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ALTIMETRY
A LITERATURE REVIEW AND BIBLIOGRAPHY

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DEPARTMENT OF TRANSPORTATION
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FINAL REPORT

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16. Abstract

The Federal Aviation Administration is interested in disseminating information which could be used by the aviation community to promote safety and economy. This document has been prepared to assist both government and the aviation industry in the design, maintainability and reliability of altimeter systems.

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INTRODUCTION

Purpose

The purpose of the literature review and bibliography was to assemble and catalog the information now available relative to altimetry, including aircraft static pressure system design, accuracy, reliability and maintainability.

Background

The subject of altimetry and its several subgroupings is of great interest and paramount importance to the aviation community. This is in part borne out by the large number of publications relating to this subject since the inception of powered flight. In addition, the National Transportation Safety Board (NTSB) noted that accidents which occur are most numerous during the approach and landing phase of flight. It was further noted by NTSB that altimetry difficulties could have been a contributing factor.

The Flight Standards Service (FSS) of the Federal Aviation Administration (FAA) requested that a research and development effort be undertaken to evaluate factors affecting the accuracy, reliability and maintainability of aircraft static pressure systems and, where necessary, establish design criteria and test techniques to eliminate harmful effects and improve aircraft altimeter systems.

Accordingly, as the initial phase of this effort, the National Aviation Facilities Experimental Center (NAFEC) undertook this literature search and review. This search was limited generally to publications produced from the year 1950 and did not include hardbound texts nor manufacturers' sales brochures.

DISCUSSION

Each of the documents contained in the bibliography, which are listed in alphabetical order by title, was reviewed in detail. The alphabetical listing includes author, date of publication, cognizant organization, and, where applicable, a critical abstract or summary. Based on this review, they were subsequently subgrouped by principal subject category.

The publications are grouped as follows:

1. Air Data Computers
2. Altimeters (Instruments)
3. Altimetry Errors (Barometric Only)
4. Altimetry Techniques
5. Calibration Procedures
6. Human Factors
7. Maintenance and Reliability
8. Specifications
9. Static Pressure Ports
10. Static Pressure Tubing
11. Static Pressure Probes
12. Static System Performance

It is recognized that some publications may relate to more than one of the above groups or may not be conveniently categorized within any of these groups. Therefore, a document may appear by title in more than one of the subgroups or may not be listed in any of the subgroupings. Such duplication or omission of listing should not be construed as a means of identifying the relative value of a given document. A subjective evaluation of each document was made. Those publications which are considered to be of significant merit within a given subgrouping are noted by an asterisk (*). The listing within the subgroupings is by title and document sequence number (Index No.) as it appears in this report. As a further aid to the reader, an authors' index is also provided with the index number reference also included.

The sources for the publications contained herewith were in part:

1. Aeronautical Engineering Index, 1955-1958.
2. International Aerospace Abstracts, Vol. 1-9, 1951-August 15, 1969.
3. NACA Index of NACA Technical Publications, 1915-1961.
4. NASA Technical Publications Announcements, April-December 1962.
5. NASA Scientific and Technical Aerospace Reports, Vol. 1-7, No. 12, 1963-June 1969.
6. Technical Abstract Bulletin, DDC, 1964-July 1969.
7. Technical Abstract Bulletin, ASTIA, 1960-1963.
8. Termatrex Index of Reports in the FAA Library, Washington, D. C.

9. U. S. Government Research and Development Reports, 1965-July 1969.
10. DDC Bibliography ARB 021131, "Barometric Altimetry," August 14, 1969, 66 sheets.

SUMMARY OF RESULTS

Air Data Computers

There are several papers contained in the bibliography relating to subsonic air data computers. However, the literature survey did not reflect any information on air data systems which would cope with the problems of the transonic range through 1.0 Mn.

Altimeters (Instruments)

Intentionally omitted from the literature survey were engineering sales brochures of specific manufacturers. The literature review for barometric type altimeters includes pertinent information on the following:

1. Mechanical aneroid altimeters with and without position error compensators.

2. Electromechanical altimeters with and without position error compensators.

3. Servo-driven altimeters with position error and scale error compensators.

The literature also reflected detailed information on the following types of altitude display:

1. Three-pointer (3P)
2. Horizontal-drum-pointer (HDP)
3. Vertical-drum-pointer (VDP)
4. Vertical-tape-pointer (VTP)
5. Dual tape (DT)
6. Counter (C)
7. Counter-Pointer (CP)
8. Counter-drum-pointer (CDP)

Much of the evolution of both the altimeter display and hardware development is summarized in D. A. Schum's paper (Index No. 15). However, the literature survey did not reflect any significant publications on direct transduction of sensed static pressure with associated display.

There is limited general technical information on other types of altimeters. Twenty-three of 39 cited publications are on aneroid-type barometric altimeters.

Altimeter Errors (Barometric Only)

The various errors which influence the accuracy of barometric altimeter systems are well documented with the following possible exceptions:

1. Dynamic maneuvering flight.
2. Precipitation and icing.
3. Correspondence error (difference between transponded and pilot-displayed altitude).
4. Overall en route operational system error.

The individual errors of barometric altimeter systems with the exception of Items 1-3, inclusive, have been summarized in R. V. DeLeo's Technical Report (Index No. 96). These errors have been individually investigated by many researchers as noted in over 20 separate reports since 1950.

The only documents of significance relating to dynamic maneuvering flight errors were William Gracey's papers (Index Nos. 174 and 213). These NASA reports covered results obtained during approach, landing, and takeoff phases of flight operations under controlled VFR conditions.

There were several recent papers relating to static pressure system errors due to precipitation (Index Nos. 84, 128, 148 and 154). These documents were principally concerned with problems associated with overcoming water surface tension.

The literature search reflected only one paper (Index No. 92) in which the subject was overall operational barometric altimeter system error. Even this document was not based on general test data, but rather was a statistical summary of operational tests of the several individual errors noted. The Pan American World Airways, Inc. (PAA) publication of August 1968 (Index No. 4) indicated that such errors were theoretically significantly reducible by system design, installation, calibration and maintenance.

Altimetry Techniques

A limited number of publications were available on various altimetry techniques. The most comprehensive of these was W. Gracey's paper (Index No. 244) of March 1961. However, since its preparation, other potential methods for establishing en route height control may be available as a fallout of the space program. Included in these potential methods are synchronous satellites, lasers, etc.

Calibration Procedures

The means of calibrating various types of altimeter systems have been very well documented. The documents contained in this subgroup are self-explanatory.

The trailing cone system has been tentatively accepted by the International Civil Aviation Organization (ICAO) and is seeing ever-increasing usage by both the military and the FAA regional offices in type certifications of airplanes.

Human Factors

The human factors aspects of altitude display and interpretation have been documented in detail by more than 20 technical documents since 1950. The analytical factors are delineated in C. A. Gainer's paper (Index No. 223). Subjective evaluations of the several factors are contained in numerous reports. The most significant of these reports are denoted by asterisks in the Human Factors subgrouping.

The subjective evaluations contained in the reports listed were in a quasi-sterile state; that is, the evaluation was not made under actual flight conditions with the altitude display evaluated as an integral part of an operational flight panel.

Maintenance and Reliability

A recent Air Transport Association (ATA) paper (Index No. 210) of December 1969 describes an extensive, but excellent, maintenance procedure and PAA's previously cited paper (Index No. 4) indicates the resultant reliability obtainable for aircraft static pressure systems.

Specifications

The design requirements for both the large transport aircraft (Index No. 208) and the military aircraft are well documented.

Static Pressure Ports

There was very limited information available on static pressure port parametric requirements. The lack of critical information is borne out by the fact that the only significant technical document in this area were written in 1949 by R. E. Rayle (Index No. 151) and in 1959 by R. Shaw (Index No. 136). These evaluations went up to a Mach number of 0.80 which is below the cruise Mach number of the earliest commercial jet aircraft.

The literature search indicated that, notwithstanding well-established theory and supporting wind tunnel tests, the final location on the aircraft for sensing static pressure, and the type and design of the production static pressure sensor are usually dependent on flight tests.

Static Pressure Tubing

The only specific information uncovered by the literature survey was information relating to pneumatic lag.

Static Pressure Probes

The design factors for pitot-static pressure probes are well documented by several investigators. However, the literature is not as complete in the area of flush static pressure probes.

One area in which there is inadequate information is the sensitivity of aerodynamically compensated pitot-static pressure probes to hole location, hole orientation, and surface imperfections.

Static System Performance

The information contained in J. Shrager's paper (Index No. 92) of October 1969 is a statistical summary of the individual operational errors which were reported by various investigators.

CONCLUSIONS

Based on the detailed review of the publications contained in the bibliography, it is concluded that:

1. Barometric altimetry techniques are extensively documented. This is particularly true for steady-state cruise flight between sea level and 40,000-foot geometric altitude.

2. Radio and radar altimetry techniques are well documented for use in close proximity to the ground where terrain topography is not a controlling factor such as over an airport runway.

3. Empirical methods for determining acceptable locations for sensing static pressure are documented by several investigators. The information is based on model testing in wind tunnels but final location of the sensors requires full-scale flight tests.

4. The design criteria for pitot-static probes for use below 0.90 Mn and above 1.0 M_n are covered in reports by several investigators. Design factors and potential problem areas relating to the aerodynamic Mach compensation techniques are not covered.

5. There is limited information available on the effects of static pressure port (hole) size up to 0.125 inches in diameter and up to 0.80 M_n.

6. Except for pneumatic lag characteristics, there is no design information available on tubing and associated fittings.

7. The various factors which influence altitude display and interpretation are very well documented by many investigators. However, evaluation of various altitude displays under actual flight operations, as an integral part of an operational flight panel, are not covered in the literature.

8. Procedures for instrument and flight calibrations of altimeter systems are covered in the literature and, to a degree, standardized by the industry.

9. Although individual barometric altimeter system errors, with the exception of errors due to maneuvering flight, are described in detail by various individuals, overall operational system performance is not documented.

10. There is a noticeable lack of published information on static pressure errors due to dynamic flight maneuvers such as yaw rate, especially in the approach and landing flight mode.

10. Factors which are pertinent to maintainability and reliability are broadly covered by industry. The procedures put forth by the air carriers are most comprehensive and, if universally employed, could improve the operational accuracy of barometric altimeter systems.

12. Detailed specifications for barometric altimeter systems are available to meet both air carrier and military requirements. The latest ATA specifications cover most aspects of barometric altimeter systems, with the exception of the altimeter and its display.

13. There is very little information available relating to altimetry for the smaller aircraft.

14. The potential application of the most recent technology for height control, especially at the higher altitudes, is not reflected in the literature.

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The sources of error that may enter into the measurement of airspeed by pitot-static methods are reviewed in detail together with methods of flight calibration of airspeed installations. Special attention is given to the problem of accurate measurements of airspeed under conditions of high speed and maneuverability required of military airplanes. The accuracy of airspeed measurements is discussed as limited by errors in each of the quantities that is directly measured in flight.

2. ACCURACY OF IN-FLIGHT COMPUTATION OF ALTITUDE FROM AIR DATA INPUTS, Erickson, Ronald A. China Lake, California, NAVWEPS Report 7784, NOTS TP 2771, December 22, 1961

This study is an error analysis of equations that can be used for in-flight computation of aircraft altitude when only the static pressure and ambient temperature at the aircraft are available.

3. THE ACCURATE DETERMINATION OF AIRCRAFT ALTITUDE, Warner, J. Institute of Navigation, Journal Vol. 2, pp. 159-164, 1949

A method of obtaining aircraft altitude to within 50 feet at altitudes of 10,000 to 20,000 feet is described. The method consists of determining the height of a pressure level at some convenient point by radar or other means, and then calculating from a knowledge of the wind vector the change of height of this pressure level between the check point and the point at which an accurate altitude is required. The limitations of alternative methods of height findings, such as the use of an aneroid altimeter corrected for temperature at the upper level, are discussed.

4. ADVANCES IN ALTIMETRY AND EFFICIENT AIRSPACE UTILIZATION, Prepared by Pan American World Airways, Inc. and Trans World Airlines, Inc., Miami, Florida, August 1968

This brochure describes improvements made in altimeter instruments, aircraft static systems and airline maintenance procedures during the past 15 years and proposes that more efficient use be made of the airspace through proper application of advanced technology.

5. AERIAL GRAVITY MEASUREMENTS, LaCoste, Lucien J. B.; Thompson, Lloyd G. D. Journal of Geophysical Research, Vol. 65, No. 1, pp. 305-322, January 1960

Tests with an airborne LaCoste and Romberg Sea Gravity Meter (surface type) have shown that gravity measurements in a flying aircraft are feasible. At high altitudes the aircraft was a sufficiently stable platform for the gravity meter to operate satisfactorily. Analysis of in-flight acceleration problems has shown that gravity observations can be made at high aircraft velocities with proper flight programming and navigation systems. North, south, and west traverses over an Askania tracking range gave 5 minute average gravity readings which plotted into smooth profiles. An accuracy of better than 10 mgal was obtained which meets requirements for geodetic applications where mean gravity values for $1^\circ \times 1^\circ$ squares are required.

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7. AERODYNAMIC CHARACTERISTICS INCLUDING PRESSURE DISTRIBUTIONS OF A FUSELAGE AND THREE COMBINATIONS OF THE FUSELAGE WITH SWEPT-BACK WINGS AT HIGH SUBSONIC SPEEDS, Sutton, Fred B.; Martin, Andrew Ames Aeronautical Laboratory, Moffett Field, California, NACA RM A50J26a, February 6, 1951

As part of an NACA transonic research program, a series of wing-fuselage combinations varying chiefly in wing planform is being investigated. In the part of the investigation reported herein, three representative model wings of the series were tested at Mach numbers up to 0.94 in the Ames 16-foot high-speed wind tunnel. Force and pitching moment data and tabulated pressure measurements are presented for the wing-fuselage combinations and for the fuselage alone.

8. AN AERODYNAMIC MEANS OF STATIC PRESSURE COMPENSATION FOR TRANSONIC AND SUPERSONIC AIRCRAFT, Korkegi, Robert H. Aeronautical Engineering Review, Vol. 16, No. 4, pp. 64-68, April 1957

This paper discusses and gives experimental results for a technique of compensating aerodynamically for the error in static pressure measurement from transonic and supersonic aircraft. The so-called "error" is the deviation of the measured static pressure at some location on the aircraft from the true free-stream pressure, due to the field of flow about the aircraft. The technique consists of using as a pressure sensor, an aerodynamic body whose pressure variation with Mach number at some position on its surface is essentially opposite in sense to the static pressure versus indicated Mach number at some location on an aircraft.

9. AIRCRAFT FLIGHT INSTRUMENT, ALTIMETER, BAROMETER, ANEROID INSTRUMENT, Ivanov, V. I. FTD-HT-23-1010-68 Translation of: Vestnik Protivovozdushnoy Oborony No. 9, pp. 74-77, (1967)

The barometric altimeter is essentially a manometer for measuring the static pressure outside an airplane and has three principal errors: (1) the methodical error caused by the deviation of the actual from the "standard" atmosphere, (2) instrumental error, and (3) error associated with airflow past altimeter air pressure sensor.

10. AIR DATA COMPUTER MECHANIZATION, Hazen, E. J. Eclipse-Pioneer Division, Bendix Aviation Corporation, Teterboro, New Jersey, January 8, 1957

The devices described illustrate one way of mechanizing an air data computer and show how the method used is dependent on the task at hand.

11. THE AIR FORCE INTEGRATED FLIGHT INSTRUMENT PANEL, Svimonoff, C. Wright Air Development Center, Dayton, Ohio, WADC TR 58-431, October 1958, AD 155 788

This report summarizes, correlates and analyzes the knowledge obtained to date from the total flight experience on the integrated flight instrument panel as well as on related new instruments and instrument systems. Production implementation of recommended improvements is defined. Areas of primary consideration associated with present and future production and product improvement programs are designated. Special attention is given to the overall problem of incorporation of such panels into particular weapon systems and recommended approaches are indicated.

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14. AIRSPEED-ALTITUDE CALIBRATION METHODS, Cooper, Leroy G. Air Force Flight Test Center, Edwards Air Force Base, California, Report No. FTFE-TM-60-3, March 1960, AD 235 697

This report presents the facilities available at the Air Force Flight Test Center for airspeed-altimeter calibrations and describes the methods to be used by engineers and pilots to obtain the best results. The data reduction involved in these calibrations is not discussed as all data reduction methods are outlined in the Flight Test Handbook, AFFTC-TN-59-22.

15. ALTIMETER DISPLAY AND HARDWARE DEVELOPMENT 1903-1960, Schum, David A.; Robertson, John R.; Matheny W. Guy Bell Helicopter Company, Fort Worth, Texas, ASD-TDR-63-288, May 1963

This report is a review of the literature on altimeter display and hardware development. It places major emphasis upon human engineering aspects of altimeter display development and upon methods and modes of altimeter mechanization and sensing. The evolution of altimeter displays is explored in an historical survey of display development. Particular emphasis is placed upon the present functional altimeters in use and those which are being experimentally tested.

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A series of investigations was recently completed to determine the relative effectiveness of various altimeter displays. These investigations were in support of a program concerned with the replacement of current altimeters in most military aircraft with a servo-pneumatic-type instrument.

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The United Kingdom Altimeter Committee was formed to advise on the best means of displaying altitude information. After the field of possible displays had been narrowed, an evaluation program was devised. The results of this program shown that (1) both forms of counter-pointer display are superior to conventional multi-pointer displays, and (2) when leveling from a descent there is a tendency for pilots to level out 950 feet too high.

