	X	X X		X	X X	
Three-Dimensional	X	X		X X	X	X	X	X	X		X	X X	X X	X	X		X X	X	X X	X
Flat Plate		X	X X		X		X			X	X X		X	X		X		X	X X	
Curved Plate or Thin Airfoil	X			X	X	X			X	X	X	X	X	X	X	X	X		X X	
Airfoil		X	X	X X	X X	X			X		X		X		X X	X	X		X	
Unswept Wing				X					X				X							
Swept or Delta Wing				X																
Method of Approach:																				
Potential Flow	X X	X	X X	X	X	X	X X	X	X X	X X	X X	X	X		X	X X	X	X	X	X
Conformal Transformation			X				X		X	X	X X		X			X X			X X	
Lifting Line	X	X X		X	X	X		X	X				X	X	X			X	X	
Lifting Surface														X						
Method of Singularities	X	X X	X	X X	X	X X			X			X	X		X		X	X	X	X
Electric Analogy					X	X	X								X X					
Image Method	X	X X	X		X	X X			X			X	X	X	X	X	X X		X	X
Approximate	X	X X		X X	X	X X	X					X	X	X				X		X
Exact			X X			X	X		X	X	X X			X	X	X X			X	
Phenomenological									X					X			X X	X		

Table 1 (Concluded)

References:	271	284	285	287	289	296	309	311	312	316	317	319	322	323	324	325	326	327	329	330	331	333	345	351	356
Configuration, or Geometry:																									
Two-Dimensional		X	X	X				X			X	X	X	X	X	X	X	X	X	X	X		X		X
Three-Dimensional		X			X	X	X		X	X												X		X	
Flat Plate				X									X	X	X	X	X	X	X	X					X
Curved Plate or Thin Airfoil											X										X				
Airfoil		X			X	X		X		X	X	X											X	X	
Unswept Wing		X				X																		X	
Swept or Delta Wing		X										X													
Method of Approach:																									
Potential Flow	X			X		X					X		X	X	X	X	X	X	Y	X	X			X	X
Conformal Transformation				X							X		X	X	X	X	X	X	X	X	X	X	X		X
Lifting Line						X						X												X	
Lifting Surface		X			X																				
Method of Singularities		X				X		X		X														X	
Electric Analogy					X																				
Image Method		X			X	X		X															X	X	
Approximate		X			X			X			X												X		X
Exact				X									X	X	X	X	X	X	X	X	X				
Phenomenological										X															

Table 2

References Dealing With Experimental Methods of Approach

References:	3	5	6	7	8	9	11	13	14	15	17	18	20	21	22	26	27	28	29	31	35	38	39	44	46	51	52	53	58	59	60	65	67	68	69	70	72	73	74
Model	X		X			X	X	X	X			X	X	X	X		X			X					X	X	X	X	X	X	X	X	X	X	X		X	X
Full Size					X		X			X	X							X	X		X	X									X		X	X	X			
Two Dimensional													X		X																								
Three Dimensional	X			X		X	X	X	X			X		X		X				X					X		X	X			X							
Wind Tunnel	X		X	X			X	X	X			X	X	X	X					X					X		X	X	X								X	X
Towing Carriage						X	X		X								X												X		X							
Towed or Tethered																										X			X	X		X		X				
Flight Test or Free Flight							X		X	X	X							X	X		X	X										X	X	X	X			
Full or Partial Ground Board	X	X	X				X	X				X	X	X	X	X				X			X		X		X	X									X	X	X
Moving Belt Surface																																							
Image Method																																						X	
Over Ground Surface																		X			X																		
Over Water or Waves						X	X		X	X	X						X									X			X	X	X	X		X	X	X			
Test Technique		X												X									X																
Test Correction																								X															
Flow Pattern Study or Spray	X					X											X													X								

Table 2 (Continued)

