REPORT No. 125

AERONAUTIC INSTRUMENTS
SECTION I

GENERAL CLASSIFICATION OF INSTRUMENTS AND PROBLEMS INCLUDING BIBLIOGRAPHY

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Bureau of Standards

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INTRODUCTION.

This report is Section I of a series of papers, comprising a general report on aeronautic instruments, published as Technical Reports Nos. 125 to 132, inclusive, which contain the results of investigations on aeronautic instruments by the Bureau of Standards and which have been prepared under research authorizations formulated and recommended by the subcommittee on aerodynamics and approved by the National Advisory Committee for Aeronautics. Much of the material contained in this report was made available through the cooperation of the War and Navy Departments.

As authorized by the committee on aerodynamics, these reports include a complete account of the status of aeronautic instruments at the end of the war and cover the subject in detail up to the beginning of the year 1920. Since that date nearly a year and a half has been required for the actual preparation of the manuscripts, which represent the cooperative effort of eighteen individual authors, many of whom have left the Government service. Report No. 132, by Dr. F. L. Hunt, now Chief of the Aeronautic Instruments Section of the Bureau of Standards, serves to bridge this gap by giving a brief statement of recent developments. The bibliography also has been kept complete up to the moment of going to press.

Technical Reports Nos. 126 to 131, inclusive, contain a systematic, illustrated description of American, British, French, Italian, Swiss, Dutch, Danish, Austrian, and German aircraft instruments, together with methods of testing developed by the Bureau of Standards, and brief statements of investigation results. In compiling the material for these reports, separate papers have been written by experts on the respective types of instruments, as, for example, altimeters, tachometers, or oxygen apparatus.

Subjects which are common to instruments in general are treated in this report. Throughout the series of reports emphasis has been placed on the description of successful types of instruments and the exposition of fundamental scientific principles, while the space devoted to investigations and developments of transitory interest has been reduced to a minimum. In this way it is expected that the reports will be of permanent value for reference.

SUMMARY.

This report is intended as a technical introduction to the series of reports on aeronautic instruments. It presents a discussion of those subjects which are common to all instruments. In the first place, a general classification is given, embracing all types of instruments used in aeronautics. The arrangement of information dealing with these various instruments throughout the reports is then briefly indicated as a guide to the reader. Finally, a classification is given of the various problems confronted by the instrument expert and investigator. In this way the following groups of problems are brought up for consideration: First, problems of mechanical design; second, human factor; third, manufacturing problems; fourth, supply and

selection of instruments; fifth, problems concerning the technique of testing; sixth, problems of installation; seventh, problems concerning the use of instruments; eighth, problems of maintenance; ninth, physical research problems. This enumeration of problems which are common to instruments in general serves to indicate the different points of view which should be kept freshly in mind in approaching the study of any particular instrument.

CLASSIFICATION OF INSTRUMENTS.

Instruments used in aeronautics may be classified first of all into three general groups according as they are used on the ground; or sent up into the air on kites and balloons, solely for aerological purposes; or installed on board navigable aircraft. Briefly, these three groups may be designated as ground instruments, aerological instruments, and aircraft instruments.

Ground instruments comprise aircraft location instruments, meteorological, and laboratory instruments. Aircraft location instruments include, first, those used for detecting the approach of hostile aircraft, usually acoustic in principle; second, instruments for measuring the altitude or speed of aircraft from the ground, based upon transits or other sighting devices; third, course-tracing instruments, such as the camera-obscura and recording theodolites. Laboratory instruments for aeronautic work include, besides wind-tunnel and power-plant testing equipment, the necessary standard or master instruments for use in calibrating aircraft instruments.

Aerological instruments may be put into four groups according as they are sent up on kites and pilot balloons, or in captive balloons, in free balloons, or in navigable aircraft. In the first case only recording instruments are wanted, and the altitude range may need to be exceedingly high. Maximum indicators have an application here as well as those yielding continuous records. For captive balloons the need of instruments would seem to be a minimum, but might include the aneroid barometer and anemometer. For free balloons the anemometer, or air-speed indicator, would not serve any purpose, but the altimeter and compass and a ground-speed indicator would be desirable, and a statoscope indispensable for delicate indications of ascent or descent. For preserving a record of the trip and investigating air conditions encountered, the various aerographic instruments would be used, including barograph, thermograph, and hygrograph. Aerological instruments may, finally, be installed in airplanes and dirigibles for investigation of atmospheric conditions, or, as in the case of the strut thermometer, to secure data needed for reducing performance tests to standard atmospheric conditions. The term aerological is employed in these reports to distinguish instruments used in studying the structure of the atmosphere from those needed as an aid to flying. The latter will be referred to as aircraft instruments.