18. ALTIMETER DISPLAY STUDY - PART I. SUMMARY AND REVIEW OF DATA REQUIREMENTS, Matheny, W. G. Bell Helicopter Company, Fort Worth, Texas, ASD-TDR-63-621 Part I, May 1964

This report presents a brief overview of a number of reports dealing with the subject of flight control information requirements. The author singles out certain points which seem worthy of note. One of these is the distinction between system data requirements (as the totality of data to be processed by the human operator).

19. ALTIMETER DISPLAY STUDY - PART II. HANDBOOK FOR STATIC TESTING OF ALTIMETERS, Elam, C. B. ; Matheny, W. G.; Schum, D. A. Bell Helicopter Company, Fort Worth, Texas, ASD-TDR-63-622, Part II, May 1964

A review of the literature revealed that the methodology for evaluating altimeter display design would have to be studied thoroughly. Because so little was known about the validity and reliability of the various evaluative techniques (static, flight simulator, inflight test), the decision was made to study all types of display evaluation, beginning with the static level. Accordingly, in September 1960, a series of static tests was begun in the attempt to uncover significant variables and suitable procedures in static testing. The present report represents the conclusion drawn and the generalization made on the basis of this series of static tests and the previous review of the literature.

20. ALTIMETER DISPLAY STUDY - PART III. SUMMARY OF EXPERIMENTAL TESTING, Elam, C. B.; Matheny, W. G.; Schum, D. A. Bell Helicopter Company, Fort Worth, Texas, ASD-TDR-63-623, Part III, May 1964, AD 601 903

Results of five altimeter display studies (four by static presentation and one by cinematic presentation) are described. The five altimeter display designs evaluated were: The Three-Pointer MA-1, The Horizontal Drum-Pointer, The Single Tape-Pointer, The Vertical Drum-Pointer MD-1, and The Dual Tape Instrument. Methods of evaluation were varied extensively. Measurements of errors and response time were taken for all studies.

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This specification covers the requirements for one type of precision pressure, -1000 to +80,000 feet, integrally lighted altimeter, designated AAU-7/A.

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This specification covers the requirements for one type of precision pressure altimeter, designated AAU-8/A.

23. ALTIMETER, PRESSURE, COMPENSATED (Turbine Powered Subsonic Aircraft), Prepared by Committee A-4 Aircraft Instruments, Society of Automotive Engineers, 485 Lexington Avenue, New York, N. Y., AS 415, August 10, 1964

This Aerospace Standard covers two types of compensated altimeters which indicate, by visual means, the pressure altitude compensated for the static pressure system errors of the aircraft. Type I - Range: 1,000 to 30,000 feet, barometric pressure--scale range: at least 28.1 - 30.99 in. Hg (952-1049 millibars). May include markers working in conjunction with the Barometric Pressure Scale to indicate pressure altitude. Type II - Range: 1,000 to 60,000 feet, barometric pressure--scale range: at least 28.1 - 30.99 in. Hg (952-1049). May include markers working in conjunction with the Barometric Pressure Scale to indicate pressure altitude.

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Review of problems and general recommendations in all areas.

28. ALTIMETRY AND THE VERTICAL SEPARATION OF AIRCRAFT, International Air Transport Association, Montreal, Canada, January 1960

The subject of vertical separation of aircraft has received a great deal of concentrated study by IATA, as well as by the International Civil Aviation Organization and a number of other organizations. IATA now has summarized the technical findings on this subject and to present the conclusions reached by the airlines as a result of these findings.

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The first step in automating the ATC system is now proposed for January 1, 1973. After that date, essentially everyone doing any sort of cross-country flying will need altitude reporting and a 4096-code transponder. A number of reporting devices which are not available, most costing more than the transponder they will be used with, are reviewed briefly.

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Collision probabilities of two airplanes assigned to adjacent flight levels or misassigned to the same flight level have been computed for a flight-level separation minimum of 500 feet, airplane vertical dimensions of 20 and 40 feet, altitude-misassignment probabilities of 1/100,000 and 1/1,000,000, and altimeter-system errors (3σ values) ranging from 0 to 2,000 feet. The results of the analysis showed that minimum collision probability occurred at an altimeter-system error of about 200 feet and that, for system errors from 500 to 2,000 feet, the collision probability was several orders of magnitude greater than that for altimeter-system errors of 250 feet or less.

38. ANALYTIC DESIGN OF IMPROVED STATIC PRESSURE SENSING PROBES FOR ALL MACH NUMBERS, Hess, John L.; Smith, A. M. O.; Rivell, Thomas L. Douglas Aircraft Company, Inc., Long Beach, California, LB-31589, February 14, 1964, AD 435 112

This report describes a systematic analytic method for designing a static-pressure sensing system for an aircraft or a missile.

The system relies on a boom-type static-pressure probe that senses free-stream static pressure independently of Mach number, Reynolds number, and flow inclination. Independence of Mach number is obtained by properly shaping the external contour of the probe. Reynolds number effects are eliminated by the use of a forward orifice location. The senses pressure is rendered insensitive to flow inclination by distributing pressure orifices around the circumference of the probe. This report is a complete summary of the design method and is intended for use as a design manual for this type of static-pressure sensing system.

39. AUTOMATIC CORRECTION OF ERRORS IN AIRPLANE STATIC PRESSURE SOURCES, Werner, Frank D.; Geronime, Robert L. Department of Aeronautical Engineering, Rosemount Aeronautical Laboratories, Minneapolis, Minnesota, WADC TR 56-193, May 1956

The problem of automatic correction of errors in airplane static pressure sources is reviewed in detail, and two models of the device called the static pressure compensator, which accomplished this correction, are described. Included is a brief discussion of the aerodynamic considerations involved in static pressure errors and of the choice of variables in terms of which the static pressure errors may be presented. It is shown that the ratio of the error in static pressure to the static pressure, may be given in terms of the Mach number and the angle-of-attack.

40. BAROMETER, MERCURIAL, ALTITUDE TEST, TYPE A-1, MIL-B-4308B(USAF), July 11, 1955, Superseding MIL-B-43084, October 13, 1953

This specification covers one type of mercurial altitude barometer with closed non-adjustable cistern, and with an integral temperature and gravity compensation system, designated Type A-1.

41. BAROMETRIC ALTITUDE - THE PROBLEM, SOLUTION AND ALTIMETER DESIGN, Cooper, R. A. AiResearch Manufacturing Company, A Division of the Garrett Corporation, Los Angeles, California, ASME Paper No. 60-AV-43, April 29, 1960

This paper reviews the problem of altitude measurement in the range of sea level to 80,000 feet and briefly discusses several methods and design approaches leading to improved accuracy levels. A new altimeter design is disclosed which is not dependent upon aneroid-element deflection and details of the mechanization are discussed. The influence of static-system errors are considered, with equipment design described for error compensation.

42. BAROMETRIC PRESSURE STANDARD AND CALIBRATION SURVEY, Albin, Leon Eclipse-Pioneer Division of the Bendix Corporation, Teterboro, New Jersey, FAA Project No. 115-22D, August 1963

This project covers a survey conducted of representative facilities employing barometric pressure devices which are used to calibrate or set aircraft altimeters (airport control towers, weather stations, instrument repair shops, certified instrument repair shops, and calibration laboratories).

43. BIBLIOGRAPHY ON ALTIMETER DISPLAYS, Anderson, O. E. E. San Francisco International Airport, San Francisco, California, United Airlines Report F-1267, March 7, 1968

44. BULOVA ALTIMETER EVALUATION, Beddingfield, Samuel T. Wright-Patterson Air Force Base, Dayton, Ohio, WADC Flight Test Report WCT 59-29, February 9, 1959

45. C-135 AIMS L-SHAPED PITOT STATIC TUBES, Cavanagh, Richard A. Directorate of Flight Test Engineering, Deputy for Flight Test Aeronautical Systems Division, U. S. Air Force, Dayton, Ohio, ASTDN FTR 68-40, November 1968

The AIMS C/KC-135 altimetry system consists of two heated, aerodynamically compensated, L-shaped pitot-static tubes. The aerodynamic compensation required on these tubes was determined during flight test in 1966 (ASTDN FTR 66-21). The purpose of the present test was to determine the repeatability of its position error with that found previously.

46. CALIBRATING STATIC PRESSURE SYSTEMS AT LOW ALTITUDES, Shrager, Jack J. FAA, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, Report No. RD-64-37, March 1964

A procedure for use in the determination of "position error" at low altitudes of aircraft airspeed systems and for the calibration of such systems is presented. The procedure describes a flight test technique, reduction of the test results by use of nomograms and a simplified statistical method for determining position error correction for different indicated airspeeds.

47. THE CALIBRATION AT TRANSONIC SPEEDS OF A MARK 9A PITOT STATIC HEAD WITH AND WITHOUT FLOW THROUGH THE STATIC SLOTS, Mabey, D. C. Royal Aircraft Establishment, Great Britain, Technical Note No. AERO 2500, March 1957, AD 139 149

48. CALIBRATION OF A COMBINED PITOT-STATIC TUBE AND VANE-TYPE FLOW ANGULARITY INDICATOR AT TRANSONIC SPEEDS AND AT LARGE ANGLES OF ATTACK OR YAW, Pearson, Albin O.; Brown, Harold A. National Advisory Committee for Aeronautics, Langley Field, Virginia, NACA RM L52F24, September 17, 1952

A wind-tunnel investigation has been made to provide information concerning the characteristics of a combined pitot-static tube and vane-type flow-angularity indicator at large angles of attack or yaw and at speeds near the speed of sound. The results indicate that the angles of attack or yaw at which the total-pressure error is 0.01, vary linearly with Mach number and increase from approximately 21.0° at a Mach number of 0.60 to about 24.3° at a Mach number of 1.10. The static-pressure error is affected more by changes in angle of yaw than by corresponding changes in angle of attack and is positive (measured pressure greater than stream pressure) for angles of attack and negative for angles of yaw.

49. CALIBRATION TESTS OF TWO AERODYNAMICALLY COMPENSATED PITOT-STATIC PROBES AT SUPERSONIC MACH NUMBERS, Lucas, Ernest J. Arnold Engineering Company, Marengo, Illinois, AEDC-TR-66-79, April 1966, AD 480 158

Two aerodynamically compensated pitot-static probes designed for use on the SAAB J-37 aircraft were calibrated in the 12-inch supersonic tunnel. Results are presented for an angle-of-attack range from -4 to 12 degrees for pressure altitudes of 31,000 feet at M sub infinity = 1.5 and 50,000 feet at M sub infinity = 2.0 and 2.5.

50. CALIBRATIONS AND COMPARISONS OF PRESSURE-TYPE AIRSPEED-ALTITUDE SYSTEMS OF THE X-15 AIRPLANE FROM SUBSONIC TO HIGH SUPERSONIC SPEEDS, Larson, Terry J.; Webb, Lannie D. Flight Research Center, Edwards, California, NASA TN D-1724, February 1963

X-15 flight calibration data to define pressure-position errors are presented for two types of pressure-sensing configurations: a standard NACA pitot-static tube attached to a nose boom and two manifolded flush static-pressure ports on the ogive nose. The position-error calibrations are presented up to M = 3.31 for the standard nose-boom installation and to M = 4 for the flush static system. Presented also are stagnation-pressure errors sensed by a pitot probe ahead of the canopy. Methods used to determine the position errors are described. The nose-boom configuration is shown to be superior from the standpoint of position error and ease of calibration for the available data range.

51. CALIBRATIONS OF AIRCRAFT STATIC-PRESSURE SYSTEMS BY GROUND-CAMERA AND GROUND-RADAR METHODS, Gracey, William; Stickle, Joseph W. National Aeronautical and Space Administration, Langley Field, Virginia, NASA TN D-2012, August 1963

This report presents the calibrations of two static-pressure systems (a fuselage vent system and a pitot-static tube mounted above and ahead of the pilot's compartment) as determined near sea level by a ground-camera technique and at an altitude of 25,000 feet by a ground-radar method. The maximum probable error (3 standard deviations) for both the low- and high-altitude calibrations of the fuselage vent system was about 1 pound per square foot, or 12 feet, at sea level and 30 feet at 25,000 feet above sea level.

52. CHARACTERISTICS OF RADAR ALTIMETERS, Goldman, Albert Wright-Patterson Air Force Base, Ohio, WADC TR 53-120, April 1953, AD 14 764

53. COMPARATIVE EVALUATION OF A KOLLSMAN THREE-POINTER, A SMITH'S COUNTER-POINTER, AND A BENDIX COUNTER-ANALOG ALTIMETER PRESENTATION, Innes, L. G.; Beldam, E. H. Royal Canadian Air Force Institute of Aviation Medicine, Canada, Report No. 62-RD-7, December 1962, AD 298 233

A comparative evaluation of the Kollsman MA-1 three-pointer, Smith's five digit counter-pointer, and Bendix counter-analog altimeters was carried out. The three-pointer and counter-pointer instruments each produced errors of 1,000 feet while the counter-analog produced only four.

54. COMPARATIVE EVALUATION OF TEN ALTIMETER PRESENTATIONS, Brown, Stuart L. Jr. Wright-Patterson Air Force Base, Ohio, WADC Technical Note WCT 54-37, April 1954

55. COMPARISON OF A LINEAR AND A NON-LINEAR SCALE AS A GROSS ANALOGUE INDICATION OF ALTITUDE, Innes, L. G. Royal Canadian Air Force Institute of Aviation Medicine, Toronto, Canada, Report No. 62-RD-6, November 1962, AD 294 708

This study was concerned with the type of scale used as a gross analogue indication of altitude to be used in conjunction with a five digit counter. A comparison was made between a linear scale and a non-linear scale in terms of accuracy of giving distance and direction to command altitude.

56. A COMPARISON OF EXPERIMENTAL ALTIMETER PRESENTATIONS, Beldam, F. E. M. Royal Canadian Air Force Institute of Aviation Medicine, Toronto, Ontario, Canada, Report No. 57/1, January 5, 1957

57. A COMPARISON OF FOUR ALTIMETER PRESENTATIONS, Beldam, F. E. M. Royal Canadian Air Force Institute of Aviation Medicine, Toronto, Ontario, Canada, Report No. 56/1, February 1, 1956

58. A COMPARISON OF FOUR ALTIMETER PRESENTATIONS OF THE THREE-POINTER INSTRUMENT TYPE, Triggs, T. J. Aeronautical Research Laboratories, Australian Defense Scientific Service, Melbourne, Australia, Human Engineering Report 10, December 1961

A comparative evaluation of the standard three-pointer altimeter and three modified presentations under both static display and simulated dynamic conditions. Thirty-two pilots were used as subjects. All three modified presentations were superior to the standard three-pointer.

59. A COMPARISON OF FOUR TYPES OF ALTIMETERS - PHASE I: TRACKING A COMMAND PROFILE - PHASE II: READING PRESENT ALTITUDES, Reilly, R. E.; Ziegler, P. N.; Hill, J. H.; Chernikoff, R. Naval Research Laboratory, Washington, D. C., NRL MR1522, April 1964, AD 601 000

A two-phase experiment was carried out comparing four altimeters: (CP), (CDP), (DP) and (3P). One phase measured accuracy of altitude control. During this phase, the operator simultaneously performed a secondary two-dimensional tracking task. The second phase measured speed and accuracy of reading random altitude presentations. Using five naval enlisted men as subjects, tracking performance was found to be best for CP and CDP, followed by DP, with 3P the poorest of the four altimeters. The results for reading accuracy in both phases showed CP to be best, followed by CDP, DP and 3P in that order.

60. A COMPARISON OF 14 ALTIMETER PRESENTATIONS, Travis, M. N. Flying Personnel Research Committee, Air Ministry, England, FPRC Memo 104, March 1959

61. A COMPARISON OF SIX VERTICAL SPEED INDICATOR PRESENTATIONS, Moir, G. D.; Innes, L. G. Royal Canadian Air Force Institute of Aviation Medicine, Toronto, Ontario, Canada, Report No. 63-RD-5, December 1963

The currently employed vertical speed dial is used as a standard in comparison with five other designs produced by the Human Engineering staff. No consideration was given to compatability with existing or possible drive mechanisms.

62. A COMPARISON OF THE EXPERIMENTAL SUBSONIC PRESSURE DISTRIBUTIONS ABOUT SEVERAL BODIES OF REVOLUTION WITH PRESSURE DISTRIBUTIONS COMPUTED BY MEANS OF LINEARIZED THEORY, Matthews, Clarence W. National Advisory Committe for Aeronautics, Langley Field, Virginia, NACA Report 1155, 1953

An analysis is made of the effects of compressibility on the pressure coefficients about several bodies of revolution by comparing experimentally determined pressure coefficients with corresponding pressure coefficients calculated by the use of the linearized equations of compressible flow. Extrapolation of the linearized subsonic theory in the subsonic-supersonic region fails to predict a rearward movement of the negative pressure-coefficient peak after the critical stream Mach number has been attained. Equations developed from a consideration of the subsonic compressible flow about a prolate spheroid are shown to predict approximately the change with Mach number of the subsonic pressure coefficients for regular bodies of revolution of fineness ratio 6 or greater.

63. COMPUTER, CENTRAL AIR DATA, TYPE MG-1A, MIL-C-25653C (USAF), February 13, 1961, Superseding MIL-C-25653B(USAF), October 21, 1957

This specification covers the requirements for one type of central air data computer, designated Type MG-1A.

64. CONSTANT HEADING AIR NAVIGATION, Fretigny, G.
Navigation (Paris) Vol. 17, pp. 159-168, April 1969. In French.

Consideration of loxodromic routes, with reference to speed and wind direction. A loxodromic route compels the pilot to frequently change his heading to compensate for drift. It is here shown, modifying Bellamy's formula, and by use of the relations between the wind and the meteorological pressure field, that a constant altitude-pressure flight can be performed.