References:	73	76	77	80	81	83	84	85	86	87	91	93	94	95	99	100	105	109	110	112	113	115	118	121	126	129	132	137	138	139	140	142	143	144	151	153	154
Model			X	X	X	X	X	X	X				X	X			X	X			X	X	X	X		X		X	X		X					X	X
Full Size	X						X				X				X				X	X					X		X		X								
Two Dimensional						X				X		X	X																								X
Three Dimensional			X	X	X			X						X			X				X	X	X	X		X		X									
Wind Tunnel	X					X	X	X	X			X	X	X			X				X	X		X		X		X		X		X				X	X
Towing Carriage		X		X	X																X		X														
Towed or Tethered		X		X	X				X									X										X									
Flight Test or Free Flight			X				X				X				X				X				X				X										
Full or Partial Ground Board			X			X	X	X	X			X	X				X				X			X		X		X		X						X	X
Moving Belt Surface																																					
Image Method							X		X													X							X								
Over Ground Surface							X																X					X									
Over Water or Waves	X	X		X											X	X		X	X	X			X		X			X		X							
Test Technique																													X		X	X	X	X	X		
Test Correction																																					
Flow Pattern Study or Spray						X	X	X																											X	X	

Table 2 (Continued)

References:	157	160	161	163	164	167	168	169	171	174	176	177	178	180	181	182	185	186	187	192	193	194	197	200	203	204	205	206	207	210	211	212	213	214	216	226	230	231	234
Model											X				X		X	X	X				X	X						X		X	X	X		X	X	X
Full Size	X	X		X			X	X	X	X				X								X			X	X	X	X		X		X				X			X
Two Dimensional																																							
Three Dimensional			X			X									X		X	X	X					X						X		X	X	X	X	X	X	X
Wind Tunnel			X								X				X	X		X	X				X						X		X			X	X		X	X	
Towing Carriage					X																		X																X
Towed or Tethered																	X							X								X							
Flight Test or Free Flight	X	X					X	X	X	X							X					X	X		X	X	X		X			X							X
Full or Partial Ground Board			X								X				X			X	X					X						X	X			X	X	X	X		
Moving Belt Surface					X																																		
Image Method																																							X
Over Ground Surface						X	X	X									X			X	X																		
Over Water or Waves	X								X	X		X	X						X		X	X			X	X	X	X	X	X		X	X			X			X
Test Technique			X																					X									X						
Test Correction																																							
Flow Pattern Study or Spray			X										X										X																

Table 2 (Continued)

References:	235	236	237	238	243	246	248	249	250	251	258	263	264	265	266	267	268	271	273	274	275	276	277	278	279	280	281	282	283	285	290	292	294	295	296	297	298	303	304
Model	X		X	X			X	X	X			X	X	X		X			X	X	X	X				X						X	X	X		X	X		X
Full Size		X				X		X															X	X	X	X	X	X	X	X									
Two Dimensional												X	X																										
Three Dimensional	X		X	X					X			X	X	X		X			X	X	X	X									X	X	X	X	X	X		
Wind Tunnel			X				X	X	X			X	X	X		X			X	X	X	X										X	X	X	X	X		X
Towing Carriage	X			X																																		
Towed or Tethered																																						
Flight Test or Free Flight						X		X															X						X	X								
Full or Partial Ground Board			X				X		X		X	X	X	X	X	X			X	X	X	X												X		X		X
Moving Belt Surface							X																															
Image Method					X		X				X				X			X																	X		X		
Over Ground Surface								X															X	X	X					X								
Over Water or Waves	X	X		X	X	X					X													X			X	X	X									
Test Technique										X							X													X					X		X	X
Test Correction																																						
Flow Pattern Study or Spray							X					X			X								X															

Table 2 (Concluded)