Aircraft instruments are fundamentally divided into two groups, those designed for experimental purposes and those furnished as a part of the regular service equipment of aircraft. Experimental instruments must be capable of more accurate results than service instruments, and the self-recording feature is desirable, but the designer has considerable latitude in attaining these objects. In contrast with this, service instruments, though less sensitive and precise, must be sufficiently reliable under a more severe range of conditions; and they must be direct-reading without elaborate corrections, not easily deranged, and possessing minimum bulk and weight.

Experimental instruments differ somewhat in operation and in requirements according as they are designed for routine performance testing, for steady flight investigations, for stunting and accelerated flight, or for competitive altitude records.

Service instruments, on the contrary, are designed more with reference to the type of aircraft than the character of the flight, since the latter is indeterminate. While the majority of service instruments are the same for all aircraft, some are specially adapted for seaplanes, others for multiple engine craft, and, finally, additional instruments such as gas-bag manometers and thermometers, water-ballast gauges, ballonet volume indicators, and hydrogen detectors may be needed for lighter-than-air craft.

These various classifications are shown concisely in Table I.

TABLE I.

INSTRUMENTS USED IN AERONAUTICS.

I. GROUND INSTRUMENTS.

- A. AIRCRAFT LOCATION INSTRUMENTS.
  - For detection.
  - For speed measurement.
  - For course tracing.
- B. METEOROLOGICAL INSTRUMENTS.
- C. LABORATORY INSTRUMENTS.
  - For wind tunnels, power-plant testing, etc.
  - For calibration of aircraft instruments.

II. AEROLOGICAL INSTRUMENTS.

- A. FOR KITES AND PILOT BALLOONS.
- B. FOR CAPTIVE BALLOONS.
- C. FOR FREE BALLOONS.

III. AIRCRAFT INSTRUMENTS.

- A. EXPERIMENTAL INSTRUMENTS.
  - For routine performance testing.
  - For steady flight investigations.
  - For stunting and accelerated flight.
  - For competitive altitude records.
- B. SERVICE INSTRUMENTS.
  - Instruments common to all aircraft.
  - Instruments adapted for seaplanes.
  - Instruments for multiple engine craft.
  - Additional instruments for airships.

Service instruments may further be classified with reference to the respective physical measurements made; this has been done more or less completely in Table II.

TABLE II.

SERVICE INSTRUMENTS.

1. ALTITUDE INSTRUMENTS.
   - (*a*) Altimeters and barographs.
   - (*b*) Statoscopes and rate-of-climb indicators.
   - (*c*) Aerographic instruments.
2. SPEED INSTRUMENTS.
   - (*a*) Air speed indicators.
   - (*b*) Ground speed indicators.
3. DIRECTION INSTRUMENTS.
   - (*a*) Inclinometers and banking indicators.
   - (*b*) Stabilizers.
   - (*c*) Compasses and turn indicators.
4. POWER-PLANT INSTRUMENTS.
   - (*a*) Tachometers.
   - (*b*) Thermometers.
   - (*c*) Pressure gauges.
   - (*d*) Gasoline depth gauges and flow meters.
5. OXYGEN AND OTHER ACCESSORY INSTRUMENTS.
6. NAVIGATING INSTRUMENTS.

The first five groups meet the requirements of local aviation, while those of the sixth group (navigation instruments) are needed for long-distance flights. Local aviation instruments may be divided into general flying instruments, power-plant instruments, and accessory instruments. The general flying instruments are classified as altitude, speed, or direction instruments, and shown here by groups 1, 2, and 3. Power-plant instruments are represented by group 4. Oxygen apparatus for the aviator constitutes the most important of the accessory instruments, group 5, although bombsights and other military or photographic equipment might also be included here, together with hydrogen detectors, buoyancy computers, and other airship accessories.

COMPOSITION OF THE SERIES OF REPORTS.

Substantially the foregoing classification (Table II) has been adopted for the framework of these reports, which deal primarily with service instruments. To a less extent experimental, aerological, and laboratory instruments are likewise discussed and grouped under the same general headings. The six classes in Table II correspond respectively to Reports Nos. 126 to 131, inclusive.