65. CONTRIBUTIONS TO AIRCRAFT INSTRUMENTATION,
Rossger, Edgar, ed. Institute for Pilotage and Air Traffic, Technical U. (Berlin), Report No. 62/1, March 1962 (English edition)

The system used at present of long distance flights on flight levels and of takeoff as well as landing by QNH altitudes is explained. Moreover, the usual method of indicating the amount of vertical displacement of the calibration curve of a barometric altimeter in the altitude-pressure-chart by pressure values is described. Then it is shown that there exists also another simple way of indicating the amount of the vertical shift of the calibration curve by values of altitude. Finally, some methods as well as indicators and slide rules for ascertaining of special subscale values which are analogous to the QNH well known in aviation are stated.

66. CONTRIBUTIONS TO PHYSICAL AND ENGINEERING PROBLEMS OF BAROMETRIC ALTITUDE MEASUREMENTS IN AVIATION,
Rossger, Edgar; Ranike, Gerhard Nordrhein-Westfalen, Forschungsberichte, No. 1531, pp. 3-185 (1966) In German

Discussion of possible ways to improve barometric altitude measurements on board an aircraft in view of the continuously growing necessity of assigning flight levels in ATC. It is seen that such an improvement can be achieved either from the meteorological or engineering standpoint, without its being possible, however, to draw a line between these two approaches. The analysis is limited essentially to the meteorological aspects of the problem. Particular attention is given to methods of reducing the residual error ("Meteorological Error") involved in the method now commonly used in which the calibration curve of a barometric altimeter is matched with the prevailing meteorological conditions. Existing methods and altimeter types are reviewed.

67. DEMONSTRATION OF THE AEROSONIC CORPORATION PRESSURE ALTIMETER, ALTITUDE REPORTING RANGE -1,000 TO +35,000 FEET, Schroder, H. M. U. S. Naval Air Development Center, Johnsville/Warminster, Pennsylvania, NADC-AI-6521, March 18, 1965

68. DESERT TEST OF THE AN/APN-22 ABSOLUTE ALTIMETER, Army Aviation Board, Fort Rucker, Alabama, Project No. AVN1257/59(D), November 1959, AD 230 928

69. DESIGN AND INSTALLATION OF PITOT-STATIC SYSTEMS FOR TRANSPORT AIRCRAFT, Committee A-4, Aircraft Instruments, Society of Automotive Engineering, Inc., New York, N. Y., ARP 920, October 15, 1968

The purpose of this Aerospace Recommended Practice is to present recommendations for the design and installation of pitot and static systems for transport-type aircraft. This document also makes recommendations for several system configurations and sets forth the acceptable quality control requirements and the means by which they are to be controlled.

70. DESIGN AND TESTS OF AERODYNAMIC STATIC PRESSURE COMPENSATORS FOR FOUR SERVICE AIRCRAFT, Smetana, Frederick O. University of Southern California, Los Angeles, California, WADC TR 59-383, May 1959, AD 233 999

71. DETERMINATION AND STABILIZATION OF THE ALTITUDE OF AN AIRCRAFT IN SPACE USING SEMI-CONDUCTOR DETECTORS, Gilly, Louis Commissariat a l'Energie Atomique, Centre d'Etudes Nuclearres, Report CEA-R-3281, November 1967, N68-20527, In French: English summary

The device studied in this paper can be used as an altimeter or as altitude stabilizer. It includes essentially a 'surface barrier' semiconductor detector which counts alpha particles of a radioactive source. This paper describes experiences made in laboratory tests which comprises electronic tests and a physic study. Systematic analysis of experimental errors is made comparatively with aneroid altimeters.

72. DETERMINATION OF A HYPSOMETER PERFORMANCE FUNCTION FROM AIRBORNE DATA, Latron, Patrice M. Massachusetts Institute of Technology, Measurements Systems Laboratory, Cambridge, Massachusetts, TE-33, February 1970

Integrated data from a vertical pendulous integrating gyro accelerometer were used to assess the altitude measuring performance of a hypsometer in an airborne gravimetric installation. Both gravity and Eotvos correction were assumed constant to simplify the integration process. The aircraft-autopilot short period (about 0.044 Hz) longitudinal mode dominates the altitude profile. The hypsometer recordings relative to the integrated accelerometer data showed lags between 2 and 3 seconds, and amplitude ratios between 0.4 and 0.9. A backlash nonlinearity of 3 feet amplitude would explain the varying amplitude ratio but only part of the lag (1 to 2 seconds). The auto-correlation and cross-correlation functions were used in an attempt to examine the linear behavior of the hypsometer; however, the spread of the data suggested that the nonlinearity was a very significant element in the instrument dynamics.

73. DEVELOPMENT, DESIGN, AND CONSTRUCTION OF HIGH ALTITUDE ALTIMETER, Roehrig, Jonathan R.; Vacca, Ralph H. National Research Corporation, Cambridge, Massachusetts, Contract AF 33(038)25720, June 1953, AD 38 615

74. DEVELOPMENT OF AERODYNAMICALLY COMPENSATED PITOT-STATIC TUBES FOR USE ON THE XB-70 AIRCRAFT, DeLeo, Richard; Hagen, Floyd D. Rosemount Engineering Company, Minneapolis, Minnesota, RTD-DR63-4085, November 1963, AD 427 231

Two types of aerodynamically compensated pitot-static tubes were investigated to find a design suitable for flight testing on the XB-70 aircraft. Both theoretical analysis of wind tunnel experiments were used to determine subsonic and supersonic performance of a number of aircraft.

75. DEVELOPMENT OF A FLIGHT LEVEL INDICATOR, Knight, Robert W.; Pigman, George L. U. S. Department of Commerce, Washington, D. C., Technical Development Report No. 46, January 1945

This report covers the development of an instrument designed to provide vertical separation between aircraft in flight by relating flight altitude levels to compass directions. The instrument consists essentially of an aneroid barometer mechanism providing an uniform measurement of pressure altitude from a fixed standard reference pressure. The use of this instrument is suggested as a possible solution to the problem of assigning safe cruising altitudes for aircraft flying along, across, or off the civil airways.

76. DEVELOPMENT OF AN OPTIMUM ALTIMETER DIAL, Innes, L. G. Royal Canadian Air Force Institute of Aviation Medicine, Toronto, Canada, Final Summary Report 64-RD-1, January 1964

This report summarizes the work done at the RCAF Institute of Aviation Medicine between 1955 and 1963 on the design of an improved display of altitude information for an interim period and as a retrofit for existing aircraft. Work done in this area by other agencies is referred to only if it is applicable to the program as it was conducted at the IAM.

77. THE DEVELOPMENT OF A SUBLIMING CARBON DIOXIDE ALTIMETER, Iberall, A. S.; Garfinkel, S. B. National Bureau of Standards, Washington, D. C., NBS Report No. 2387, March 30, 1953, AD 9054

78. DEVELOPMENT OF IMPROVED STATIC PRESSURE SENSING PROBES FOR ALL MACH NUMBERS, PHASE I, Hess, John L.; Smith, A. M. O.; Rivell, Thomas L. Douglas Aircraft Company, Inc., El Segundo, California, Report No. ES40336, April 28, 1961, AD 259 008L

79. DEVELOPMENT OF IMPROVED STATIC PRESSURE SENSING PROBES FOR ALL MACH NUMBERS, PHASE III, FINAL REPORT, 1 JAN - 31 DEC 1963, Douglas Aircraft Company, Inc., Long Beach, California, February 6, 1964, N64-18359

The purpose of the entire effort is to develop systematic, analytic methods for the design of static pressure probes, which will correctly sense free-stream static pressure independently of Mach number, Reynolds number, and flow inclination. This report describes the design of two service-type static pressure probes designed by this method and analyzes the results of wind tunnel tests of these probes.

80. DEVIATIONS FROM STANDARD ALTITUDE SEPARATIONS DUE TO ATMOSPHERIC TEMPERATURE VARIATIONS,
Hilsenrod, Arthur FAA Systems Research and Development Service, Washington, D. C., Report No. RD-65-12, Project No. 115-2312R, July 1966

In order to provide a firmer basis for evaluating standards for vertical separation, e. g., permit 1,000 foot separations above 29,000 feet, a determination is made of the deviations from the assumed 1,000 foot standard vertical separations of aircraft when actual atmospheric temperature distributions are considered. The assumed 1,000 foot standard vertical separation is decreased to less than 900 feet with some frequency during certain times of the year at some altitudes because of the occurrence of temperatures 10% below the standard temperature.

81. A DISCUSSION OF PITOT-STATIC TUBES AND OF THEIR CALIBRATION FACTORS WITH A DESCRIPTION OF VARIOUS VERSIONS OF A NEW DESIGN, Salter, C.; Warsap, J. H.; Goodman, D. G. Aeronautical Research Council Reports and Memorandum, London, England, ARC TR R&M No. 3365, May 1962

With the help of a specially selected design of static-pressure tube, some peculiarities of normal types of pitot-static tube have been investigated. New instruments (both pitot-static and static-pressure) have been produced having noses of modified-ellipsoidal shape. Particular attention is given to a discussion of the implications of the term "calibration factor," of the limitations of various types of instrument and of the requirements for reliable experimentation and to the inclusion of associated information and comments.

82. THE EFFECT OF COMPRESSIBILITY OF STATIC HEADS,
Lock, C. N. H.; Knowler, A. E.; Pearcey, H. H. Aeronautical Research Council, London, England, R&M 2386, January 1943

Systematic tests up to High Mach numbers were made on model static heads (0.292 inch diameter) having: (1) three nose shapes, viz: standard hemispherical; pointed (ogival) with and without a blind pitot hole; (2) variations of distance of static holes behind the nose; (3) a bulge in the tube similar to Mark VIII A & B at an adjustable distance behind the static holes; and (4) a dummy support similar to Mark VIII C & D also at an adjustable distance behind the static holes.

83. THE EFFECT OF FLOW DISTURBANCE ON AIRSPEED STATIC VENT READINGS, Dunlop and Lapin, Douglas Corporation, Long Beach, California, Douglas (internal memo) A250-Aero-243, July 1954

84. THE EFFECT OF RAIN INGESTION BY AIRCRAFT STATIC PORTS ON THE INDICATED ALTITUDE DURING DESCENT, Brumby, R. E. Douglas Aircraft Company, Long Beach, California, Report No. DAC-33749, May 18, 1967

A cause of sticky altimeter operation during final descent in landing configuration in rain has been identified as the entrainment of rainwater into static-port orifices. The entrained water results in pause and subsequent jump of the altimeter indicator hand, ranging from 40 to 100 feet in magnitude. It has been established that orifice diameter, orifice length and system response contribute to both the probability of occurrence and the magnitude of the disturbance.

85. THE EFFECT OF TURBULENCE ON STATIC PRESSURE MEASUREMENTS, Toomre, Alar Aeronautical Research Council, London, England, ARC Report No. 22010, June 20, 1960 AD 240 988

It is shown theoretically that the difference between the pressure measured with a conventional static pressure tube and the actual static pressure in a situation where the flow is turbulent approaches either of two specified values which are of opposite sign, when the ratio of the size of typical eddies and the probe radius becomes either very large or very small. The situation between these extremes is also discussed.

86. THE EFFECT OF VARIATIONS IN INDICATOR DESIGN UPON SPEED AND ACCURACY OF ALTITUDE READINGS, Grether, Walter F. Wright-Patterson Air Force Base, Ohio, Report #TSEAA 694-14, September 1947

87. EFFECTS OF SOME DIMENSIONAL VARIABLES ON THE CALIBRATION CHARACTERISTICS OF STATIC PRESSURE SOURCES, Teigen, Mary J. University of Minnesota, Rosemount Aeronautical Laboratories, Minneapolis, Minnesota, WADC TR 59-596, June 1959

An experimental investigation of the effects of some dimensional variations on the calibration characteristics of static pressure sources is described. The static pressure errors of two configurations of orifice burrs were measured with various burr heights and orifice diameters at four Mach number to 2. 54. The static pressure errors due to hole-size variations for pitot-static tubes at angles of attack also were measured. Burrs and hole-size variations significantly affect static pressure calibration.

88. ENGINEERING ANALYSIS OF TECHNICAL PROPOSALS FOR SEVEN ELECTRONIC ALTIMETER SYSTEMS, Bowers, George J. Aeronautical Electronic and Electrical Laboratory, NAVAL Air Development Center, Johnsville, Pennsylvania, Report No. NADC-EL-5998, Projects TED No. ADC AV-32019. 2, 3, 4, 5, 6, and 7, October 29, 1959, AD 230 940L

89. ERROR IN AIRSPEED MEASUREMENT DUE TO THE STATIC-PRESSURE FIELD AHEAD OF AN AIRPLANE AT TRANSONIC SPEEDS, O'Bryan, Thomas C.; Danforth, Edward C. B.; Johnston, J. Ford Langley Aeronautical Laboratory, Langley Field, Virginia, NACA Report 1239, 1955

The magnitude and variation of the static-pressure error for various distances ahead of sharp-nose bodies and open-nose air inlets and for a distance of 1 chord ahead of the wing tip of a swept wing are defined by a combination of experiment and theory. The mechanism of the error is discussed in some detail to show the contributing factors that make up the error. The information presented provides a useful means for choosing a proper location for measurement of static pressure for most purposes.

90. ERROR IN AIRSPEED MEASUREMENT DUE TO THE STATIC-PRESSURE FIELD AHEAD OF SHARP-NOSE BODIES OF REVOLUTION AT TRANSONIC SPEEDS, Danforth, Edward C. B.; Johnston, J. Ford Langley Aeronautical Laboratory, Langley Air Force Base, Virginia, NACA RM L9C25, August 19, 1949

As part of a study of means of airspeed measurement at transonic speed, studies have been made at Mach numbers up to 1. 1 by the NACA wing-flow method of the static-pressure (or position) error ahead of two sharp-nose bodies of revolution at zero angle of attack. A method is shown by which the linearized subsonic theory and the transonic similarity rule can be applied to the data contained herein to predict the position error at any reasonable distance ahead of a sharp-nose body of revolution.

91. ERROR IN AIRSPEED MEASUREMENT DUE TO THE STATIC PRESSURE FIELD AHEAD OF THE WING TIP OF A SWEPT WING AIRPLANE MODEL AT TRANSONIC SPEEDS,
Danforth, Edward C. B.; O'Bryan, Thomas C. National Advisory Committee for Aeronautics, Langley Aeronautical Laboratory, Langley Field, Virginia, NACA RM L50L28, March 1, 1951

As part of a study of means of airspeed measurement at transonic speeds the use of static orifices located ahead of the wing tip has been investigated for possible application to service or research airspeed installations. The local static pressure and local Mach number have been measured at a distance of 1 tip chord ahead of the wing tip of a model of a swept wing fighter airplane at true Mach numbers between 0.7 and 1.08 of the NACA wing-flow methods. The linear theory was found to predict qualitatively the effect of the fuselage on the static pressure ahead of the wing tip but gave a reasonable prediction of the effect of the wing on the static pressure only at Mach numbers below 0.95.

92. ERRORS IN BAROMETRIC ALTIMETERS, Shrager, Jack J.
Proceedings of the U. S. Army Electronics Command, Army Aviation Association of America, Institute of Navigation, Technical Symposium on Navigation and Positioning, Fort Monmouth, New Jersey, p. 226-239, September 23 - 25, 1969

The barometric altimeter errors are discussed in general terms. The factors which contribute to the probable error at sea level, 6,000 feet, 10,000 feet, and 30,000 feet altitudes and their respective magnitudes based on existing published documents are summarized.

93. EVALUATION OF ALTIMETERS: COUNTER-POINTER VS. DRUM-POINTER, Anon, Naval Air Test Center, Patuxent, Maryland, Project TED #PTRAF-7058.2, March 1957

94. EVALUATION OF BAROMETRIC ALTIMETER AT LOW ALTITUDE,
Bourque, Donald J. FAA, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, Report No. RD-65-7, Project No. 320-205-01V (Part I), January 1965

An evaluation was conducted at the National Aviation Facilities Experimental Center to determine the mean and standard deviation of errors in determining a height of 100 feet above the runway by utilizing the barometric altimetry systems on Instrument Landing System (ILS) approaches. The ILS approaches were extended as low level runs above the runway to determine the barometric altimetry systems error during level flight.

95. EVALUATION OF BAROMETRIC ALTIMETRY FOR CATEGORY II APPROACHES (PART I - BOEING 720 AIRCRAFT),
Bourque, Donald J. FAA, National Aviation Facilities Experimental Center, Test and Evaluation Division, Atlantic City, New Jersey, Report No. RD-64-74, Project No. 114-015-02V, May 1964

An operational evaluation of two Kollsman Type No. 32506-10-004 precision barometric altimeters to determine the capability of that altimetry system to indicate 100 feet of height above the plane of the runway while on a standard Instrument Landing System (ILS) approach and to provide information for maintaining a constant height of 100 feet above the runway. It was concluded that the altimeters as installed and employed were not acceptable as altitude sensors for determining altitudes of 100 feet during either ILS approaches or level flight.

96. EVALUATION OF FACTORS AFFECTING THE CALIBRATION ACCURACY OF AIRCRAFT STATIC PRESSURE SYSTEMS,
DeLeo, Richard V.; Hagan, Floyd W.; Kooiman, Robert R.; Thompson, Donald I. Rosemount Engineering Company, Minneapolis, Minnesota, SEG-TR-65-35, July 1965, AD 621 678

Several factors affecting the calibration accuracy of flight vehicle static pressure systems have been considered in some detail. Altimeter calibration techniques and standards are discussed. The influence of pressure system leakage has been evaluated both analytically and experimentally. The influence of skin irregularities in the vicinity of fuselage static pressure ports has been calculated from linearized theory and the results presented in graphical form. A few revisions are suggested to the USAF document governing the design of flight vehicle static and total pressure systems, MIL-P-26292.