References:	305	306	307	312	316	317	333	334	336	337	339	340	341	342	348	349	350	351	353	354	355	356	357	360	361	362	363
Model	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X		X			X	X		X	
Full Size		X					X							X		X			X				X				X
Two Dimensional												X													X		
Three Dimensional	X	X	X	X	X	X	X	X	X	X			X				X	X						X		X	
Wind Tunnel	X		X		X	X		X	X	X	X		X				X	X		X				X		X	
Towing Carriage			X	X			X			X												X					
Towed or Tethered				X												X											
Flight Test or Free Flight	X	X					X							X		X			X				X				X
Full or Partial Ground Board	X	X	X				X	X	X	X	X	X	X		X			X						X		X	
Moving Belt Surface																				X							
Image Method											X	X			X		X					X					
Over Ground Surface					X	X																X	X				X
Over Water or Waves																			X				X				
Test Technique										X	X				X					X							
Test Correction											X																
Flow Pattern Study or Spray		X											X		X						X						X

Table 3

References Dealing With Experimental Results

References:	3	5	6	7	10	11	13	14	15	18	25	26	28	31	35	46	49	50	51	52	53	54	58	60	61	62	63	64	69	70	72	73	74	76	77	80	81	83
Geometry Varied:																																						
Planform (tapered, swept)							X	X																X														
Aspect Ratio							X	X																														
Thickness							X	X										X					X															
Tip Plate						X																	X				X										X	
Tip Paired or Shaped						X																																
Parameters Varied:																																						
Height			X			X							X	X		X		X		X	X		X	X	X		X			X							X	
Angle of Attack or Trim			X			X	X	X		X	X		X		X		X	X		X	X		X	X						X		X	X		X		X
Roll						X						X								X	X									X				X				
Yaw (Sideslip)				X		X						X																		X				X		X	X	
Flap Angle	X			X					X				X	X			X	X		X								X			X			X			X	
Quantities Measured:																																						
Lift	X		X			X	X	X		X	X	X	X	X	X	X	X			X	X		X	X	X	X					X	X	X		X			X
Drag or Resistance	X		X		X	X	X	X		X	X	X	X		X	X	X			X	X		X	X	X	X		X	X			X	X					X
Moment	X			X		X	X	X		X	X	X			X		X	X		X			X						X			X	X					X
Downwash		X																				X																

Table 3 (Continued)

References:	84	85	87	92	93	94	95	105	107	109	110	113	115	118	121	125	128	131	132	140	143	153	154	157	162	163	166	168	176	180	181	185	186	187	192	194	197	198	209
Geometry Varied:																																							
Planform (tapered, swept)												X				X																							
Aspect Ratio																X					X										X							
Thickness								X				X	X			X																							
Tip Plate								X					X																								X		
Tip Faired or Shaped												X	X																										
Parameters Varied:																																							
Height	X	X	X	X		X		X				X	X	X			X		X						X		X		X			X	X		X		X		
Angle of Attack or Trim	X	X					X	X				X	X	X	X	X								X							X	X				X		
Roll							X							X																	X	X		X				
Yaw (Sideslip)							X							X																								
Flap Angle		X								X		X														X		X	X	X								
Quantities Measured:																																							
Lift	X	X	X	X	X	X	X	X			X	X	X	X	X	X		X	X			X		X	X		X	X	X		X					X	X		X
Drag or Resistance		X		X			X	X			X	X	X	X	X	X		X	X									X			X					X	X		X
Moment		X			X	X	X	X				X	X	X	X	X	X	X	X				X								X	X	X			X		
Downwash									X											X			X						X								X	

Table 3 (Continued)

References:	211	214	216	224	225	230	231	234	235	237	238	243	246	248	249	250	257	263	264	265	266	267	271	272	273	274	275	280	285	288	292	294	295	296	297	298	300	302	303
Geometry Varied:																																							
Planform (tapered, swept)	X																			X																			
Aspect Ratio	X																			X																		
Thickness	X																																					
Tip Plate	X	X																X						X														
Tip Faired or Shaped	X																																					
Parameters Varied:																																						
Height	X	X				X	X							X				X	X	X	X	X	X	X	X	X	X	X	X	X			X		X	X	X	X
Angle of Attack or Trim	X		X		X	X							X			X		X					X	X	X	X	X		X		X		X	X	X	X		X	
Roll	X																																						
Yaw (Sideslip)	X																																						
Flap Angle	X		X							X					X	X										X	X				X		X	X		X			
Quantities Measured:																																							
Lift	X	X	X		X	X	X				X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
Drag or Resistance	X	X	X	X	X	X	X	X	X		X	X				X		X			X	X		X	X	X	X		X	X				X	X	X	X		
Moment	X		X			X					X					X	X	X				X			X	X	X		X		X		X	X	X	X			
Downwash															X																	X								