Thus, Report No. 126 covers the general field of altitude instruments and closely-related subjects in the following papers:

Part I, by A. H. Mears, H. B. Hendrickson, and W. G. Brombacher, on altimeters and barographs;

Part II, by J. B. Peterson and J. R. Freeman, jr., on precision altimeter design;

Part III, by A. H. Mears, on statoscopes and rate-of-climb indicators;

Part IV, by J. A. C. Warner, on aerographic instruments.

Report No. 127, dealing with aircraft speed instruments, by F. L. Hunt and by H. O. Stearns, is composed of one part descriptive of air-speed indicators, a second on testing methods, and a third on principles of ground speed measurements.

Direction instruments, a complex group, are brought together in Report No. 128, in the following papers:

Part I, by W. S. Franklin and M. H. Stillman, covering inclinometers and banking indicators, including all necessary gyroscopic principles;

Part II, by R. L. Sanford, dealing specifically with methods adopted for testing magnetic compasses;

Part III, by J. A. C. Warner, comprehensively describing compasses;

Part IV, by R. C. Sylvander and Lieut. E. W. Rounds, U. S. N., describing turn indicators.

Report No. 129 includes the numerous power-plant instruments in five parts, as follows:

Part I, by G. E. Washburn, dealing with aircraft tachometers;

Part II, by R. C. Sylvander, on testing methods for tachometers;

Part III, by E. F. Mueller and R. W. Wilhelm, on thermometers for aircraft engines.

Part IV, by H. N. Eaton, on pressure gauges;

Part V, by J. A. C. Warner, on gasoline depth gauges and flow meters.

Report No. 130, by F. L. Hunt, presents a complete account of oxygen equipment for the aviator.

Report No. 131, by H. N. Eaton, is a comprehensive report on modern navigating instruments for long-distance flight, including radio equipment. This subject is approached from the standpoint of aerial navigation methods rather than that of the physical operation of the instruments. Passing from one problem of navigation to another, the instruments needed are described in turn. This paper naturally overlaps with several of the others; for example, in the case of air-speed indicators and compasses, because the navigator has to depend on all of the instruments to some extent in addition to his own special equipment. In such instances reference can be made to other reports of the series for the details of mechanical construction, so that it remains only to discuss those characteristics of the instrument pertaining to the navigation problem itself, especially questions concerning the accuracy attainable.

This understanding of the general arrangement of subject matter should make it possible for the reader to locate a given topic without any alphabetical index by reference to the table of contents at the beginning of each report. In one or another of these tables every instrument discussed in the body of the reports will be found listed, taking usually the maker's name or trade name as its designation. Altogether in Reports Nos. 126 to 131, inclusive, some 250 different instruments are specifically described, aside from testing equipment. (Practically all of the more important of these instruments have been available for examination in the Government instrument collection maintained at the Bureau of Standards in Washington.)

While the general outline or plan of these reports was entirely the work of the Aeronautic Instruments Section, organized by the author under the personal supervision of Dr. Stratton, all departments of the bureau have been freely called upon for cooperation. Thus wind tunnel tests were made in cooperation with the staff of the aerodynamic laboratory, other tests were carried on with the facilities of the low temperature laboratory, and the contributions of Messrs. Freeman, Stillman, Sanford, and Mueller and Wilhelm were made possible through courtesy of the metallurgy, weights and measures, electrical, and heat divisions, respectively.

Any adequate attempt to acknowledge cooperative assistance received from outside the circle of those who participated directly in this work would develop almost into a complete catalogue of the aviation authorities and instrument experts in the United States and allied countries. However, the authors and compilers of these reports cordially recognize these innumerable courtesies, in the absence of which the reports could not have been made at all complete.

CLASSIFICATION OF PROBLEMS.

While the concrete details of the respective instruments will be thoroughly taken up in the subsequent papers, there are some problems common to all instruments which may well be considered first. Such problems originating in the study of one particular instrument, oftentimes lead to a general solution which can later be applied with advantage to other instruments presenting analogous questions. Moreover, it ought to stimulate the imagination to take this bird's-eye view of instrument problems in the abstract, enabling one to study the remaining reports more critically and to be better prepared to anticipate the difficulties involved in any contemplated project of instrument development.

PROBLEMS OF MECHANCIAL DESIGN.

The art of designing aeronautical instruments is at present almost wholly on a cut-and-try basis. It is to be expected that rational design will eventually supersede empirical design, so that the designer, utilizing available results of physical research, can go almost directly to the drawing board and lay out the necessary proportions for securing the desired performance.