97. EVALUATION OF KOLLSMAN COUNTER-POINTER ALTIMETER,
Naval Air Test Center, Patuxent River, Maryland, Project No. TED PTR-AE-7253.2, Serial No. ST38-2, January 8, 1954, AD 36 173

98. EVALUATION OF KOLLSMAN STATIC POSITION ERROR COMPENSATING (SPEC) SYSTEM, FINAL REPORT, Manson, A. L.; Ober, D. G. Naval Air Test Center, Patuxent River, Maryland, NATC FT-29R-69, March 26, 1969

A flight evaluation of the Kollsman prototype Static Position Error Compensating (SPEC) system was conducted. Flight testing showed that, in the test configuration, the SPEC system could provide a maximum of ±200 feet corrective capability at 185 KIAS. The effectiveness of the SPEC system is limited below 185 KIAS and is negligible at low airspeeds. It is recommended that high Mach and high altitude testing be conducted prior to further development of this particular static position error compensating system.

99. EVALUATION OF NEW METHODS FOR FLIGHT CALIBRATION OF AIRCRAFT INSTRUMENT SYSTEMS, PART I: Analysis of Altimeter, Airspeed and Free-Air-Temperature Systems, DeLeo, Richard V.; Cannon, Peter Jr.; Hagen, Floyd W. Rosemount Engineering Company, Minneapolis, Minnesota, WADC TR 59-295, June 1959

An evaluation of new methods for the flight calibration of aircraft instrument systems has been performed with emphasis on methods of determining the static pressure position correction. Calibration accuracies of dual aircraft fly-by or single aircraft with ground tracking methods were comparable. The use of the single aircraft ground tracking procedure is attractive from the standpoint of flight economy. For the self-calibrating methods, the nose boom offers operational advantages over the trailing static head method although the latter should yield greater accuracy. The variation of specific heat of air under varying flight conditions should be included in improved calibration accuracies particularly above Mach 2.

100. EVALUATION OF NEW METHODS FOR FLIGHT CALIBRATION OF AIRCRAFT INSTRUMENT SYSTEMS, PART III: Development of Altimeter, Airspeed, and Free-Air-Temperature Calibration Systems, DeLeo, Richard V.; Hagen, Floyd W. Rosemount Engineering Company, Minneapolis, Minnesota, WADC TR 59-295, REC Report 26123, February 1961

101. EVOLUTION OF THE MODERN ALTIMETER, du Feu, A. N. Aviation Review, pp. 9-12, September 1968

Review of the past and present status of the barometric altimeter, and indication of the likely lines of future development. The servo altimeter, the operation of which is performed by a servo powered by the aircraft electrical supply, is described. Attention is given to various modifications of the three-pointer altimeter, with a view to easier reading. It is considered that the accuracy necessary to fly dense air routes at subsonic speeds during the next ten years has been achieved. A description is given of the Smith's Type 3 concept, basically a servo altimeter which is able to function as a Central Air Data Computer (CADC) repeater under normal conditions but upon failure of the CADC, or by choice, it can revert to function as a self-sensing servo altimeter of similar basic accuracy to that of the CADC.

102. EVOLUTION OF THE MODERN ALTIMETER, du Feu, A. N. Technical Air Vol. 25, pp. 12-16, February 1969

Review of the past and present status of modern altimeters with indication of the likely lines of future developments. Attention is given to the advantages and disadvantages of radio and radar altimeters. The introduction of the servo altimeter, with its 5-digit counter/pointer presentation made misreading virtually impossible, and this promises to be the preferred standard for many years to come. Aspects of accuracy are examined. A current development of greater importance, the Central Air Data Computer (CADC), is described. For the immediate future, increasing use of servo altimeters is anticipated. Other possibilities are briefly outlined.

103. EXAMINATION OF A RUSSIAN ALTIMETER (TWO-POINTER TYPE, RANGE 17 KM), Valentine, Morris C. Naval Air Development Center, Johnsville/Warminster, Pennsylvania, NADC-AM-6828, November 26, 1968

A Russian Altimeter with a 17 kilometer (55774 foot) pressure altitude range was examined and tested. Altitude dispersion is low. Most indications are ambiguous by 10 kilometers. Numerals on the zero setting scale may become hidden. Scale errors are low at room temperatures, but position errors are high and the instrument case leaks.

104. EXPERIMENTAL DESIGN FOR QUANTITATIVE MEASUREMENT AND EVALUATION OF PILOT PERFORMANCE ON COCKPIT DISPLAYS, Bradley, W. A. Naval Air Development Center, Johnsville, Pennsylvania, NADC-A1-6146, June 9, 1961

With few exceptions, the only evaluations of instruments and displays which have been made thus far, have been subjective flight evaluations. Such evaluations, although permissible in the past, are no longer completely adequate in view of the sophistication and sometimes dramatic changes in the new instruments and displays. In some cases, improvements in instruments or displays have resulted in minor changes which cannot be detected in the relatively gross subjective flight evaluation. The purpose of this experimental design is to set up a method of quantitatively measure pilot performance on cockpit displays in order to permit objective evaluations of new instruments and displays and to isolate display requirements.

105. AN EXPERIMENTAL EVALUATION OF DIGITAL ALTIMETERS, Triggs, T. J. Aeronautical Research Laboratories, Melbourne, Australia, ARL/HE-21, August 1966, N68-30381

Three advanced displays and an improved three-pointer display were evaluated in a comparative experiment. Six airline pilots were used as subjects in this study. Static presentations were first read using subject-controlled exposures in a single-task situation. Reading accuracy and display exposure time were recorded during this action. Then an extra-task situation was used where subject performed a tracking task continuously and was called on to make altimeter readings at random times. Tracking performance was recorded in this section in addition to reading times and accuracy.

106. AN EXPERIMENTAL EVALUATION OF FOUR TYPES OF ALTIMETERS USING BOTH PILOT AND ENLISTED MEN SUBJECTS, Chernikoff, R.; Ziegler, P. N. Naval Research Laboratory, Washington, D. C., NRL-6232, December 18, 1964, AD 610 665

Eighteen pilots and seven Navy enlisted men participated in an evaluation of the four altimeters: counter-pointer (CP), counter-drum-pointer (CDP), drum-pointer (DP), and three-pointer (3P). The experimental situation required the subjects to track a dot on a crt while reading altimeter settings suddenly presented by the opening of a shutter.

Subjects operated a hand-switch to close the shutter after reading the altitude presented. Measures were taken of the length of the exposure time and the accuracy of the reported altitude. The results indicated that for both pilots and enlisted men the CP and CDP altimeters yielded nearly identical exposure time.

107. AN EXPERIMENTAL EVALUATION OF THE HIGGINS'S MODIFIED AAU-8/A ALTIMETER, (Master's Thesis), Milauckas, Edmund W. Texas University, Austin, Texas, August 1960, AD 241 857

The standard AAU-8/A altimeter, a barometric pressure instrument currently in use in most USAF jet and reciprocating aircraft was experimentally compared with a modified version of the altimeter. The modification, designed with the intent of reducing errors of reading the altimeter, were simple, inexpensive, and easily implemented additions to the standard altimeter. The four modifications included a white arc painted on the face of the altimeter which was intended to provide a quick gross altitude reading, a relocated and changed low-level warning area; a dynamic low-level warning, and 50 feet scale markers instead of 20 feet markers. Pilots using the modified altimeter made only about half as many errors as pilots using the current AAU-8/A altimeter. The white arc apparently was the single most important factor in the reduction of errors.

108. EXPERIMENTS ON THE USE OF A STATIC TUBE IN THE WING WAKE AND A SHORT PITOT TUBE IN THE LEADING EDGE AS AN AIRSPEED INDICATOR, Royal Aircraft Establishment, Aerodynamics Staff, London, England, R & M 1779, November 10, 1936

Mr. E. T. Jones has suggested that the drag of a pitot-static head would be reduced and its speed indication improved if the static tube were placed in the wing wake to the rear of the trailing edge and a short pitot tube fixed to the leading edge.

109. EXPERIMENTS WITH STATIC TUBES IN A SUPERSONIC AIRSTREAM - PARTS I AND II, Holder, D. W.; North, R. J.; Chinneck, A. Aeronautical Research Council Reports and Memorandum, London, England, ARC TR R & M No. 2782, July 1950

Systematic tests have been made at a Mach number of 1.6 on a family of static tubes. The variables which have been investigated are the shape of the nose, the distance of the holes downstream, and the inclination of the tube to the flow. (Part I)

A family of flat-nosed pitot-tubes has been tested at Mach numbers of 1.6 and 1.8. At both Mach numbers it was found that no change of reading could be detected when the ratio of the external diameter to the bore was varied from 2 to 16. (Part II)

110. EXTERNAL INTERFERENCE EFFECTS OF FLOW THROUGH STATIC PRESSURE ORIFICES OF AN AIRSPEED HEAD AT SEVERAL SUPERSONIC MACH NUMBERS AND ANGLES OF ATTACK, Silsby, Norman S. National Aeronautics and Space Administration, Langley Field, Virginia, NASA Memo 2-13-59L, November 13, 1958

Wind tunnel tests were made to determine the static pressure error resulting from external interference effects of flow through the static pressure orifices of an NACA airspeed head at Mach numbers of 2.4, 3.0, and 4.0 for angles of attack of 0°, 5°, 10°, and 15°. The static pressure error increased linearly with increasing mass-flow rate for both the forward and rear sets of orifices at all Mach numbers and angles of attack of the investigation. For a given value of flow coefficient, the static pressure error varied appreciably with Mach number but only slightly with angle of attack.

111. F-4C L-SHAPED PITOT-STATIC TUBE, Kraus, John J. Directorate of Flight Test Engineering, Deputy for Flight Test Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, ASTDN FTR 66-14, August 1966

112. FIELD APPRAISAL OF THE STORED PROGRAM ALPHA NUMERIC BEACON SYSTEM (SPAN), Levy, Joseph FAA, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, Report No. RD-66-53, Project No. 122-521-01X, November 1966

The field appraisal of the Stored Program Alpha Numeric Beacon System (SPAN) was conducted, using the high altitude airspace at the Indianapolis ARTC Center between April 1965 and February 1966. The primary objective of the appraisal was to determine firm operational and technical requirements for a semi-automatic data processing and data display system designed to track radar beacon targets and present associated alpha numeric flight data on enroute radar control displays.

113. FINAL REPORT ON RELIABILITY INVESTIGATION OF PRESSURE ALTIMETERS, U. S. Naval Air Development Center, Johnsville, Pennsylvania, Report No. NADC-AI-6510, April 28, 1965

Three each of the altimeters were subjected to a series of 125 environmental temperature cycles in accordance with the chart on page 11 of MIL-R-22973(WEP) and with certain vibration and varying pressure altitude requirements.

114. FINAL REPORT ON THE OPERATIONAL SUITABILITY TEST OF THE POINTER-DRUM ALTIMETER, Anon, Air Proving Ground Command, Eglin Air Force Base, Florida, Project #APG/SAT/893-A, December 1955

115. FLIGHT CALIBRATION OF AIRCRAFT STATIC PRESSURE SYSTEMS, DeLeo, Richard V.; Hagen, Floyd W. Rosemount Engineering Company, Minneapolis, Minnesota, FAA Report No. RD-66-3, REC Report 76431, February 1966

This report describes four methods of static pressure flight calibration: (1) Camera Fly-Over or Tower Fly-By, (2) Pacer Aircraft, (3) Radar Tracking, and (4) Trailing Probe. The equipment required for each method is listed as well as the accuracy expected and the personnel and flight time required. Complete pre-flight, in-flight, and post-flight procedures and detailed data reduction procedures are described for each method. Data formats are included, as well as suggestions for final data analysis and presentation in correction card form. General background information on the standard atmosphere, altimeters, altimeter errors, and static pressure system errors are included.

116. FLIGHT CALIBRATION OF FOUR AIRSPEED SYSTEMS ON A SWEPT-WING AIRPLANE AT MACH NUMBERS UP TO 1.04 BY THE NACA RADAR-PHOTOTHEODOLITE METHOD, Thompson, Jim R.; Bray, Richard S.; Cooper, George E. National Advisory Committee for Aeronautics, Langley Field, Virginia, NACA TN 3526, Supersedes NACA RM A50H24, 1955

The characteristics of four different airspeed systems installed in a swept-wing airplane have been investigated in flight up to 1.04 Mach number by the NACA radar-phototheodolite method of airspeed calibration. The variations of static-pressure defect per unit indicated impact pressure with Mach number and a limited amount of information on the effect of airplane normal-force coefficient are presented for each system. The results are compared with available theory and wind-tunnel tests of the isolated heads.

117. FLIGHT CALIBRATION OF FUSELAGE STATIC-PRESSURE-VENT INSTALLATION FOR THREE TYPES OF TRANSPORTS, Silsby, Norman S.; Stickle, Joseph W. National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia, NASA TN D-1356, May 1962

Results are presented of flight tests to determine the static-pressure error of the fuselage vent installations of 16 military transports representing three different types of airplanes. The results were determined from flights at constant speed and constant low altitude over a fixed ground camera station for a speed range from near minimum to near maximum for the cruise condition for each type of airplane.

118. FLIGHT EVALUATION OF SERVO-ALTIMETER DISPLAYS FOR THE AIR TRAFFIC CONTROL RADAR BEACON SYSTEM/IFF/MARK 12/SYSTEM (AIMS) PROGRAM, Lee. R. P. Naval Air Test Center, Patuxent River, Maryland, Report ST 32-92R-64, November 23, 1964

The Counter-Drum- Pointer, Counter-Pointer, Drum-Pointer, and Three-Pointer altimeter presentations were evaluated by twenty-three pilots to select the best altimeter display for use in airplanes operating above 18,000 feet. The Counter-Drum-Pointer (CDP) was the first choice of 80% of the pilots.

119. FLIGHT EVALUATION OF THE MODIFIED COUNTER-DRUM-POINTER SERVO-ALTIMETER DISPLAYS FOR THE AIR TRAFFIC CONTROL RADAR BEACON SYSTEM/IFF/MARK 12/SYSTEM (AIMS) PROGRAM, Lee, R. P. Naval Air Test Center, Patuxent River, Maryland, Final Report ST 32-22R-65, February 26, 1965

Evaluation of CDP Servo-Altimeter for AIMS Program usage. Several encountered deficiencies are noted.

120. FLIGHT INFORMATION SENSORS, DISPLAY, AND SPACE CONTROL OF THE X-15 AIRPLANE FOR ATMOSPHERIC AND NEAR-SPACE FLIGHT MISSIONS, Fischel, Jack; Webb, Lannie D. National Aeronautics and Space Administration, Edwards Air Force Base, California, NASA TN D-2407, August 1964

Several sensors and systems evaluated appear to be satisfactory for providing research and pilot-display information relative to airspeed, altitude, dynamic pressure, flow-direction angles, and vehicle attitude.

121. FLIGHT INVESTIGATION AT LARGE ANGLES OF ATTACK OF THE STATIC-PRESSURE ERRORS OF A SERVICE PITOT-STATIC TUBE HAVING A MODIFIED ORIFICE CONFIGURATION, Gracey, William; Scheithauer, Elwood F. National Advisory Committee for Aeronautics, Langley Field, Virginia, NACA TN 3159, February 1954

The effect of inclination of the airstream on the static pressure ensured by two similar pitot-static tubes and by one of these tubes with three modified orifice arrangements has been determined in flight. The tests of this configuration were conducted over an angle-of-attack range of -15° to 45°, at Mach numbers from 0.20 to 0.68. Test results showed that, for Mach numbers between 0.20 and 0.68 the error will remain within 1 percent of the impact pressure q_c over an angle-of-attack range of -10° to 30°. At angles of attack between 30° and 45°, the static-pressure error increases rapidly and reaches values as high as 15 percent of q_c at an angle-of-attack of 45°.

122. FLIGHT INVESTIGATION OF THE EFFECT OF SIDESLIP ON THE PRESSURE AT THE STATIC ORIFICES OF THE BOEING B-29 AIRPLANE, Chilton, Robert G.; Brown, B. Porter Langley Aeronautical Laboratory, Langley Field, Virginia, NACA-RM-L50J30, April 11, 1951

Flight tests have been conducted to determine the sensitivity to sideslip of the static-pressure orifices of the Boeing B-29 airplane. The results of the tests show that the pressure measured by the two orifices increased as the square of the angle of sideslip. Theoretical considerations, apparently substantiated by the test results, indicate that the variation with sideslip could be reduced to zero by relocating the static orifices.

123. FLIGHT INVESTIGATION OF THE VARIATION OF STATIC-PRESSURE ERROR OF A STATIC-PRESSURE TUBE WITH DISTANCE AHEAD OF A WING AND A FUSELAGE, Gracey, Wm.; Scheithauer, Elwood F. National Advisory Committee for Aeronautics, Langley Field, Virginia, NACA TN 2311, March 1951

The variation of static-pressure error with lift coefficient of a static-pressure tube located from 1/4 to 2 chords ahead of the wing of an airplane is presented. Similar calibrations of tubes located 1/2 to 1-1/2 body diameters ahead of the fuselage nose and 1 chord ahead of the wing of a second airplane are also presented. The results of the tests of the fuselage-nose installations showed that the static-pressure error was reduced for all values of lift coefficient when the distance of the tube from the nose was increased.

124. FLIGHT MEASUREMENTS OF THE PRESSURE ERRORS OF A NOSE AND WING BOOM AIRSPEED SYSTEM ON A SWEPT-WING AIRCRAFT (Hunter F Mk. I) AT MACH NUMBERS UP TO 1.2 Andrews, D. R.; Nethaway, J. E. Royal Aircraft Establishment, Farnborough, England, Technical Note No. Aero 2354, January 1955

The pressure errors of an experimental nose boom airspeed system and of the standard wing tip instllation on a Hawker Hunter Mk I aircraft have been measured in-flight. Tests were made at sea level by the "aneroid" method and at high altitude by the "formation" and "fly-past" methods. The results presented cover a range of speeds up to 500 knots and of Mach numbers up to 1.23.