Table 3 (Concluded)

References:	305	307	309	312	316	317	333	334	335	337	339	340	341	342	349	350	355	356	359	360	361	362
Geometry Varied:																						
Planform (tapered, swept)		X				X																
Aspect Ratio		X																	X			
Thickness		X				X																
Tip Plate				X												X						
Tip Paired or Shaped																						
Parameters Varied:																						
Height			X		X	X		X		X	X	X	X	X	X	X	X		X	X	X	
Angle of Attack or Trim		X			X	X	X	X	X		X	X	X		X		X			X		X
Roll		X																				
Yaw (Sideslip)									X													
Flap Angle					X				X			X			X	X		X		X		
Quantities Measured:																						
Lift	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Drag or Resistance	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X				X		X
Moment		X			X	X	X	X	X			X			X	X				X		X
Downwash			X	X									X				X					

Table 4

References Dealing With Applications

References:	2	3	4	6	7	8	9	11	12	13	14	15	17	21	24	25	26	27	28	29	35	38	42	43	45	46	50	51	52	56	57	59	60	61	64	65	68	69	70
Boat With Wing Between Hulls (Catamaran)								X	X				X		X	X						X			X													
Boat With Wings Outboard of Hull	X					X						X																								X			X
Integrated Planing Hull or Float Wing						X																									X								
Auxiliary Hydrofoil or Fin																																X				X			
Sponsons or Stub Wings							X											X								X	X					X			X		X	X
Jet Flap				X																									X									
Side Air Curtain Sealing									X								X																	X				
GETOL																																							
Landplane		X								X											X					X			X									
Seaplane or Amphibian					X	X								X												X				X		X			X			
Land Wheeled Vehicle																																							
Air Propulsion						X					X								X	X															X		X		
Water Propulsion								X				X	X																										
Landing or Taking Off		X																															X	X		X		X	X
Performance of Complete System								X			X		X							X	X					X			X							X			
Flying Fish			X																				X	X														
Seabirds Near Water Surface																																							
Natural Observation			X																				X	X														
Performance (Natural Phenomena)			X																					X														
Measurement (Natural Phenomena)																																							
Katzmayer, Betz-Knoller, or Lilienthal Effect																																							

Table 4 (Continued)

References:	71	72	74	75	76	78	79	80	81	83	85	86	87	88	90	91	93	94	95	97	98	99	100	101	102	103	104	105	106	108	109	110	112	113	114	116	117	118	
Boat With Wing Between Hulls																									X														
(Catamaran)																																							
Boat With Wings Outboard of Hull				X		X																X		X	X							X	X					
Integrated Planing Hull or Float				X				X	X													X		X														
Wing																																							
Auxiliary Hydrofoil or Fin																																	X						
Sponsons or Stub Wings					X			X	X											X	X	X								X								
Jet Flap											X	X	X	X			X	X										X	X	X							X	
Side Air Curtain Sealing											X	X																X	X								X	
GETOL											X				X														X	X								
Landplane										X																													
Seaplane or Amphibian			X	X	X			X	X										X	X	X	X	X	X	X						X	X					X	
Land Wheeled Vehicle																																							
Air Propulsion				X												X						X						X	X				X	X				
Water Propulsion																																							
Landing or Taking Off				X			X	X		X					X							X																
Performance of Complete System		X		X																		X											X	X			X	
Flying Fish																										X	X								X	X		
Seabirds Near Water Surface	X																										X											
Natural Observation	X																										X										X	
Performance (Natural Phenomena)																										X									X			
Measurement (Natural Phenomena)																										X												
Katzmayer, Betz-Knoller, or																																X			X	X		
Lilienthal Effect																																							