In either case the design will be carried forward in two general stages, first accomplishing what might be called the functional design, and then modifying this design in conformity with practical restrictions that may have been imposed.

This preliminary or functional design includes in typical cases the design of the force element, the transmission mechanism, the indicating or recording element, and the compensation, in all their interrelations.

Practically every type of instrument is actuated by some force element. The force in question is produced by some effect corresponding in magnitude with the physical quantity to be measured. In the various aeronautic instruments this initial force action may be set up by hydrostatic pressure, impact pressure, centrifugal force, gyrostatic torque, viscous drag, thermal expansion, magnetic field, or otherwise. However, produced it is usually registered by the deformation of some elastic system, such as a steel spring, a German silver diaphragm, or some combination of elastic parts. In the consideration of spring design, regardless of the particular instruments in question, certain problems will come up. Among these are the determination of the stiffness needed; the calculation of the necessary dimensions or shape to produce this amount of stiffness; the amount of deflection possible without departing from a uniform scale relation; and means for securing sufficient rigidity in the attachment of the spring. Similar problems arise in diaphragm design, including the consideration of the effect of corrugations; thickness of metal; variability of thickness from center to circumference as a means of controlling the scale relation; relative advantage of combining diaphragms in series as contrasted with increasing the area of a single diaphragm; best method for joining the top and bottom diaphragms together at the rim. Many other such questions are involved in successful diaphragm design, and it is notable that flexible diaphragms are used in a large number of the most diverse instruments. The design of the complete force element may also require the consideration of the properties of coupled systems.

The problems of transmission design are largely geometrical. Uniformity of scale in the finished instrument is usually desirable, and expedients for securing this by suitable arrangement of levers, cams, or other movements are of interest in connection with all instruments. The mechanism must also be provided with a sufficient degree of adjustability as regards both the zero point and the total multiplying power. Other considerations involved are the relative merits of jewelled or metallic bearings; of knife-edge contacts or flexible plate connections; of large multiplying power or large force action. In all mechanisms, finally, a suitable compromise has to be determined between friction and lost motion. Neither one can be completely eliminated without suffering too large an influence from the other.

Even the dial and pointer design involves scientific problems which have not been completely solved. The graduations may either be laid out empirically, after assembling and testing the instrument with a substitute dial, or they may be laid out in a uniform manner beforehand, with the expectation of subsequently adjusting the movement to agree with the dial. Maximum visibility and precision must be secured for both the dial and pointer. The pointer must be sufficiently close to the dial surface to reduce the parallax without danger of contact, and the attachment of the pointer to the spindle must be such as to permit readjustment of position without danger of slipping around while the instrument is in use.

The design of compensation devices is likewise difficult. It seems comparatively simple to compensate for gravitational effects (inclination of instrument) by suitable counterweights, but this has rarely been done with complete success. Compensation for angular accelerations such as are always present due to the vibration of the instrument board has rarely been undertaken. The effect of temperature on the reading of the instrument, other conditions remaining constant, can be compensated by thermal expansion devices, such as the bimetallic bar familiar in aneroid construction, but the compensation of instruments for change of sensitivity with temperature may practically be classed as an unsolved problem.

The final stage of design has mainly two objects in view; First, conformity with limitations of weight and size; second, interchangeability.

In regard to the former requirement, it is evident that, while a large force action is desirable to overcome friction in the mechanism, this on the one hand may, in the case of diaphragm instruments, require large areas and tend to make the total instrument too large; on the other hand large force action requires greater strength of supporting parts, thus tending to make the weight of the final instrument excessive. Here, as in so many other problems of mechanical design, a suitable compromise has to be determined upon.

Standardization of design for the purpose of interchangeability applies to the external size of case, arrangement of holes and flanges, connections to shafting or tubing, cover glasses, screw threads, etc. A beginning has been made toward international standardization on many of these details by the work of the International Aircraft Standards Board as temporarily organized in Washington during the war. This general subject of standardization would seem to merit further consideration in the future.

THE HUMAN FACTOR.