125. FLIGHT TECHNICAL ERROR OF GENERAL AVIATION AIRCRAFT, Morton, W.; Peckham C.; Braum, J. FAA, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, FAA RD-65-60, June 1965

This report represents a study of the Flight Technical Error (random deviations from intended cruise altitudes) of six general aviation aircraft. Based in Ohio, Indiana, and New Jersey, these aircraft were a Beech C-45, a Bonanza H-35, an Apache PA-23-160, a Navion Rangemaster, a Cessna Skyland, and a Comanche PA-24-180. A total of 626 hours of cruise data was collected. A statistical analysis of the results is presented.

126. FLIGHT TEST, EVALUATION AND CALIBRATION OF AIMS AIRBORNE ATCRBS EQUIPMENT: POSITION ERROR DETERMINATION OF THE A-6A AIRPLANE, FINAL REPORT Manson, A. L.; Willis, C. T. Naval Air Test Center, Patuxent River, Maryland, NATC FT-39R-69, May 6, 1969

The production static position error of the A-6A airplane was determined as part of a continuing effort to document position errors of the production static systems of AIMS (ATCRBS/IFF/MARK XII/System) programmed aircraft.

127. FLIGHT TEST EVALUATION OF AIRCRAFT PRESSURE ALTIMETER INSTALLATIONS, Fine, Russell L. Wright Air Development Center, Wright-Patterson Air Force Base, Ohio, WADC TN 56-438, October 1956, AD 110 554

Results of USAF study are presented relative to accurate flight calibration of the altimeter systems of a large number of military and scheduled air carrier aircraft. The flight evaluation establishes quantatively the errors of the aircraft pressure altimeter installation and the repeatability of these errors from aircraft to aircraft of the same configuration. The majority of aircraft exhibited reasonable correlation of altimeter installation errors and handbook values and the variation of installation errors between aircraft of the same configuration was normally small.

128. FLUSH STATIC PORT WATER INGESTION, Browne, J. A.; Brainerd, C. H. Trans World Airlines, Inc., Kansas City, Missouri, TWA Attachment B, January 8, 1969

Investigate the relative merits of various flush static port configurations with regard to susceptibility to ingestion of water presented at the openings, and to determine the ability of these static ports to drain without causing a pressure differential between the static systems and the outside air.

129. FURTHER STUDY OF ANGLE-OF-ATTACK, ANGLE-OF-SIDESLIP PITOT STATIC PROBES, Smetana, Frederick O.; Headley, Jack W. University of Southern California, Los Angeles, California, WADC TR 57-534, Part 4, June 1958

Development and results are given of an analytical experimental program to produce an improved angle-of-attack, angle-of-sideslip, pitot-static probe. Compared to currently used devices, this probe offers approximately 50% greater sensitivity, better linearity in the usual range of operation, and reduced a-b interaction. Computer mechanizations required with such a probe are discussed. Analytical and mechanization studies are described on the motion-sensing system for measuring angle-of-attack and angle-of-sideslip.

130. HEIGHT MEASUREMENT IN SUPERSONIC AIRCRAFT, Davies, W. P. Institute of Navigation, Journal Vol. 19, pp. 56-82, No. 1, 1966

131. A HIGH-ALTITUDE ALTIMETER, Morse, Arthur O.; Milson, Harvey M. Diamond Ordnance Fuze Laboratories, Washington, D. C., DOFL Report No. TR-623, Project No. TU1-2031, June 15, 1960

An altimeter system capable of providing accurate re-entry altitude data in multiples of 5,000 feet has been designed and developed. It is for use on ballistic nose cones at altitudes between 190,000 and 5,000 feet and velocities up to 15,000 fps. The system operates on a UHF pulse radar.

132. HUMAN ENGINEERING EVALUATION AND STANDARDIZATION (RELOCATION OF COCKPIT PRESSURE ALTIMETER IN A-7A AIRPLANE), Field, L. F.; Ozimek, J. Naval Air Test Center, Patuxent, Maryland, ST-14R-69, October 18, 1969 - December 15, 1968

An Airframe Change has been proposed by Attack Squadron Eighty-Six to provide stowage space for pilot's navigation equipment in the A-7A airplane cockpit. The proposed change included relocation of the cockpit pressure altimeter. The relocated altimeter installation has been evaluated for pilot/copilot compatibility and found to be satisfactory.

133. AN IMPROVED ALTITUDE COMPUTER, Johanson, C.; Peterson, V. Z.; Rogness, D. Pioneer-Central Division of the Bendix Corporation, SEG-TR-64-70, December 1964, AD 610 508

This report describes the design, development and prototype construction of an instrument which provides accurate corrected pressure altitude outputs. The corrected pressure altitude outputs consist of a fine and coarse autosyn transmitter signal, provided to drive altitude indicators, and a Moa Gilham coded shaft position encoder output intended to provide the altitude signal for altitude reporting. A major achievement with the instrument is the 20 foot accuracy obtained from -1,000 to 10,000 feet and the 0.2 percent accuracy from 10,000 to 80,000 feet. Another achievement is the extent of correction of the static pressure defect characteristic of the aircraft, in the transducer through the range of .2 to 3.0 Mach number, for the altitude range of -1,000 to 80,000 feet.

134. INDICATOR, BAROMETRIC PRESSURE, Heusinkveld, H.; Jordan, W.; D'Amico, R.; Smith, R. National Transportation Safety Board, Washington, D. C., Spec. MC432-0052c, November 1, 1965, AD 808 189

135. THE INFLUENCE OF AERODYNAMIC CLEANNESS OF AIRCRAFT STATIC PORT INSTALLATIONS ON STATIC POSITION ERROR REPEATABILITY, Brumby, Ralph E. Douglas Aircraft Company, Long Beach, California, Report No. DAC 67484, November 20, 1968

Wind tunnel investigations have established that the cause of incorrect pressures sensed by static orifices is the degree of aerodynamics cleanness of both the orifice installation and the surface in the immediate vicinity of the orifice. Some examples of such errors caused by static port mismatch, non-flush rivets, and specific types of waves or bumps are given. Detailed flight test static position error calibrations have been obtained for 54 Douglas DC-8 and DC-9 aircraft spanning five basic models. All aircraft are shown to have static position error calibrations at typical cruise conditions within approximately ±100 feet of the FAA approved calibration curve for the particular model.

136. THE INFLUENCE OF HOLE DIMENSIONS ON STATIC PRESSURE MEASUREMENTS, Shaw, R. J. Fluid Mechanics Vol. 7, Pt. 4, pp. 550-564, April 1960

The pressure measured at a static pressure hole differs slightly from the true static pressure, by an amount which depends on the hole size and shape. The present investigation extends the range of previous work to determine the error in static pressure measurements in incompressible turbulent flow. The observed static pressure was always greater than the true static pressure. The results are presented in dimensionless form as a function of the Reynolds number based on hole diameter and friction velocity.

137. THE INFLUENCE OF METHODOLOGY ON RESEARCH ON INSTRUMENT DISPLAYS, Senders, V. L.; Cohen, J. Wright Air Development Center, Dayton, Ohio, WADC TR 53-93, April 1953

138. INFLUENCE OF ORIFICE GEOMETRY ON STATIC PRESSURE MEASUREMENTS, Rayle, R. E. The American Society of Mechanical Engineers, New York, N. Y., ASME 59-A-234, November 29, 1959

The effect of varying hole size from 0.006 to 0.125 inches in the measurement of static pressure as a function of Mach number up to 0.80 M_n is theoretically discussed.

139. INSTRUCTIONS FOR THE LOCATION, INSTALLATION AND CALIBRATION OF FLUSH STATIC VENTS, Bureau of Aeronauctics (Navy), Washington, D. C., July 1944, AD 15 150

140. INSTRUMENTS SYSTEMS, PITOT TUBE AND FLUSH STATIC PORT OPERATED, INSTALLATION OF, MIL-I-6115A, March 29, 1951, Superseding MIL-I-6115, April 26, 1950

This specification covers the general requirements for the installation of all types of pitot tubes and flush static port-operated instrument systems for use on aircraft to provide a source for dynamic and static pressures.

141. INVESTIGATION, DESIGN AND DEVELOPMENT OF A PRESSURE SENSING SYSTEM FOR DETERMINING ALTITUDE, Whitten, Robert P. Progress Report, Allied Research Associates, Inc., Boston, Massachusetts, Document No. ARA-885, Contract DA 19-020-501-ORD-5066, August 1-31, 1960, AD 318 945

142. INVESTIGATION, DESIGN AND DEVELOPMENT OF A PRESSURE SENSING SYSTEM FOR DETERMINING ALTITUDE, Whitten, Robert P. Progress Report, Allied Research Associates, Inc., Boston, Massachusetts, Document No. ARA-893, Contract DA 19-020-501-ORD-5066, October 15, 1960, AD 319 533

143. INVESTIGATION OF FREE-STREAM PRESSURE AND STAGNATION PRESSURE MEASUREMENT FROM TRANSONIC AND SUPERSONIC AIRCRAFT, Korkegi, Robert H.; Mannes, Robert L. University of Southern California, Engineering Center, Los Angeles, California, WADC TR 55-238, March 1955

A survey and analysis of literature and existing methods on pressure measurement from transonic and supersonic aircraft are presented. Included is a comprehensive discussion of the field of flow about an aircraft at subsonic, transonic, and supersonic speeds. A complete survey of static and pitot probes and their performance is given; there is also a brief discussion of lag and instrument errors, and pressure-error compensation. It is concluded from the analysis that no single, fixed source on a transonic or supersonic aircraft will yield a measurement of local pressure within 1% of true free-stream pressure over the whole Mach number range.

144. INVESTIGATION OF FREE-STREAM PRESSURE AND STAGNATION PRESSURE MEASUREMENT FROM TRANSONIC AND SUPERSONIC AIRCRAFT, Smetana, Frederick O.; Stuart, Jay Wm.; Wilber, Paul C. University of Southern California, Engineering Center, Los Angeles, California, WADC TR 55-238, July 1957

The procedure employed and the results obtained in a program to apply aerodynamic static-pressure compensation to a service-type aircraft are given. The program used as its basis previous wind tunnel results on 1/8-scale models. It was found that in increasing the size of the models the influence of Reynolds number for $M < .6$ was, in some cases, greater than had been expected and that all the large models tested produced a sudden rise in the resultant error at Mach numbers $(.8 \leq M \leq .9)$ well below that at which the aircraft bow shock crosses the compensated pressure source. Results of preliminary investigations into the feasibility of using surface-pressure sources on faired and unfaired bodies for Mach number and angle of attack compensation and of reducing the length of a static-pressure-compensated probe are also given.

145. INVESTIGATION OF HIGH ALTITUDE REPORTING WITH AIR TRAFFIC CONTROL RADAR BEACON SYSTEM, Mahnken, George H.; Hierbaum, Felix FAA, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, Report No. RD-65-2, Project No. 242-006-03X (108-03X), January 1965

This document covers the high altitude phase of the test program on Altitude Transmission Equipment. For the most part, the technical data yielded expected results with the exception of the poor returns from inbound flights at long ranges. Operational feasibility was demonstrated whereby live altitude reporting from an equipped commercial airliner operating within the normal ATC environment was automatically available to the ground.

146. INVESTIGATION OF MEASUREMENT TECHNIQUES AT SUPERSONIC SPEEDS AND HIGH ALTITUDES, Marquardt, J. F.; Kerbs, W. A. Booz-Allen Applied Research, Inc., Chicago, Illinois, Contract AF33(616)6273, Quarterly Engineering Report No. 2, July 1 - October 1, 1959, AD 227 756

The measurement is discussed of several atmospheric parameters from an airborne platform travelling at speeds up to M3 and at altitudes up to 85,000 feet. The parameters considered are wind, turbulence, humidity, ozone, and altitude. In addition an analysis of the errors obtained when wind is derived from the "wind triangle" was considered. The errors to be expected are summarized in graphical form. It was concluded that the error in determining air speed is the major contributing factor to the wind speed error. A new type of altimeter called the gravity altimeter was considered. The gravity altimeter, through measurement of the variation of gravitational attraction with height, was shown to yield accurate altitude measurements even at extreme altitudes. The concept of a gravity altimeter is new and as such is essentially a feasibility study.

147. AN INVESTIGATION OF METHODS FOR DETERMINING THE VERTICAL VELOCITY OF AN AIRCRAFT, Erickson, Ronald A. Naval Ordnance Test Station, China Lake, California, NOTS TP3293, NAVWEPS 8387, March 1964, AD 436 815

The accuracy of the vertical velocity of an aircraft as determined from vertical acceleration from a vertical accelerometer, barometric altitude from a radar altimeter is not good enough for military aircraft fire-control systems. For military application, vertical velocity can be computed from the proper combination of barometric altitude and vertical acceleration.

148. INVESTIGATION OF PRECIPITATION EFFECTS ON STATIC PORT ACCURACY, Knerr, W. M.; Bohannon, R. R. Pan American World Airways, Inc., Miami, Florida, SC-69-1, March 7, 1969, Revised June 26, 1969

This study has been conducted with the following as its objectives: A. Determine the susceptibility of static systems on turbojet aircraft to ingestion of snow or water during the following periods: (1) Flight operations in precipitation, (2) Taxi, takeoff and landing operations in wet/slushy runway conditions, and (3) Aircraft parked or being loaded in precipitation. B. Determine the effect of ingested water on altimeter system accuracy. C. If required recommend corrective action or further tests needed to resolve questionable areas.

149. AN INVESTIGATION OF THE EFFECT OF RANDOM FUSELAGE WALL IRREGULARITIES ON FLUSH STATIC PRESSURE PORT CALIBRATIONS, Werner, Frank D.; Teigen, Mary J. University of Minnesota, Rosemount Aeronautical Laboratories, Minneapolis, Minnesota, WADC TR 57-365, April 1957, AD 130 805

An investigation of the effect of random surface irregularities in the vicinity of flush pressure ports on the static pressure calibration characteristics of presumably identical aircraft is described. A method for analysis of wall irregularity effects is presented together with useful computation tables. Such irregularities were measured on 13 B-47, 11 B-52, and 11 F-101 airplanes and the resulting pressure errors were computed and are summarized with the help of small sampling theory statistics. The magnitude of these errors is significant. Other factors important to static pressure reproducibility for nose boom, pitot-static tube, and flush port installations will be dealt with in a future report.

150. AN INVESTIGATION OF THE FEASIBILITY OF INDICATING ALTITUDE BY GRAVIMETRIC MEASUREMENTS, (Master's Thesis), Butler, Charles M.; Haller, Norman M. Massachusetts Institute of Technology, Cambridge, Massachusetts, June 1962 AD 278 112

Indication of vehicle altitude by inertial means would be feasible if the primary source of vertical position indications were solely a gravity-measuring device. A secondary closed-loop double-integration of the difference between the accelerometer output and certain computed gravity and compensation terms is proposed.

151. AN INVESTIGATION OF THE INFLUENCE OF ORIFICE GEOMETRY ON STATIC PRESSURE MEASUREMENTS, (Master's Thesis), Rayle, Roy E. Jr. Massachusetts Institute of Technology, Cambridge, Massachusetts, 1949

The errors in static pressure as a function of dynamic pressure up to Mach 0.80 due to hole size, cleanliness, probe extensive or retraction within the boundary layer, and orifice edge form are evaluated.

152. INVESTIGATION OF VERTICAL DISPLAYS OF ALTITUDE INFORMATION: I. A COMPARISON OF A MOVING-TAPE AND STANDARD ALTIMETER ON A SIMULATED FLIGHT TASK, Mengelkoch, Robert F.; Houston, Robert C. Wright Air Development Center, Dayton, Ohio, WADC TR 57-385, March 1958

153. INVESTIGATION OF VERTICAL DISPLAYS OF ALTITUDE INFORMATION: III. THE EFFECT OF AN EXPANDED SCALE ON PERFORMANCE OF A SIMULATED FLIGHT TASK USING A MOVING-TAPE ALTIMETER, Mengelkoch, R. F; Houston, R. C. Wright Air Development Center, Dayton, Ohio, WADC TR 57-549, March 1958

The third of a series of studies in the vertical display of altitude information, this experiment compared an expanded scale, moving tape altimeter with a standard altimeter on a simulated flight task.

154. INVESTIGATION OF WATER ACCUMULATION IN FLUSH-MOUNTED STATIC PRESSURE PORTS IN RAIN, Kerr, R. M. Boeing Company, Renton, Washington, D6-23898TN, May 22, 1969

Laboratory tests results are presented which show water ingestion characteristics for various configurations of flush-mounted static ports. Recommendations are made of revised static ports which have greater resistance to water accumulation than do the existing 707/727 static ports.

155. JET INSTRUMENTATION PROGRAM, EVALUATION OF MODIFIED THREE-POINTER ALTIMETER CONFIGURATIONS, Naval Air Test Center, Patuxent River, Maryland, Project TED No. PTR AE-7046-2, July 30, 1954, AD 39 720

Five 3-pointer altimeter presentations were evaluated as replacements of the standard altimeter in high performance airplanes. The counter-pointer altimeter (AD-36-173) was evaluated for comparative purposes. The six instruments mounted in F9F-6/7/8, FJ-2/3, and F7U-3 airplanes were evaluated in both day and night flight tests. All instruments were compared for ease of interpretation, and any tendency to misread was noted. Results showed that the counter-pointer presentation was the most desirable altimeter. However, the inverted pointer altimeter was the desired presentation of the five proposed modifications with the circular needle altimeter next in order of preference.