Table 4 (Continued)

References:	122	123	124	125	128	131	134	135	139	145	147	148	149	150	153	154	155	157	159	160	161	162	163	164	165	166	167	168	173	177	178	179	180	181	183	184	185	187	
Boat With Wing Between Hulls (Catamaran)	X	X																												X	X				X				
Boat With Wings Outboard of Hull			X																										X				X					
Integrated Planing Hull or Float Wing									X	X										X			X										X					
Auxiliary Hydrofoil or Fin																																							
Sponsons or Stub Wings					X																																		
Jet Flap															X	X	X				X					X								X					
Side Air Curtain Sealing																																		X					
GETOL				X																	X	X															X		
Landplane				X	X				X																X														
Seaplane or Amphibian									X									X					X		X			X						X				X	
Land Wheeled Vehicle																																							
Air Propulsion			X						X											X							X						X					
Water Propulsion			X																											X								
Landing or Taking Off					X										X			X						X														
Performance of Complete System				X														X									X							X				
Flying Fish							X	X			X	X	X	X					X																			
Seabirds Near Water Surface							X												X													X						
Natural Observation							X	X			X	X	X	X																								
Performance (Natural Phenomena)							X																															
Measurement (Natural Phenomena)							X						X																									
Katzmayer, Betz-Knoller, or Lilienthal Effect						X																														X			

Table 4 (Continued)

References:	188	189	191	192	193	194	195	196	200	201	203	204	205	206	207	210	216	217	222	223	224	225	226	227	228	229	230	233	234	235	236	237	238	244	245	246	247	248	249
Boat With Wing Between Hulls (Catamaran)											X			X		X									X		X							X				
Boat With Wings Outboard of Hull	X										X	X	X	X		X									X					X								
Integrated Planing Hull or Float Wing											X			X		X	X		X																	X		
Auxiliary Hydrofoil or Fin																																							
Sponsons or Stub Wings											X													X					X	X								
Jet Flap				X																							X											
Side Air Curtain Sealing																																							
GETOL									X																														
Landplane																	X																					X	
Seaplane or Amphibian						X					X					X			X				X	X	X	X			X			X			X	X		
Land Wheeled Vehicle																										X												
Air Propulsion									X		X			X		X			X				X			Y			X				X			X		X
Water Propulsion											X	X	X																		X							
Landing or Taking Off																X				X									X	X					X		X
Performance of Complete System											X	X	X	X	X	X					X	X													X			
Flying Fish		X					X	X		X																								X				
Seabirds Near Water Surface																		X																				
Natural Observation		X					X	X										X																X				
Performance (Natural Phenomena)			X					X										X																X				
Measurement (Natural Phenomena)																		X																				
Katzmayer, Betz-Knoller, or Lilienthal Effect			X		X	X												X																				

Table 4 (Continued)

References:	250	253	254	257	264	265	266	267	269	271	272	273	275	276	277	278	279	281	282	283	285	286	292	293	294	295	300	301	304	305	306	307	309	313	314	318	320	321	333
Boat With Wing Between Hulls (Catamaran)				X					X									X	X	X		X		X										X	X			X	
Boat With Wings Outboard of Hull																						X					X											X	
Integrated Planing Hull or Float Wing																																							
Auxiliary Hydrofoil or Fin																																							
Sponsons or Stub Wings		X																																				
Jet Flap			X			X	X	X		X															X							X							
Side Air Curtain Sealing					X														X	X													X					
GETOL					X	X	X	X			X			X																	X	X							
Landplane	X												X		X		X				X					X													
Seaplane or Amphibian		X																				X			X		X							X			X	X	
Land Wheeled Vehicle																													X										
Air Propulsion																		X	X	X		X																	
Water Propulsion																																			X				
Landing or Taking Off				X								X	X	X	X	X	X				X										X						X		X
Performance of Complete System														X		X		X	X	X	X									X	X								
Flying Fish																											X								X				
Seabirds Near Water Surface																																							
Natural Observation																												X											
Performance (Natural Phenomena)																							X					X											
Measurement (Natural Phenomena)																												X											
Katzmayer, Betz-Knoller, or Lilienthal Effect																																				X			