The reaction of the aviator to his instruments has to be considered, as well as the operation of the instruments themselves. This is evident enough in the case of appliances such as oxygen apparatus, intended solely for the comfort and efficiency of the aviator, or in the case of complicated instruments such as bomb sights. But it is equally true with the more simple, direct-reading instruments. It is not enough for such instruments to be mechanically correct; they must be, in the case of service instruments, readily intelligible to the pilot. The manipulation of the instrument must not make an appreciable demand on his time or attention. The visibility must be satisfactory both day and night. Finally, service instruments must be "fool proof." While much can be accomplished by technical instruction courses for aviation personnel, still the personal prejudice of the average pilot has to be reckoned with. If the instrument for any reason fails to appeal to the individual pilot, he will take great chances rather than trouble to look at it. On the other hand, if the instrument pleases his fancy, he may grow so attached to it that he will claim he could not fly safely without it, even though the instrument be scientifically known to be incorrect. Curious examples of this circumstance were found in the popularity of the earlier liquid type Pitot tube among the British pilots and the spinning-top inclinometer among the French.

MANUFACTURING PROBLEMS.

For best results the instrument designer must look beyond the intrinsic problems of his instrument to consider the difficulties of actual construction, and especially of quantity production. The problems of casting, stamping, machining, tempering, assembling, and other processes may, of course, be such as to make one design more economical or capable of quicker production than another of the same quality.

Having agreed upon a given design, there still remain problems of production efficiency which the manufacturer must settle by himself. Take, for example, the question of uniform or empirical scale graduations already referred to. Machines are on the market for graduating mercury-in-glass thermometers automatically in such a manner that any three fixed points may be scratched on the stem and the remainder of the scale smoothly interpolated. The same process should be applicable to aeronautic instruments of the circular dial type. Now for quantity production, this method, whether executed automatically or by hand, is without doubt the most efficient for turning out properly adjusted instruments. It eliminates the time needed on uniform scale instruments for tinkering with each individual movement; and the empirical scale instrument passes inspection tests with practically no rejections for calibration error. Yet after being out in service for some time, if the respective instruments undergo exactly the same internal change, the uniform scale will now show the less error, as careful reasoning might predict. Thus, there is something to be said in favor of each method, and the problem can not be settled *a priori*.

Besides many such special problems, the manufacturer is always confronted by the general question whether it will pay better to force production rapidly, permitting a high percentage of test rejections, or to more carefully examine the material entering each instrument, thus slowing down the process but insuring a nearly perfect product in each case. While this problem exists to some degree in all manufacturing work, it is a specially prominent and interesting one for measuring instruments.

SUPPLY AND SELECTION OF INSTRUMENTS.

Proper coordination of instrument orders, not merely speed of production, was found to be of critical importance during the war. Such coordination requires both a correct relative amount of different items and correct choice of corresponding parts. Questions of this kind can not be satisfactorily settled by office personnel. Technical knowledge and personal contact with conditions at the airdromes are necessary.

The control of quality of output by systematic inspection is generally necessary. Such inspection in this country and England is based on written specifications. In France such specifications were not in vogue during the war, greater reliance being placed on the artistic pride and professional skill of the numerous instrument manufacturers of established reputation.

An important difference between the inspection system followed in England and in this country was that in England practically all of the inspection and testing was done at one large central station, the Royal Aircraft Establishment at Farnborough, while in this country inspectors were sent out by the Government and stationed at the different factories. As it was, the inspectors were trained for their work at the Bureau of Standards, and a certain proportion of the instrument production from all parts of the country was shipped to the Bureau of Standards for more complete tests.

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Factory inspection tests may legitimately be accelerated in various ways if the instruments will be individually tested, as they always should be, immediately before installation on the aircraft. Unless this is done, the instruments are liable to errors incurred during transportation. If it is done, the factory tests, at least those conducted by the Government inspection staff, may be directed to the rejection of defective instruments rather than to the observation of calibration errors. The distinction between defects and errors is a fundamental one. Defects—that is, mechanical imperfections—are avoidable and need not be permitted. Errors, on the other hand, must be present in every measuring instrument; they can not be avoided in kind, but only diminished in magnitude.

This leads up to the general matter of instrument selection, which is best accomplished by written specifications. The routine of preparing, revising, and enforcing instrument specifications can be facilitated by separating the technical specifications from other items and dividing them into construction and performance specifications.

Opinions differ regarding the need of construction specifications. One view is that the purchaser, except in special instances, should not bind the manufacturer to any particular set of constructive details. It is held that since ultimately the purchaser can only be interested in the performance of his instrument, the expedients available for securing this performance may better be left to the discretion of the manufacturer. In fact, at times rigid insistence upon construction specifications has resulted in eliminating valuable improvements. On the other hand, performance specifications formulated in ignorance of the mechanical details of the instrument are liable to overlook some item which might give rise to serious sources of error not provided for. In such a case the instrument, though worthless, could not legitimately be rejected. The best practice seems to be a compromise, leaving the construction specifications as liberal as possible but protecting the purchaser by making the performance specifications quite complete. This situation is also helped by not placing unduly large orders each time, thus leaving the manufacturer free to propose improvements which can be adopted from time to time with a revision of specifications.