156. KOLLSMAN INSTRUMENT CORPORATION PILOT-LINE PRODUCTION COUNTER-POINTER ALTIMETER EVALUATION IN HIGH PERFORMANCE AIRCRAFT, REPORT NO. 2, FINAL REPORT, Anon, Naval Air Test Center, Patuxent River, Maryland, Project PTR AE-7253.3, November 29, 1954

Twenty-five Kollsman production counter-pointer altimeters were qualitatively evaluated to determine if they duplicated the performance of the experimental model. It was concluded that vibrator reliability and altimeter performance with vibrator inoperative was unsatisfactory.

157. LABORATORY PRESSURE MEASUREMENT REQUIREMENTS FOR EVALUATING THE AIR DATA COMPUTER, Eberlein, A. J. Aero. Engr. Review, pp. 53-57, April 1958

158. LABORATORY TESTS OF SMALL LIGHT WEIGHT ALTITUDE TRANSMISSION EQUIPMENT (SLATE), Mahnken, George H. FAA, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, Report No. RD-66-36, Project No. 242-006-01X, May 1966

The performance characteristics of several Small Lightweight Altitude Transmission Equipment (SLATE) were determined through laboratory tests. A description of the SLATE components is given, and the test procedures and results are presented. Test results indicated that design changes would be required in order to achieve the desired performance. It was concluded that the production of suitable small lightweight altitude transmission equipment is feasible.

159. LAG DETERMINATION OF ALTIMETER SYSTEMS, Head, Richard M. Presented at the Summer Annual Meeting I. A. S., Los Angeles, California, July 27-28, 1944, Journal of the Aeronautical Sciences, Vol. 12, pp. 85-93, 1945

160. LAG IN AIRCRAFT ALTITUDE MEASURING SYSTEMS, Irwin, Kirk S. Air Force Flight Test Center, Edwards Air Force Base, California, FTC-TDR-63-26, December 1963

The nature of pressure lag in aircraft altitude measuring systems is discussed and several methods of lag correction are compared. The influence of the instrumentation system temperature and the pitot-static probe surface temperature on the pressure lag are shown through theoretical and experimental analysis. A system and procedure for ground lag checking on an aircraft static pressure system is presented in an appendix to the report.

161. LAG IN PRESSURE SYSTEMS AT EXTREMELY LOW PRESSURES, Davis, William T. Langley Aeronautical Laboratory, Langley Field, Virginia, NACA TN 4334, September 1958

A theoretical formula for determining time lags in pressure-measuring systems at all pressures, including extremely low pressures where molecular flow occurs, is derived and shown to be accurate to within 10 percent for pressures down to approximately 0.2 millimeter of mercury (0.556 lb/sq. ft) for nearly linear pressure changes.

162. LASER ALTIMETER, Vaughan, P. A. In: Lasers and Opto-Electronics: Institution of Electronic and Radio Engineers, Joint Conferences, University of Southampton, England March 25-28, 1969 Proceedings, pp. 1-12

Discussion of the design, development, and test of a fully engineered airborne pulsed laser system for the measurement of altitude in a combat aircraft. It will be employed as a height datum for trials work on radio altimeters which suffer from inaccuracies due to "penetration effects." The system employs a gallium arsenide laser and determines the height by measurement of the transmit time of a pulse of laser energy travelling from the transmitter to the ground and back to the receiver.

163. LIMITED SURVEY OF COMMERCIAL JET AIRCRAFT ALTIMETER SYSTEM POSITION ERROR BY PACER WITH TRAILING CONE, Shrager, Jack J. FAA, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, Report No. RD-64-157, Project No. 320-205-02X, December 1964

Limited flight tests were conducted using the trailing cone static pressure measuring technique to determine the repeatability of commercial jet aircraft altimeter systems. The maximum difference between the six types tested at 30,000 feet was 500 feet.

164. LOW ALTITUDE LASER MEASUREMENT SYSTEM, Hopson, James E.; Isaac, William D.; Beavin, Rudy C.; Polishuk, Paul In: NAECON '68; Proceedings of the 20th National Aerospace Electronics Conference, Dayton, Ohio, May 6-8, 1968, pp. 87-92

An experimental Low Altitude Laser Measurement System (LALMS) has been developed for use in the terminal phase of flight.

The device is described, and both laboratory and flight test results are presented and discussed. These results demonstrate that highly precise and accurate altitude measurements are possible over various terrain with a small, lightweight laser device using state-of-the-art solid state technology.

165. MANUEL OF BAROMETRY, Vol. I, First Edition, 1963, Washington, D. C., December 1962

166. MARATHON 1 MK. 11 XA. 260 (4 GIPSY QUEEN 172) A. S. I. AND ALTIMETER PRESSURE ERROR CORRECTIONS, Aeroplane and Armament Experimental Establishment, Great Britain, Report No. AAEE/840/1, Part I, January 11, 1954, AD 34 603

167. MARATHON 1 VX. 229 (4 GIPSY QUEEN 71) A. S. I. AND ALTIMETER PRESSURE ERROR CORRECTIONS, Aeroplane and Armament Experimental Establishment, Great Britain, Report No. AAEE/40/Part 13, January 13, 1953, AD 1836

168. THE MEASUREMENT OF HYPERSONIC VELOCITIES AND ALTITUDES UP TO 300,000 FEET WITH A SELF-CONTAINED SYSTEM, Geronime, Robert L.; Huppert, Lawrence D. Rosemount Aeronautical Laboratories, University of Minnesota, Minnesota, WADC TR 57-712, September 1957, AD 142 177

The problem of measuring altitude and velocity with a self-contained system has been reviewed in detail. The results of this study indicate that pitot and fuselage static pressure measurements are the most reliable for an altitude range from 0 to 300,000 feet and Mach number range from 0 to 7. The effects of temperature and background ionization, the time lag of the system, and methods for providing a suitable readout have been considered in detail.

169. THE MEASUREMENT OF POSITION ERROR AT HIGH SPEEDS AND ALTITUDE BY MEANS OF A TRAILING STATIC HEAD, Smith, K. W. Aeronautical Research Council, London, England, Technical Note No. Aero 2163, June 1952

The static position error of a service wing-tip leading edge pressure head installation has been measured by means of a trailing static head, developed especially for use at high speeds. These tests cover an altitude range from zero to 38,000 feet, and include measurements in 'g' turns. The maximum Mach number reached was 0.84.

170. MEASUREMENT OF POSITION ERROR ON HIGH SPEED AIRCRAFT,
Cushing, R. K. Aeronautical Research Committee, London, England,
R & M No. 1472, April 1932

During an intensive training period of the High Speed Flight at Calshot in 1931 an opportunity arose to determine the position error of the pitot static heads of the racing seaplanes. The indicated airspeed given by the A. S. I. at top level speed is lower than the actual speed for all the aircraft, the correction varying from 1-1/2 to 19 mph. The agreement with model results is fair.

171. THE MEASUREMENT OF PRESSURE ALTITUDE ON AIRCRAFT,
Gracey, William National Advisory Committee for Aeronautics,
Langley Field, Virginia, NACA TN 4127, October 1957

The various errors which determine the accuracy of an altimeter system are discussed and numerical values are assigned to each error. A statistical method for combining the individual errors is described. The overall errors of altimeter installations are calculated for Mach numbers up to 1. 0 and altitudes up to 40, 000 feet. An indication of the means by which some of the errors can be reduced is given. Various systems of barometric reference are also discussed.

172. MEASUREMENT OF STATIC PRESSURE ON AIRCRAFT,
Gracey, William National Advisory Committee for Aeronautics,
Washington, D. C. , NACA TN 4184, November 1957

Existing data on the measurement of static pressure by means of static-pressure tubes and fuselage vents at subsonic, transonic, and supersonic speeds are presented. Static-pressure errors are given for isolated tubes and vents and for installations ahead of the fuselage nose, wing tip, and vertical tail fin, and on the fuselage. Various methods of calibrating installations in flight are briefly discussed.

173. MEASUREMENT OF STATIC PRESSURE OF AIRCRAFT,
Gracey, William National Advisory Committee for Aeronautics,
Langley Field, Virginia, NACA TR 1364, 1958

Existing data on the errors involved in the measurement of static pressure by means of static-pressure tubes and fuselage vents are presented. The errors associated with the various design features of static-pressure tubes are discussed for the condition of zero angle of attack and for the case where the tube is inclined to the flow. Errors which result from variations in the configuration of static pressure vents are also presented.

174. MEASUREMENT OF THE ERRORS OF SERVICE ALTIMETER INSTALLATIONS DURING LANDING-APPROACH AND TAKE-OFF OPERATIONS, Gracey, William; Jewel, Joseph W. Jr.; Carpenter, Gene T. National Aeronautics and Space Administration, Washington, D. C., NASA TN D-463, November 1960

The overall errors of the service altimeter installations on a variety of civil transport, military, and general aviation airplanes have been experimentally determined during the routine landing-approach and takeoff operations. The errors of the installations of 196 airplanes during 415 landing-approaches and of 70 airplanes during 152 takeoffs are presented herein.

175. MERCURY BAROMETERS AND MANOMETERS, National Bureau of Standards, Washington, D. C., Monograph 8, May 1960

176. A METHOD FOR THE SURFACE INSTALLATION AND FAIRING OF STATIC-PRESSURE ORIFICES ON A LARGE SUPERSONIC CRUISE AIRPLANE, Taillon, Norman V. National Aeronautics and Space Administration, Flight Research Center, Edwards, California, NASA TM-X-1530, March 1968, N68-19341

A method for installing and fairing static pressure orifices on the wing surface of a supersonic airplane without penetrating the skin is described.

177. A METHOD OF CALIBRATING AIRSPEED INSTALLATIONS ON AIRPLANES AT TRANSONIC AND SUPERSONIC SPEEDS BY THE USE OF ACCELEROMETER AND ATTITUDE-ANGLE MEASUREMENTS, Zalovcik, John A.; Lina, Lindsay J.; Trant, James P. Jr. Langley Aeronautical Laboratory, Langley Field, Virginia, NACA Report 1145, 1953

A method is described for calibrating airspeed installations on airplanes at transonic and supersonic speeds in vertical-plane maneuvers in which use is made of measurements of normal and longitudinal accelerations and attitude angle. In this method, all the required instrumentation is carried within the airplane.

178. A METHOD OF CALIBRATING AIRSPEED INSTALLATIONS ON AIRPLANES AT TRANSONIC AND SUPERSONIC SPEEDS BY USE OF TEMPERATURE MEASUREMENTS, Zalovcik, John A. Langley Aeronautical Laboratory, Langley Field, Virginia, NACA TN 2046, March 1950

A method is described of calibrating airspeed installations on airplanes at transonic and supersonic speeds by use of instrumentation in the airplane only. The method consists in first making a survey of temperature, static pressure, and total pressure over the desired range of altitudes at speeds for which the airspeed calibration is known. The airplane is then flown at speeds for which the calibration is desired through the range of altitude surveyed, and the measurements of temperature, static pressure, and total pressure are repeated.

179. METHODS OF BAROMETRIC HEIGHT MEASUREMENT, Rossger, E.; Ranike, G. RAE-LIB-TRANS-1090, Translated into English from Z. Flugwiss (Brunswick, W. Germany), Vol. 11, pp. 322-339 (1963), Royal Aircraft Establishment, Farnborough, England

This investigation deals with the meteorological principles of vertical navigation based on measurements of pressure, and with the use of an altimeter, the main scale of which is calibrated in units of altitude. Included is a description of several altimeters of this type, and a discussion of navigational consequences arising from their application. The meteorological principles of altimeters having the main scale calibrated in units of pressure are cited and the features of some of these altimeters examined. Hybrid altimeters are also considered.

180. METHODS OF MEASURING FREE AIR TEMPERATURE AND AIRCRAFT TRUE AIRSPEED AND GROUND SPEED, Brombacher, W. G. National Bureau of Standards, Washington, D. C., NBS Report 5740, January 1958

This survey covers in detail, methods and instrumentation for measuring free air temperature, true airspeed, and ground speed solely from aircraft instrumentation during flight. Included are over 900 pertinent references indexed by both subject matter and author.

181. MINIMUM SAFE ALTITUDE FLIGHT, Obermayer, R. W.; Green, M. R. The Martin Company, Human Engineering Support Group, Baltimore, Maryland, Conference Memo 174, Contract AF 33(616)5472, May 2, 1960

182. A NEW FAIL-SAFE COMPENSATED ALTIMETER, Angst, Walter,; Angus, James American Society of Mechanical Engineers, New York, N. Y., Paper No. 60-AV-45, May 1960

183. A NOTE ON A METHOD OF CORRECTING FOR LAG IN AIRCRAFT PITOT-STATIC SYSTEMS, Charnley, W. J. Aeronautical Research Council, London, England, R & M 2352, August 22, 1950

The lag in pressure reading in a recording instrument in a fast dive may be divided into two parts, one the pressure lag in the tubes connecting the instrument to the pressure source and the other any mechanical lag in the recording instrument itself. In this note, a theoretical solution of the pressure lag in the tubes is developed, and both lab and flight tests are described which show how the solution can be modified, quite empirically, to include the instrument mechanical lag. Methods of reducing the lag to a minimum are outlined.

184. OPERATIONAL SUITABILITY TEST OF C-12 MODIFIED KOLLSMAN ALTIMETER, Air Proving Ground Command, Eglin Air Force Base, Florida, Project No. APG/TAT/148-A, June 15, 1954, AD 36 161

185. ORIENTATION OF ORIFICES ON BODIES OF REVOLUTION FOR DETERMINATION OF STREAM STATIC PRESSURE AT SUPERSONIC SPEEDS, Cooper, Morton; Hamilton, Clyde V. National Advisory Committee for Aeronautics, Washington, D. C., NACA TN 2592, January 1952

Experimental data obtained for a parabolic body of revolution of large fineness ratio at a Mach number of 1.59 and a Reynolds number of 3.6×10^6 have been analyzed to locate positions which will indicate a constant static pressure independent of the pitch-yaw attitude of the body. Results show that by locating two orifices at symmetrical radial positions with respect to the angle-of-attack plane and using a single pressure given by the average of the two orifice readings, appreciable pitch-yaw ranges can be obtained while a constant static pressure is maintained.

186. PANEL ON VERTICAL SEPARATION OF AIRCRAFT - SECOND MEETING - REPORT, Anon, International Civil Aviation Organization, Montreal, Canada, Doc. 7835-AN/863, June 1957

187. THE PHYSICAL BASIS OF ELECTRIC ALTIMETRY,
Zetzmann, H. J. Royal Aircraft Establishment, Farnborough,
England, RAE Library Translation 963, August 1961

The physical principles of the various electrical phenomena that can be utilized for the measurement of height in an aircraft are stated. The merits and shortcomings of the possible techniques are discussed. A bibliography is included.

188. THE PHYSICO-METEOROLOGICAL PRINCIPLES OF BAROMETRIC HEIGHT MEASUREMENT (ALTIMETRY),
Rossger, E.; Ranike, G. Ministry of Aviation, London,
England, RAE Library Translation No. 1018, November 1962

The physico-meteorological principles underlying barometric height measurement (altimetry) are considered. The errors arising from various meteorological conditions are discussed as well as the various subscale settings. The methods at present in use for correcting the indicated altitude by temperature measurements are examined in detail, and the correction formulae which apply to the use of arithmetical and barometric mean temperatures are given.

189. PILOT OPINION SURVEY: THREE-POINTER ALTIMETER,
Green, M. R.; Mengelkoch, R. F. The Martin Company, Human
Engineering Support Group, Baltimore, Maryland, Conference
Memo #161, Contract AF 33(616)5472, January 22, 1960

190. PILOT SIMULATOR PERFORMANCE WITH STANDARD AND VERTICAL READING PRIMARY FLIGHT INSTRUMENTS, ENGINEERING REPORT 10,846, Mengelkoch, R. F.
The Martin Company, Baltimore, Maryland, AF Contract
33(616)5472, August 1959

191. PITOT AND STATIC PRESSURE SYSTEMS, INSTALLATION AND INSPECTION OF, MIL-P-26292C(USAF), Project No. 6610-F123, December 3, 1969, Superseding MIL-P-26292B(USAF),
August 18, 1967

This specification covers the requirements for the installation and inspection of pitot-static tubes, pitot tubes, and flush static ports on aircraft and missiles.

192. PITOT-STATIC PROBES FOR SUBSONIC AND SUPERSONIC AIRCRAFT, Chaffois, J.; Translator Townend, L. N. Royal Aircraft Establishment, Great Britain, RAE LT1032, Trans. from Techniques et Sciences Aeronautiques et Spatiales, Vol. 1, pp. 7-17 (1962), AD 433 145

The problem of measuring reference pressures (stagnation pressure and undisturbed static pressure) is fairly simply solved for subsonic aircraft. On the other hand, for a supersonic aircraft the choice is extremely difficult, particularly for the static measurements.

193. PITOT-STATIC SYSTEMS, Patton, O. E.; Bryan, Samuel Civil Aeronautics Agency, Washington, D. C., CAA Airframe and Equipment Engineering Report 46, October 24, 1950

The summarized information in the report covers design considerations for various types of systems, installation practices and safeguards, calibration techniques, and maintenance procedures.

194. POSITION ERROR CALIBRATION OF THREE AIRSPEED SYSTEMS ON THE F-86A AIRPLANE THROUGH THE TRANSONIC SPEED RANGE AND IN MANEUVERING FLIGHT, Roe, M. North American Aviation, Inc., Los Angeles, California, Report No. NA-51-864, October 5, 1951

This report describes and gives flight test results on a method for determining an airplane correct airspeed and altitude without reference to the ground. The configuration required is a nose boom having a total head orifice and a series of static orifices distributed along the length of the boom.