Table 4 (Concluded)

References:	336	337	341	342	344	345	346	347	348	349	354	355	356	357	358	360	361	362	363
Boat With Wing Between Hulls (Catamaran)					X										X				
Boat With Wings Outboard of Hull				X			X												
Integrated Planing Hull or Float Wing					X	X							X						
Auxiliary Hydrofoil or Fin							X												
Sponsons or Stub Wings													X						
Jet Flap		X	X			X			X		X	X					X		
Side Air Curtain Sealing						X					X								
GETOL						X					X								
Landplane	X													X		X			X
Seaplane or Amphibian					X														
Land Wheeled Vehicle																			
Air Propulsion					X	X													
Water Propulsion				X															
Landing or Taking Off										X			X			X			X
Performance of Complete System				X						X									
Flying Fish								X											
Seabirds Near Water Surface																		X	
Natural Observation																			
Performance (Natural Phenomena)																			
Measurement (Natural Phenomena)																			
Katzmayer, Betz-Knoller, or Lilienthal Effect														X					

Table 5

Tabular Breakdown of Contents of References

References:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Illustrations			X	X			X	X		X	X		X	X	X	X	X	X			X					X		X	X									X	
Diagrams or Drawings	X	X	X	X	X		X			X	X	X	X	X		X	X	X	X	X	X		X	X	X	X			X		X	X		X	X	X	X	X	
Graphs or Charts	X		X	X	X		X			X	X		X	X		X	X	X		X	X	X	X			X					X	X			X		X		
Tables			X	X			X	X						X			X	X		X		X				X			X		X				X	X		
Formulas			X		X											X																					X		
Bibliography or Reference	X			X	X	X				X	X		X	X						X		X				X			X							X			
Patent Description		X										X							X					X	X													X	
Proposal																																							
Final, Progress, or Summary Report											X																												
Textbook Discussion or Standard Work Source																																							
Thesis																																							
Comment of Unusual or Historical Interest								X		X				X																X		X		X		X			
Analysis of Previous Studies														X		X																		X	X				
Document not Generally Available							X		X																		X												
Not Searched						X																					X					X							

Table 5 (Continued)

References:	40	41	42	43	44	45	46	47	48	49	50	51	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Illustrations			X				X										X	X	X					X		X	X		X	X	X				X		X		
Diagrams or Drawings		X		X	X	X	X		X	X			X	X			X		X	X	X	X	X	X				X	X		X		X	X			X	
Graphs or Charts		X		X	X		X			X							X		X	X		X						X	X		X	X	X	X		X		
Tables		X			X		X												X		X							X	X			X		X					
Formulas							X		X	X			X	X	X				X			X											X						
Bibliography or Reference		X			X		X			X							X				X	X						X		X		X						
Patent Description						X										X							X																
Proposal																											X							X					
Final, Progress, or Summary															X																					X			
Report																																							
Textbook Discussion or Standard																				X																	X	
Work Source																																							
Thesis																																							
Comment of Unusual or Historical																		X		X	X					X		X		X				X			X	X	
Interest																																							
Analysis of Previous Studies															X																								
Document not Generally								X																	X		X				X					X			X
Available																																							
Not Searched	X		X					X			X	X													X										X				

Table 5 (Continued)