The art of writing specifications, particularly performance specifications, involves two main problems: First, that of simplifying and standardizing the form of the specifications; second, that of securing sufficient flexibility in the requirements laid down.

Test reports are necessary in order to show whether an instrument conforms to the performance specifications, and unless the specifications have been prepared with just this difficulty in mind, the corresponding test report will drag out to an inconvenient length, requiring a voluminous set of curves, perhaps, to represent the observations on a single instrument. By long study of this problem in the case of altimeter testing it was found possible to select and define mathematically a minimum number of performance characteristics which could be represented by single numerical magnitudes. As a result, it became possible to give the essential test results of a large group of instruments on one single sheet of paper, a significant economy when instruments are tested in quantity, and also an advantage when investigating statistically the progressive improvement in the quality of instruments from time to time.

The other problem, flexibility of requirements, may be illustrated by an example. Suppose that a given instrument is required by the specifications to show satisfactory performance in five particulars, A, B, C, D, and E, each determined by some laboratory test. The simplest way of writing the specifications is to say that the instrument will be accepted if each of the errors, A, B, C, D, and E, is less than a stated numerical amount; otherwise, rejected. This system is satisfactory for instruments showing uniformly large or small errors throughout the schedule. But suppose that two sample instruments are submitted by rival concerns, X and Y, seeking contracts. Suppose, further, that the X instrument shows practically perfect performance on the last four items, but just barely falls below the limit on item A, while instrument Y just barely slips by on all five items. Which instrument is the better for practical use? Obviously the X instrument, because of its exceptionally good performance in the majority of the tests. Therefore, the simple system of rejection limits formulated above is unfair to the manufacturer and disadvantageous to the purchaser.

Two suggestions at least have been made for solving this problem, but nothing has yet been settled upon. One proposal is to formulate two sets of limits, a maximum and a minimum for each of the errors A, B, C, D, and E. If the instrument exceeds the maximum error for any one item, it is rejected; if it exceeds the minimum error for all items, it is likewise rejected; but if it exceeds the minimum limit in a sufficiently small number of items only, say, A and B, while showing figures below the minimum limit for the remaining items C, D, and E, then it is not rejected. The other plan is to assign numerical weights to the different errors reported in order to derive a figure of merit or average result, such as is furnished in the civil service report of a candidate's examination. Calling numerical errors A, B, C, D, and E, and the arbitrary weighting factors a, b, c, d, and e, one computes the quotient:

$$\frac{Aa+Bb+Cc+Dd+Ee}{a+b+c+d+e}$$

The resulting figure shall not exceed a prescribed numerical magnitude. This system has been followed for some time in the testing of timepieces at the Bureau of Standards and elsewhere, but it can not be adopted hastily on account of the difficulty of establishing suitable values for the relative weights, a, b, c, d, and e.

The determination of numerical limits for performance specifications, after agreement upon the form of the specifications, depends on two sources of information—first, production possibilities; second, actual needs in the air on the part of the pilot. Very much further study is needed on the subject of instrument specifications.

PROBLEMS CONCERNING THE TECHNIQUE OF TESTING.

The fundamental problems of laboratory testing are: First, the development of suitable standards of measurement; second, the reproduction or simulation in the laboratory of the essential physical conditions experienced in flight. The question of standards will be found discussed in each of the subsequent papers.

The most significant conditions experienced in flight are these five:

1. Extreme change of temperature;
2. Change of pressure or density;
3. Inclination or acceleration;
4. Vibration;
5. Time elapsed during flight.

Practically all instruments are liable to be influenced by change of temperature. For the testing of completed instruments it is convenient to control the temperature of a confined body of air, inside of which the instrument will then be operated and tested in the usual manner. But for preliminary testing and adjustment in the factory time can be saved by immersing the mechanism alone in a liquid bath before assembling. For eliminating very imperfect instruments it is sufficient to secure the desired temperature change by heating. But for accurate results cooling is likewise necessary, for some instruments give sharply parabolic temperature curves, showing fair compensation in the warm region but sloping off steeply toward the cold.