195. POSITION ERRORS OF THE SERVICE AIRSPEED INSTALLATIONS OF 10 AIRPLANES, Gracey, William Langley Aeronautical Laboratories, Langley Air Force Base, Virginia, NACA TN 1892, June 1949

The "position" errors of the static systems of 10 service airspeed installations including static-pressure vents on the nose and rear section of the fuselage and pitot-static tubes mounted on the wing, the vertical tail, and the fuselage nose are presented. Tests were conducted at speeds between the stalling speed and 260 miles per hour for four flight conditions. Calibrations are analyzed to show variation of static-pressure error with position of static source, angle of attack, flap setting, and engine power.

196. PRECISION PRESSURE ALTIMETERS FOR AIR TRAFFIC SEPARATION AND TERRAIN CLEARANCE (Conference Paper), Melchoir Engineering Corporation, New York, January 1959

197. PRESENTATION OF HEIGHT INFORMATION, Jackson, K. F. International Air Transport Association, Lucerne, Switzerland, Technical Conference Report No. 13/WP-39, May 1960

198. PRESSURE ALTIMETRY IN COLOMBIA, Anon, Federal Aviation Administration, Regional Aviation Assistance Group, Panama, R. P., March 1963

199. PRESSURE LAG IN PIPES WITH SPECIAL REFERENCE TO AIRCRAFT SPEED AND HEIGHT MEASUREMENTS, Smith, Keith Royal Aircraft Establishment, Farnborough, England, RAE Report No. Aero 2507, November 1954

A new method of applying lag corrections in flight is presented. It is based on the results of ground tests employing simulated steady dives and is shown to be more accurate than the method of Charnley using the response to a step input. The errors involved in the measurement of lag in a pullout are considered theoretically and are shown to be just appreciable in certain cases. Instrument lag is also briefly touched upon. A routine procedure for lag correction in flight is set out in paragraph 7.

200. PRESSURE MEASUREMENT FOR PRESSURE ALTIMETRY, Russell, William M. Federal Aviation Administration, Washington, D. C., Report No. RD-64-119, Project No. 320-205-02N, August 1964

The report recommends equipment and maintenance standards for use in pressure altimetry. It covers both measuring pressure for calibrating altimeters and measuring pressure to determine altimeter setting. Specifications for advanced automatic equipment are included. Implementation of the recommended standards should reduce calibration errors to acceptable limits.

201. PRESSURE PROBES USED IN AERODYNAMIC RESEARCH TECHNOLOGY, Wuest, W. In: Wiss. Ges. fur Luft- u. Raumfahrt, Cologne (W. Germany) Aerodynamic Meas. Technol. Proc. of the Meeting of the Subcomm. on Aerodynamic Meas. Technol., Aachen, April 26, 1962, pp. 46-94 In German

The pressure characteristics in both subsonic and supersonic flow are discussed and determined. Also, discussed are: (1) various design of pitot tubes, static-pressure probes, dynamic-pressure probes, and flow-direction probes; and (2) the error effects of flow direction, pressure gradient, wall, viscosity, Mach number, and degree of turbulence on these instruments.

202. THE PROBLEM OF ALTIMETRY AT HIGHER ALTITUDES, von Villiez, Hansjurgen Frhr. Zeitschrift fur Flugwissenschafter Vol. 13, pp. 380-384, October 1965 A66-11987

Discussion of various alternative systems for accurately determining the altitude of aircraft up to altitudes of 80,000 feet. The physically possible and operationally practicable methods of altimetry are reviewed for altitude in the 40,000 to 80,000 feet range. Pressure altimetry error is examined in terms of static pressure error and meteorological error. On the basis of the equipment presently available it can be deduced that instrument accuracy will be on the order of ±1 mb, which corresponds to ±720 feet at 80,000 feet. A common calibration procedure is essential if maximum equipment accuracy is to be obtained.

203. A RADAR METHOD OF CALIBRATING AIRSPEED INSTALLATIONS ON AIRPLANES IN MANEUVERS AT HIGH ALTITUDES AND AT TRANSONIC AND SUPERSONIC SPEEDS, Zalovcik, John A. Langley Aeronautical Laboratory, Langley Air Force Base, Virginia, NACA Report 985, 1950

A method of calibrating the static-pressure source of a pitot-static airspeed installation on an airplane in level flight, dives, and other maneuvers at high altitude and at transonic and supersonic speeds is described. The method principally involves the use of radar-phototheodolite tracking equipment. The various sources of error in the method are discussed and sample calibrations are included.

204. RADIATION PHYSICS: ITS IMPACT ON INSTRUMENTATION, Beavin, Rudy C. Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, ASD-TDR-63-697, September 1963, AD 428 970

Presented in an argument for exploiting radiation physics for the solution of problems in the instrumentation area. A brief review is given of basic physics connected with radiation. Several problems in the flight control area are stated and possible solutions presented using radiation physics concepts. Three of these problems, low altitude altimetry, high altitude altimetry, and fuel mass measurement, are examined in detail and experimental and analytical results given. A program philosophy and the establishment of an in-house experimental facility for exploitation of radiation physics are also reported.

205. RANDOM DEVIATIONS FROM CRUISE ALTITUDES OF A TURBOJET TRANSPORT AT ALTITUDES BETWEEN 20,000 AND 41,000 FEET, Gracey, William; Shipp, Jo Ann National Aeronautics and Space Administration, Langley Field, Virginia, NASA TN D-820, April 1961

The random deviations from the cruise altitudes of a large turbojet transport have been determined from an evaluation of NASA VGH records of 190 scheduled airline flights through an altitude range of 20,000 to 41,000 feet. The results of the study are presented in terms of the altitude deviations at or above which the airplane would be expected to operate for 0.3 percent of the total cruise time.

206. RECENT DEVELOPMENTS IN PRESSURE ALTIMETRY, Gracey, William NASA-TM-X-51619, Journal of Aircraft, Vol. 2, pp. 161-165, 1965

Some of the most significant accomplishments of recent years relating to the improvement of instruments, the measurement and compensation of the errors of static-pressure systems, and the collection of information on the flight technical error are reviewed.

207. RECOMMENDATION ON DESIGN OF PITOT/STATIC SYSTEMS FOR TRANSPORT AIRCRAFT, Anderson, O. E. E. United Airlines, Inc., Chicago, Illinois, Engineering Department Report 8238, July 3, 1963

Recommendations on the design of future altimeter systems for aircraft, based on the suggestions of airline operators, are presented in a form easily assimilated into aircraft specifications. The altimeter systems recommended are servo-corrected system which include the best possible static pressure sensors. Three pitot (total pressure) systems, the captain's, copilot's and an auxiliary, are recommended: and four static systems, the captain's, copilot's, and an auxiliary and an alternate are planned.

208. RECOMMENDATION ON DESIGN OF PITOT/STATIC SYSTEMS FOR TRANSPORT AIRCRAFT, Anderson, O. E. E. United Airlines, Inc., San Francisco, California, United Airlines Report F-1242, February 1970

Replaces that of July 3, 1963 (No. 207) same title.

209. RECOMMENDATION ON FLUSH STATIC PORT MAINTENANCE, Anderson, O. E. E. United Airlines, Inc., Chicago, Illinois, Report No. F-829B, August 12, 1963, N63-22866

An attempt is made to establish comparatively simple methods of measuring and setting limits on surface irregularities on existing airplanes for pressure sensing at flush ports. Static-system test-recommendation topics include leakage, surface measurement, repair methods, and flight testing. A complete reference section is included.

210. RECOMMENDATION ON MAINTENANCE OF PITOT-STATIC SYSTEMS OF TRANSPORT AIRCRAFT, Anon, Air Transport Association of America, Washington, D. C., ATA Recommendation 34-10-4, December 1969

Sets forth maintenance principles and recommended practices for maintaining, and check calibrating pitot-static and flush static pressure systems of transport aircraft.

211. RE-EVALUATION OF DRUM-POINTER ALTIMETER DISPLAY, Harris, Isaac D. Wright Air Development Center, Dayton, Ohio, WCT 59-17, April 1959

212. REPEATABILITY, DRIFT, AND AFTER EFFECT OF THREE TYPES OF AIRCRAFT ALTIMETERS, Gracey, William; Stell, Richard E. National Aeronautics and Space Administration, Langley Field, Virginia, NASA TN D-922, July 1961

The results are presented for a series of laboratory tests of sensitive and precision altimeters to determine the repeatability throughout the full range of the instruments, the drift characteristics during 1-hour periods of various altitudes, and the drift and after-effect for a variety of simulated flight profiles.

213. REPEATABILITY OF THE OVERALL ERRORS OF AN AIRPLANE ALTIMETER INSTALLATION IN LANDING-APPROACH OPERATIONS, Gracey, William; Stickle, Joseph W. National Aeronautics and Space Administration, Langley Field, Virginia, NASA TN D-898, May 1961

The results of flight tests to determine the overall altimetry errors of the service altimeter installation of a transport airplane in the landing-approach condition are presented. Data on two sensitive altimeters and four precision altimeters were obtained for a speed range of 62 to 100 knots during 42 landing approaches.

214. REPORT OF LABORATORY EVALUATION OF F-4 AIRCRAFT MODIFIED CENTRAL AIR DATA COMPUTER, Joeckel, Carl T. Naval Air Development Center, Johnsville/Warminster, Pennsylvania, NADC AM-6820, August 21, 1968

A laboratory evaluation was performed on an F-4 aircraft central air data computer, modified to provide automatic altitude report capabilities. The major modifications to the air data computer include the incorporation of a more accurate altitude sensor and the provision of a two speed synchro output of log altitude. A separate altitude encoder unit was developed to accept the log altitude output of the central air data computer and also to provide an encoded altitude output to the I. F. F. transponder.

215. REPORT OF QUALIFICATION TEST ON BAROMETRIC PRESSURE INDICATOR TYPE 31233-13B-A1, Nelson, R. J. The Bendix Corporation, Davenport, Iowa, CTR-26456006, November 30, 1966, AD 814 443

This is a qualification test report for altimeters submitted to qualification tests. The equipment tested performed satisfactorily and met all test objectives without failure or unusual incident.

216. REPORT ON TEST AND EVALUATION OF KOLLSMAN INSTRUMENT CORPORATION AIRSPEED, MACH NUMBER, AND MINIMUM SPEED INDICATOR, Kalatucka, S. Aeronautical Instruments Laboratory, U. S. Naval Air Development Center, Johnsville, Pennsylvania, Report No. NADC-A1-5680, TED ADC AE-7272, November 9, 1956

The Kollsman Airspeed, Mach Number, Minimum Speed Indicating System incorporates a minimum speed marker which assumes an angular position relative to the airspeed pointer to indicate a qualitative measure of flight speed above stall speed. General operation of the system was good, but further development work is required before it would be satisfactory for service use. The system as submitted approximates the indicator landing requirements for an F9F-5 aircraft and may be suitable for installation on this type aircraft after further development.

217. RESEARCH ON STATIC PRESSURE SOURCES FOR AIRCRAFT, Bartlett, G. E.; Vidal, R. J. Cornell Aeronautical Laboratories, Buffalo, New York, AF Technical Report 5848, March 1954

Analytical and experimental research directed toward devising a method for providing an accurate source of static pressure on aircraft is described. Results of the investigation lead to the conclusion that a computing unit will be an essential part of any highly accurate static pressure source system. Three sensing arrangements; namely, a nose probe, a wing probe, and a flush orifice installation on the fuselage between the wing and tail plane, appear satisfactory and approximately equivalent from the aerodynamic point of view. A simplex fixed probe insensitive to cross-flow in the pitch plane was developed that can replace the swiveling tube as a static-pressure sensing device insensitive to angle of attack for applications where the angles of yaw are relatively smaller than the angle of attack variations encountered.

218. RESULTS OF SPECIALTIES ALTIMETER PILOT OPINION SURVEY, Mengelkoch, R. F. The Martin Company, Human Engineering Support Group, Baltimore, Maryland, Conference Memo No. 171, Contract AF 33(616)5472, March 28, 1960

219. RESULTS OF THE 1965 FLIGHT-DECK DATA COLLECTION ON HEIGHT KEEPING OVER THE NORTH ATLANTIC, Anderson, R. G. Royal Aircraft Establishment, Farnborough, England, RAE TR No. 65268, November 1965

In response to a recommendation of the special NATRAN meeting of the I. C. A. O. at Montreal in February 1965, the International Air Transport Association has collected flight-deck records of altimeter readings on 11,000 trans-atlantic jet flights in the period April to August 1965. These data do not, on their own, suffice to determine that the vertical separation standard above FL 290 may be safely reduced.

220. RESULTS OF TRAILING CONE TESTS ON PAA JET AIRCRAFT, Nairn, J. B. Pan American Airlines, Miami, Florida, PAA Report SC-65-6, September 9, 1965

Flight tests results using a trailing cone reference for 27 aircraft which includes 8 types of operational transport category jet transports are shown graphically.

221. REVIEW OF AIRCRAFT ALTITUDE ERRORS DUE TO STATIC PRESSURE SOURCE AND DESCRIPTION OF NOSE BOOM INSTALLATIONS FOR AERODYNAMIC COMPENSATION OF ERROR, Gracey, William; Ritchie, Virgil S. National Aeronautics and Space Administration, Langley Field, Virginia, NASA Memo 5-10-59L, June 1959

Aircraft altitude errors due to static-pressure source are briefly reviewed. Wind-tunnel test information concerning nose boom pressure installations for aerodynamically compensating static-pressure errors due to position and angle of attack at subsonic and low supersonic speeds are also presented.

222. REVIEW OF WADD RESEARCH AND DEVELOPMENT EFFORTS ON ALTIMETRY, Stone, John T. Flight Control Laboratories, Wright-Patterson Air Force Base, Ohio, April 1960

223. SCALING OF ALTITUDE INFORMATION: AN ANALYTIC STUDY, Gainer, Charles A. The Martin Company, Human Engineering Support Group, Baltimore, Maryland, Conference Memo No. 101, AF Contract 33(161)5472, June 4, 1958

224. SCOPE OF THE 1965 FLIGHT-DECK DATA COLLECTION ON HEIGHT KEEPING IN THE NORTH ATLANTIC, Anderson, R. G.; Reich, P. G. Royal Aircraft Establishment, London, England, Technical Memo No. Math 66, May 1965

The special N. A. T. meeting of I. C. A. O., March 1965, recommended that flight-deck data be collected under the auspices of I. A. T. A. to assist in the assessment of the feasibility of a reduction in the 2,000 feet vertical separation, for jets above 29,000 feet. This memo discusses the information which is being obtained, outlines the sources of error not covered and considers the probable validity of the results.

225. SEVERAL METHODS FOR AERODYNAMIC REDUCTION OF STATIC-PRESSURE SENSING ERRORS FOR AIRCRAFT AT SUBSONIC, NEAR-SONIC, AND LOW-SUPERSONIC SPEEDS,
Ritchie, Virgil S. National Aeronautics and Space Administration, Langley Field, Virginia, NASA TR R-18, 1959

Several methods for aerodynamic reduction of errors in sensing static pressures at subsonic, near-sonic, and low-supersonic speeds were investigated. The tests were conducted at Mach numbers from 0.4 to 1.2 for angles of attack from 0° to 8°. The principal static-pressure error investigated was that due to position of pressure-sensing device ahead of airplane fuselage or missile nose; a suitable means for estimating this error was provided. A method of error compensation by use of probe surface induced pressures is described.

226. SERVICE TEST OF THE AN/APN-22 ABSOLUTE ALTIMETER AND LOW-ALTITUDE MODIFICATION, AN/APN-117,
Army Aviation Board, Fort Rucker, Alabama, Project No. AVN 1257, July 31, 1959

A service test was made of the AN/APN-22 Absolute Altimeter (and the low-altitude modification, AN/APN-117) to determine its suitability to satisfy the Army's requirement for an absolute altimeter in helicopters and fixed-wing aircraft. The AN/APN-22 performed satisfactorily in both fixed- and rotary-wing aircraft over the range of altitudes tested (0 to 10,000 feet). The AN/APN-117 (a low-altitude modification of the AN/APN-22) was not as reliable as the AN/APN-22. The AN/APN-22 is considered suitable for Army use. The AN/APN-117 is considered unsuitable for Army use.

227. SIMULATOR TEST OF KOLLSMAN DRUM-POINTER ALTIMETER, COUNTER-POINTER ALTIMETER, AND SPECIALTIES ALTIMETER,
Gainer, C. A.; Brown, J. E. The Martin Company, Baltimore, Maryland, Engineering Report 11,787, June 1961

Twenty-four pilots flew a simulator over a standardized profile using the drum-pointer altimeter, the Kollsman counter-drum-pointer altimeter, and the Specialties altimeter. An analysis was made of performance in terms of root-mean-square and average error as a function of altimeter, maneuvers, altitude ranges, and order of altimeter presentation. The results indicate that the drum-pointer altimeter was superior to those altimeters tested in conjunction with it.

228. SMALL LIGHTWEIGHT ALTITUDE TRANSMISSION EQUIPMENT, Hazeltine Corporation, Hazeltine Electronics Division, Little Neck, New York, Report No. 10136, Project No. 108-28-1D, FAA Contract ARDS-558, April 15, 1964

229. SOLID STATE, DIGITAL TYPE PRESSURE TRANSDUCER, Intraub, Julius Sixth International Aerospace Instrumentation Symposium, Kollsman Instrument Corporation, Elmhurst, New York, TP-69-4, 1970

This report describes a new approach for solid state, digital, precision pressure measurement developed over the past three years. The basic principle is the variation in natural frequency of typical aneroid capsules caused by pressure induced curvature changes. In addition to detailed performance data of the "Resonant Capsule Pressure Transducer," a specific application, the design of an air data, static/pilot pressure system is described.