References:	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	148	149
Illustrations			X		X	X					X				X				X	X					X			X					X		X		X	
Diagrams or Drawings			X		X			X	X					X	X	X	X	X	X		X	X	X		X	X	X		X		X	X	X	X			X	X	X
Graphs or Charts			X		X		X		X			X	X	X	X	X									X		X	X			X	X	X	X				X	
Tables			X		X	X																			X							X							
Formula					X							X																					X	X						
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Illustrations		X	X							X			X		X	X		X							X				X		X			X			X	X	X	X
Diagrams or Drawings	X		X		X	X	X	X	X	X		X			X	X	X	X	X	X	X	X	X			X			X	X					X		X		
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Illustrations	X			X	X		X	X	X		X		X	X	X		X	X	X			X	X	X		X					X	X	X			X	X	
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Illustrations	X	X	X	X				X	X	X	X	X			X					X														X	X	X			
Diagrams or Drawings	X		X	X	X			X	X			X		X	X	X		X	X			X	X	X	X	X	X		X		X	X	X		X	X	X	X	
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Illustrations			X		X		X				X						X					X	X		X		X	X					X		X	X			
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Illustrations	X	X	X		X							X		X	X		X							X	X	X	X		X	X		X		X		X		X	
Diagrams or Drawings	X	X	X		X	X	X		X	X		X	X	X	X	X	X		X	X	X		X	X	X	X	X			X	X	X	X			X	X		X
Graphs or Charts	X	X	X	X	X		X		X	X		X		X		X	X	X	X		X	X			X	X	X		X	X	X	X				X	X		X
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Illustrations														X		X	X				X	X					X	X	X	X			X	X						X			
Diagrams or Drawings		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X		X	X	X		X	X	X	X	X		X	X			X	X	X	X	X	X	
Graphs or Charts			X	X	X	X	X	X	X	X	X	X	X	X		X	X		X		X	X								X	X	X	X		X	X	X	X		X	X	X	X	X	
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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)

Foshag, William F.

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A comprehensive survey and literature search is made of the general field of wings operating in ground effect and related phenomena. Comments are included of some of the papers published, to present a sketch of the methods of approach of a number of authors. The bibliography presents sources which consider the problem from the theoretical, experimental, and/or applications point of view. Tables are included which provide a convenient breakdown of the various sources, for a quicker method of locating specific references dealing with an area of special interest to the reader.

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Appendix B (p.53-77): Survey of theoretical papers.

Analytical subject tables: p.79-104.

A comprehensive survey and literature search is made of the general field of wings operating in ground effect and related phenomena. Comments are included of some of the papers published, to present a sketch of the methods of approach of a number of authors. The bibliography presents sources which consider the problem from the theoretical, experimental, and/or applications point of view. Tables are included which provide a convenient breakdown of the various sources for a quicker method of locating specific references dealing with an area of special interest to the reader.

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A comprehensive survey and literature search is made of the general field of wings operating in ground effect and related phenomena. Comments are included of some of the papers published, to present a sketch of the methods of approach of a number of authors. The bibliography presents sources which consider the problem from the theoretical, experimental, and/or applications point of view. Tables are included which provide a convenient breakdown of the various sources for a quicker method of locating specific references dealing with an area of special interest to the reader.

GROUND EFFECT—BIBLIOGRAPHY
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LIFT
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AIRPLANES, VTOL
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GEMS, RAM-WING
PLANING SURFACES
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AUTOMOBILES—AERODYNAMICS
INSECT FLIGHT
BIRD FLIGHT
KATZMAYER EFFECT
NOMENCLATURE—GEMS, CAB
Foshag, William F.
DTMB Aero Rpt 1098
DTMB Aero Test A-601
...Wings in ground effect.

David Taylor Model Basin. Report 2179.
LITERATURE SEARCH AND COMPREHENSIVE BIBLIOGRAPHY OF WINGS IN GROUND EFFECT AND RELATED PHENOMENA, by William F. Foshag. Wash., Mar 1966. ii,108p. incl. illus. (Aerodynamics Laboratory. Aero Rpt 1098. Aero Problem 631-601)

Bibliography: p.8-51.

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