Change of pressure and density can be regulated in the laboratory by placing the instrument in some air-tight container, connected to an insulated air chamber of large volume in which the requisite vacuum is maintained. Expedients necessary for operating most of the instruments under reduced pressure are described in the subsequent papers, while such observations on air speed nozzles have already been presented in Report No. 110, The Altitude Effect on Air Speed Indicators, published by the National Advisory Committee for Aeronautics (Sixth Annual Report).

The effects of inclination and of linear acceleration are equivalent, because either is equivalent to a change in the effective component of gravity. Linear acceleration errors equivalent to a decrease of gravity can be reproduced in the laboratory then by tilting or inverting the instrument. Accelerations corresponding to an increase of gravity may be realized by the use of a whirling table. This has been done in connection with the laboratory testing of accelerometers and gyro turn indicators.

The vibrations of an airplane instrument board have been observed to consist mainly of torsional vibrations in the plane of the board. They can be reproduced in the laboratory by the elastic suspension of a structure carrying an unbalanced motor. Such devices, capable of regulation, are described in Report No. 126, Part I; Report No. 127, Part II; and Report No. 129, Part II. Vibrations may obscure the reading, shift the reading, or cause progressive changes in the mechanism of an instrument. Most instruments also show less hysteresis (lag) under vibration than when tested on a stationary support. Such tests are particularly important with new types of instruments and should be run for an extended period.

The absolute amount of time elapsed during any given part of a flight is an essential factor when the instrument is subject to irreversible effects, such as temperature lag or elastic lag. For the exact determination of the errors of an instrument in such cases, the same variation of temperature and instrument reading from moment to moment which occurred during the flight must be reproduced in the laboratory. This is known as a flight-history test, and although difficult, has been found necessary in establishing competitive altitude records. Short-cut methods for discovering the magnitude of these irreversible effects in instruments based on elastic action are the observation of drift, hysteresis, or after-effect. These tests are explained in the paper on altimeters and barographs, Part I of Report No. 126, but are equally applicable in principle to other instruments.

Besides the foregoing physical problems, an interesting field is offered for efficiency engineering in the development of appliances for testing a great quantity of instruments simultaneously, and in perfecting the procedure for recording and computing observations with a minimum pay-roll.

PROBLEMS OF INSTALLATION.

The problems of installation are hardly less important than those relating to the design of the instruments themselves, because a good instrument can be made ineffective by improper location or faulty connections.

The force element of typical instruments, referred to above under the head of mechanical design, consists of two parts, the collecting or receiving element and some elastic system. In general these two parts are connected by long-distance transmissions (wires, tubing, or shafting), but in particular cases the two parts are consolidated. Table III shows the usual arrangement of the receiving and indicating elements for the more familiar instruments. The modern tendency is toward the separated type, particularly with large aircraft.

TABLE III.—*Installation of receiving and indicating elements.*

Consolidated.		Separated.
In cockpit.	Remote.	
Altimeters and barographs. Statoscopes and rate-of-climb indicators. Aerographic instruments. Inclinometers and banking indicators. Most compasses and turn indicators. Timepieces.	Proposed barograph with static collector. Strut thermometer. Pensuti and similar air speed indicators. Morell anemometer. Certain compasses. Gasoline float gauges. Wind driven turn indicator.	Proposed altimeter with static collector. Vertimeter. Pressure-head air speed indicators. Angle of incidence, side slip and yaw meters. Bamberg remote indicating compass. Flexible shaft and electric tachometers. Radiator thermometers. Hydrostatic and electric gasoline gauges. Static head turn indicator.

Problems of installation can be investigated from the standpoint of the receiving element, the long-distance transmission, and the indicating element. Compasses, for example, may be in serious error unless the magnetic element can be separated and placed sufficiently far away from the engine; likewise the pressure head of an air-speed indicator might as well be left off entirely as to be installed too close to the propeller slip stream. These difficulties have been analyzed by Prof. S. Herbert Anderson, in a recent discussion of aeronautic instruments.[1]

[1] Trans. Am. Soc. Mech. Eng., *42*: 107-109, 1920.

Again the difficulties of long-distance transmissions are the tendencies toward time lag, excessive weight, and breakage. The breakage difficulty was particularly noticed in France with radiator thermometer capillaries. A great proportion of the planes sent back from the front for salvage at Romorantin were found to have these broken transmissions. It was concluded that in many cases the breakage occurred through delicacy of the fine metal tubing, but that in numerous other cases the mechanics had cut the tubes as one would cut wire with the intention of soldering them together again. Breakage of tachometer shafts occurred through stresses caused by sudden twisting. Air-speed indicator tubing proved difficult to keep intact, while it is well known that the hydrostatic long-distance gasoline gauges were abandoned on combat planes because of fire risk and loss of gasoline caused by exposure of the tubing to gunfire.