230. SPECIFYING THE CALIBRATION OF STATIC PRESSURE SYSTEMS FOR THE SAFE USE OF 1,000-FOOT VERTICAL SEPARATION STANDARD IN NORTH ATLANTIC JET TRAFFIC, Reich, P. G.; Anderson, R. G. Royal Aircraft Establishment, Farnborough, England, RAE TR 66156, May 1966

The collision risk associated with the use of a 1,000-foot separation standard for North Atlantic jet traffic in the period 1966-71 is related to the quality of aircraft height-keeping. By allowing for those component errors of height-keeping that have already been measured, safety from collision is related directly to measures of the quality with which the altimeter static pressure system is calibrated and maintained. Suggestions are made for the form of the initial calibration and for checks to guard against the effects of subsequent damage which may invalidate it. Evidence is offered on the durability of a calibration, and hence, on the frequency of checking that is consistent with a given level of safety from collision.

231. STATIC-PRESSURE ERROR CALIBRATIONS FOR NOSE-BOOM AIRSPEED INSTALLATION OF 17 AIRPLANES, Larson, Terry J.; Stillwell, Wendell H.; Armistead, Katherine H. National Advisory Committee for Aeronautics, Edwards, California, NACA RM H57A02, March 1957

Static-pressure error calibrations made for nose-boom airspeed installations of 17 airplanes are presented. The calibrations are given in the form of true Mach number against indicated Mach number, Mach number error, and static-pressure error per recorded impact pressure. Static-pressure errors are compared and are shown to be dependent on nose-boom length, fuselage diameter, and nose fineness ratio. Information is presented to provide a useful means for predicting the static-pressure errors for similar airspeed installations.

232. STATIC-PRESSURE ERROR OF AN AIRSPEED INSTALLATION ON AN AIRPLANE IN HIGH-SPEED DIVES AND PULL-OUTS, Zalovoik, John A.; Wood, Clotaire National Advisory Committee for Aeronautics, Langley Field, Virginia, NACA WRL-43, NACA RB No. L5K29a, February 1946

Tests were made in high-speed dives and pullouts to determine, by combined radar-optical tracking equipment, the static pressure error of an airspeed-head installation on a P-51B airplane. The installation included a pitot-static head mounted on a boom 95 percent chord ahead of the leading edge of the wing near the tip. The tests were made in dives at flight Mach numbers up to 0.75 and included pullouts up to 4g normal acceleration. The results indicated that the static pressure error did not vary with Mach number by more than about 1 percent of the impact pressure over the range of conditions investigated.

233. A STATIC PRESSURE PROBE THAT IS THEORETICALLY INSENSITIVE TO PITCH, YAW, AND MACH NUMBER, Smith, A. M. O.; Brumby, R. E. McDonnell-Douglas Corporation, Long Beach, California, McDonnell-Douglas Report DAC-66624, May 1, 1968

The report describes a special static pressure probe which is insensitive to angle-of-attack, pitch, and yaw up to $\pm 10^{\circ}$ and relatively insensitive to Mach number from subsonic through the supersonic range.

234. A STUDY OF ANGLE-OF-ATTACK, ANGLE-OF-SIDESLIP, PITOT-STATIC PROBES, Smetana, Frederick O.; Stuart, Jay Jr. University of Southern California, Los Angeles, California, WADC TR 57-234, January 1957

The requirements for means to measure angle-of-attack, angle-of-sideslip, pitot and static pressure are stated. A survey of the literature indicates that the requirements for pitot and static pressure measurements can be met with refinements of existing techniques of those presently under development. Measurement of angle-of-attack and angle-of-sideslip without recourse to devices which have moving parts external to the aircraft was found to be in a more elementary state of development. The result of the literature survey indicated that the most suitable method fitting these instruments was either a fixed-type or a pressure sensing system.

235. STUDY OF ATTITUDE CHANGE TOWARD EQUIPMENT DESIGN, EFFECTS OF BRIEF EXPERIENCE VERSUS PRINTED COMMUNICATION OF ALTIMETER PREFERENCE, Matheny, W. G.; Berger, Philip K. Life Sciences, Inc., Fort Worth, Texas, Report No. TR-1, October 1964, AD 614 655

The study was undertaken in an effort to gain a better understanding of the problem of resistance to change and how such resistance may be counteracted. The report discusses and illustrates some of the problems surrounding the methodology for investigating equipment preferences and reports the results of a preliminary investigation into procedures for producing changes in preference for new equipment. The selection of the altimeter as an instrument for use in the study was based upon the fact that suitable data was available as to the relative adequacy of the two instruments chosen and that the altimeter is an instrument around which controversy still revolves.

236. STUDY OF ATTITUDE CHANGE TOWARD EQUIPMENT DESIGN, THE MEASUREMENT OF ALTIMETER DISPLAY PREFERENCE AND AN INVESTIGATION OF PREFERENCE CORRELATES, Berger, Philip K. Life Sciences, Inc., Fort Worth, Texas, Report No. TR-2, August 1965

The purpose of this study was to evaluate the test-retest reliability of two single item measures of altimeter preference and to investigate some correlates of display preference. One altimeter display has been operational for many years (MA-1 Three Pointer) while the second display is a development design (Moving Tape Single Pointer). Adequate reliability for the two preference measures was demonstrated.

237. A STUDY OF REQUIREMENTS FOR EVALUATION OF AIRCRAFT INSTRUMENTS BY SIMULATION METHODS, Baldwin, L. C. Naval Air Test Center, Patuxent River, Maryland, Report ST03-27R-64, March 25, 1964, AD 433 949

General requirements for a Simulation Laboratory designed to evaluate instrument systems for a wide range of naval aircraft, including fixed, rotary wing and V/STOL were determined. A cockpit simulator with moving base, several visual and electromagnetic sensor simulator devices, and computer facilities are essential elements. A preliminary layout of the laboratory, a development plan and schedule, and funding and staffing requirements are presented. Simulation techniques extend the science to aircraft testing, provide means to reduce testing time and cost and improve safety. Acceptance of a four-year funding and development plan, and establishment of the Simulation Laboratory at the Naval Air Test Center are recommended.

238. A STUDY TO DETERMINE AN OPTIMUM ALTIMETER PRESENTATION, Beldam, F. E. M. Royal Canadian Air Force Institute of Aviation Medicine, Toronto, Canada, Report No. 59/2, May 1, 1959

239. SUBSONIC AIR DATA COMPUTER SYSTEM, Airlines Electronic Engineering Committee, Annapolis, Maryland, ARINC Characteristic No. 545 (including Supplement 1), October 1, 1961

The Air Data System is an airborne instrumentation system which obtains static pressure and pitot pressure from the usual pitot-static sources on the aircraft, along with total temperature from a temperature probe on the aircraft and computes correct altitude, Mach airspeed, temperatures, and other outputs, including corrections to each of these outputs necessary because of the characteristics of the particular aircraft.

240. SUBSTANTIATION OF THE PRESSURE RECOVER CHARACTERISTICS OF THE REVISED STATIC PORT CONFIGURATION FOR THE 727 AND 707 AIRPLANES, Cashman, J. E. The Boeing Company, Renton, Washington, Report No. D6-22642, January 10, 1969

Revised static port configurations have been developed for the 727 and 707 airplanes to improve water drainage characteristics of the static lines in the event water enters or condenses in the static systems. The modified configurations differ from the present standard ports in that the six 0.047-inch diameter holes surrounding the single 0.125-inch diameter hole are replaced by six 0.125-inch diameter holes. The demonstration showed nearly identical pressure recovery characteristics over a range of four simulated airplane flight conditions, the maximum difference between the two ports being less than 10 feet of altitude error at 35,000 feet.

241. SUGGESTIONS FOR THE STANDARDIZATION OF TEST PROCEDURES FOR BAROMETRIC ALTIMETERS AND PRESSURE-HEAD SPEED INDICATORS, Nickel, E.
Deutsche Forschungsanstalt fur Luft - und Raumfahrt Brunswick (W. Germany), Inst. fur Luftfahrzeugfuhrung, 1963, N64-17543

Barometric altimeter measurement (on the basis of the pertinent standard atmosphere) and velocity-head speed indications (on the basis of the current hydrodynamic and gas dynamic laws) are discussed. The use of a scale reference temperature, instrument adjustments, and calibration tests are suggested in order to improve the accuracy of altimeter recordings. The physical interrelations between the altimeter and the indicator are described. The following are mathematically treated: (1) the relationship between altitudes, in geometrical length units, and geo-potential altitude; (2) pressures at geometrical altitudes and the respective densities in altitude units; (3) geometrical altitude from the pressure at that altitude; (4) the relationship between the velocity head in the subsonic and supersonic area; (5) the velocity of sound, in different units, at different temperatures and altitudes; and (6) the calculation of a local acceleration due to gravity.

242. SURVEY AND PRELIMINARY EVALUATION OF BAROMETRIC ALTIMETRY TECHNIQUES, FINAL REPORT, Harlan, Raymond B.
Massachusetts Institute of Technology, Cambridge Measurement Systems Laboratory, Cambridge, Massachusetts, NASA-CR-86242, October 2, 1969

This report summarizes a brief survey of the state-of-the-art of barometric altimetry with emphasis on the problems concerning vertical separation of aircraft. Consideration of the terminal phase of flight is omitted because the future role of barometric altimetry during this phase is questionable. Research on landing aids is centered principally on automated radiation systems for use under low visibility conditions.

243. SURVEY OF ALTIMETER INSTRUMENT AND POSITION ERROR FOR CAR 3 TYPE AIRCRAFT, Shrager, Jack J. FAA, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, Memorandum Report Project 115-22D, October 1962

244. SURVEY OF ALTITUDE-MEASURING METHODS FOR THE VERTICAL SEPARATION OF AIRCRAFT, Gracey, William Langley Research Cneter, Langley Field, Virginia, NASA TN D-738, March 1961

An evaluation of altitude-measuring methods based on measurement of gravity, acceleration, atmospheric pressure and density, cosmic-ray and magnetic field intensities, capacitance, and radio and sound wave propagation is presented. Each of the methods is evaluated primarily for the high-speed, high-altitude cruise condition. Estimates are given for the overall errors of pressure-measuring systems which incorporates various types of limited-range and full-range instruments.

245. SURVEY OF THE ERRORS OF PRESSURE MEASURING INSTRUMENTS IN RELATION TO AIR TRAFFIC SEPARATION STANDARDS, Anderson, R. G. Royal Aircraft Establishment, Farnborough, England, RAE TR 65262, December 1965

A simple account is given of the accuracy of height and speed measurements in current types of aircraft. Estimates of the errors likely to be encountered at jet cruising levels are given together with an outline of the conditions which should be met before any reduction in separation standards can be justified.

246. A SYSTEMATIC METHOD FOR DETERMINING THE BEST ALTIMETER DISPLAY FOR HIGH PERFORMANCE AIRCRAFT, Master's Thesis, Heininger, Howard G. Jr. School of Engineering and Applied Sciences, George Washington University, Washington, D. C., February 22, 1966, AD 638 318

The methodology was implemented by conducting static and dynamic laboratory testing. The results of the testing were thoroughly analyzed and presented to the Air Force and the Navy. As a result, the Air Force and the Navy standardized upon the counter-drum-pointer altimeter display. The display should also reduce the number of aircraft accidents caused by altimeter reading errors. The methodology was further refined and extended so that it can be utilized in future flight display developments and evaluations.

247. THE TEST OF THE AEROSONIC CORPORATION TYPE AR-35-MA ALTITUDE REPORTING ALTIMETERS (SECOND SUBMISSION), Mitchell, H. U. S. Naval Air Development Center, Johnsville/Warminster, Pennsylvania, NADC AM 6519, February 1, 1966

The Aerosonic Corporation Altitude Report Altimeter is a self-contained static pressure operated instrumented designed to provide the aircraft pilot with a display of pressure altitude in the range -1,000 to +35,000 feet and simultaneously provide an encoded altitude output based on standard sea level pressure. The encoded altitude output is provided to IFF transponders for use in automatic altitude reporting. The results of laboratory tests of the two altimeters comprising the second submission are reported.

248. TEST OF TRAIL CONE SYSTEM TO CALIBRATE STATIC PORTS FOR BAROMETRIC ALTIMETERS, Shrager, Jack J. FAA, National Aviation Facilities Experimental Center, Atlantic City, New Jersey, Report No. RD-64-156, December 1964

An experimental trail cone stabilized static source system was fabricated and tested during various towing aircraft at speeds up to 1.12 Mach number to determine its suitability as a "standard" method for determining altimeter static pressure error. Flight tests were conducted at sea level, 5,000 to 10,000, 15,000, 25,000, 30,000 and 40,000 feet, to determine the static pressure defect of the trailing cone system. Test results indicated that the experimental system had a nominal "position error" equal to +12 feet at sea level and ±30 feet at 30,000 feet.

249. TEST SET, AUTOMATIC ALTITUDE REPORTING ENCODERS AND ALTIMETERS TTU-229/E (REVISION B), Part II of Two Parts, Kollsman Instrument Corporation, Elmhurst, New York, Spec. No. CP189 60010000, (DOD AIMS 65-852 II)

250. TRAIL CONE STATIC SYSTEM CALIBRATION TECHNIQUES, Russell, William M. In: International Air Transport Association Technical Conference, 16th, Miami, Florida, April 22-30, 1965, Working Papers, Volume 2, WP/105, 14 pages

The results of a test program conducted on the trail cone technique are depicted graphically. All errors found were well within the accuracy of the calibration techniques used to measure the errors. The report concludes that the trail cone is a suitable, economical method of measuring static system position errors.

251. TRAILING CONE METHOD OF MEASURING STATIC SOURCE POSITION ERROR, EVALUATION AND CALIBRATION PHASE, FIRST INTERIM REPORT, Mickle, Don A.; Soderquist, Robert H. U. S. Naval Air Station, Patuxent River, Maryland, Report No. FT2123-56R-64, WEPTASK No. RAV09P003/2011/F012-04-05, Problem No. 35, August 17, 1964

The trailing cone static source equipment was designed to measure actual ambient pressure from which accurate pressure altitude is derived. The equipment was evaluated and calibrated in an F-8C airplane from 130 kt IAS at sea level to 500 kt IAS (1. 37 Mach) at 35, 000 feet. The position error was negligible throughout this range which is unique particularly in the transonic region. The trailing cone exhibited positive dynamic stability from 170 kt IAS to 550 kt IAS at altitudes from sea level to 40, 000 feet except during wing transition at airspeeds below 170 KIAS.

252. TRAILING CONE REFERENCE SYSTEM, Watson, E. T. Jr. Douglas Aircraft Company, Inc., Long Beach, California, Report No. DEV-3674, November 30, 1964

In the quest for an improved reference system with which to calibrate the static portions of an airplane's airspeed system, a new system, the trailing cone, was investigated.

253. TRAILING CONE TESTS IN LARGE TURBOJET, Russell, Wm. M. Federal Aviation Administration, Washington, D. C., Report No. RD-66-15, Project No. 320-205-02N, March 1966, AD 650 142

The report explains FAA tests in a large turbojet airplane of the trailing cone technique for measuring static source error. Several items pertinent to conducting trailing cone calibration are also discussed.

254. TRANSONIC WIND TUNNEL TEST OF TWO PITOT-STATIC PROBES DESIGNED FOR PRESSURE-ERROR COMPENSATION ON THE RC-4C (RF-110) AIRCRAFT, Anon, Arnold Engineering Development Center, Arnold Air Force Station, Tennessee, AEDC TDR64-44, February 1964, AD 431 534

255. USAF IMPROVED ALTIMETRY SYSTEMS, Marshall, Philip R.
In: AEDC Processings of the 13th Annual Air Force Science and Engineering Symposium, Vol. III, 34 pages (1966)

This paper discusses the accuracy limits of altimetry systems being considered as requirements, the problems associated with the systems that must be resolved to meet the requirements, and results of various development and test efforts aimed at providing improved altimetry. Specific factors discussed are: (1) vertical separation criteria, (2) static pressure systems, (3) altitude computers, (4) servo-pneumatic altimeters, and (5) altimeter displays.

256. VERTICAL INSTRUMENTS, Kearns, J. H.; Warren, E.
North Atlantic Treaty Organization, Advisory Group for Aeronautics Research and Development, Paris, France, AGARD Report 404, 1962

This report is a discussion of vertical scale instruments covering the historical facts which lead to their design through to their application. The point is made that vertical instruments represent the foundation of a new approach to the creation, design, and development of displays. This was our first attempt to deliberately design displays so that they would be suited to the total system job.

257. WIND-TUNNEL INVESTIGATION OF A NUMBER OF TOTAL-PRESSURE TUBES AT HIGH ANGLES OF ATTACK,
Gracey, William; Coletti, Donald E.; Russell, Walter R.
National Advisory Committee for Aeronautics, Langley Aeronautical Laboratory, Langley Field, Virginia, NACA TN 2261, January 1951

A wind-tunnel investigation has been conducted to determine the effect of inclination of the air stream on the measured pressure of 20 total-pressure tubes through an angle of attack of -15° to 45° at Mach numbers 1.62, 1.94, and 2.40. Results obtained with these same tubes at subsonic speeds have been previously reported in NACA RM L50G19. The present tests also showed that the effect of the various design variables was the same at supersonic speeds as at subsonic speeds. The performance of cylindrical tubes was superior to that of tubes having conical- and ogival-nose shapes. Sharp leading edges and impact openings which were large with respect to the diameter of the tube were also shown to increase the performance of the tube.

259. WIND-TUNNEL TESTS OF SEVEN STATIC-PRESSURE PROBES AT TRANSONIC SPEEDS, Capone, Francis J. National Aeronautics and Space Administration, Langley Research Center, Langley Field, Virginia, NASA TN D-947, November 1961

The errors of seven static-pressure probes mounted very close to the nose of a body of revolution were determined at Mach numbers from 0.80 to 1.08 and at angles of attack from -1.7° to 8.4°.

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