The study of best location for indicating elements leads to the general question of instrument board design. The instruments must be so placed, without mutual interference, as to offer the greatest convenience for the pilot. This is not easy with multiple engine planes where each of the power-plant instruments has to be repeated from two to four times. The problem is still more difficult in relation to visibility at night. Three plans have been tried for artificial illumination of instruments. One of the earliest was to provide small incandescent lamps underneath translucent dials. The plan most extensively followed during the early part of the war consisted in the use of luminous paint. The requirements for satisfactory illumination by this process are complex and have been fully investigated by Dr. N. E. Dorsey.[2] There was a tendency to provide too great luminosity, which was found objectionable by many pilots and night bombers. For observation of the landscape the natural sensitivity of the eye at night has to be relied upon, and this was destroyed by the glare from the luminous paint, even in the case of dials seemingly capable of giving out only the very faintest glow. The demand consequently arose for small shielded incandescent lamps adjacent to the respective instruments, which could be put on and off at will.

Many further problems have been considered regarding instrument board design, such as the development of antivibration boards; the construction of a curved instrument board with dials normal to the line of sight; while the possibility of thermostatically maintaining a constant temperature for the instruments by the use of a circulating fluid bath has been considered as a means of eliminating temperature errors. This last expedient might have had the advantage during the war of speeding up the supply of instruments by eliminating the test for temperature compensation.

In general the further investigation of installation improvements is very much to be desired.

PROBLEMS CONCERNING THE USE OF INSTRUMENTS.

For best results in the practical use of instruments, attention must be given to their proper adjustment and care, to the application of the necessary corrections, and to the proper interpretation of observations.

Instruments must be adjusted where possible to read zero when not in action. This is important especially with altimeters at the start of a flight; otherwise the altimeter will be on help in making a landing. Instruments which are not adjustable should be read at the start of a flight. For this reason instruments provided with stops, as is very common with pressure gauges, are objectionable. In such cases there is no way to tell, before operating an instrument over its scale, whether it is in working order or not. Instruments should be tapped before starting to see that the pointer swings freely, and all connections looked over, tubes being tested to see that they are not plugged. Such details will be brought out in the separate papers, but it may be stated in general that the most important precaution to secure accuracy is to make sure that the instrument in use has been recently given an authoritative laboratory test.

Corrections may be divided into two classes, theoretical and instrumental. The theoretical correction is the amount which would still have to be applied even if the instrument were

[2] Report No. 33, National Advisory Committee for Aeronautics, 4th Annual Report.

mechanically perfect. For example, the usual altimeter is subject to correction for the temperature of the atmosphere, an item which is oftentimes forgotten though it may readily amount to a thousand feet or more. Similarly the air speed meter has to be corrected for the density of the atmosphere and the compass for the departure of magnetic north from true north. Instrumental corrections, on the other hand, have to be discovered by laboratory test in comparison with a suitable standard. The instrumental corrections might well be noted down in tabular form on a small card placed beside each instrument in front of the pilot. This practice is already quite common with compasses.

The interpretation of observations, after the necessary corrections have been applied, depends on the object sought; this subject is quite fully discussed in the paper on navigating instruments, Report No. 131.

PROBLEMS OF MAINTENANCE.

Instruments which are satisfactory when used the first time may not remain so indefinitely. Attention must be given to questions of inspection, calibration, readjustment, and salvage.

The instrument equipment of aircraft should be regularly inspected by experts who are able to tell at a glance whether anything is wrong. If any derangement is discovered, the instrument should be plainly marked, "Out of order," and, of course, replaced when possible. Some of the defects which may be discovered by ground inspection are the following: Failure of pointer to read zero; failure to vibrate readily when vigorously tapped; bent or loose pointer; dial in wrong position; cover glass cracked; illumination out of order; connections broken; leakage from liquid-filled instruments.

In addition to the periodical inspection, instruments should be specially inspected after a crash or transportation, and before starting on any important flight. And besides such records, obtained by regular inspectors, a record may profitably be kept of troubles reported by the flyers themselves. These reports will furnish raw material for important scientific study in the future, regardless of whether the troubles reported are genuine or only psychological.

At long intervals instruments should be detached and tested in the laboratory as a matter of precaution, even if no troubles have been reported either by the pilots or inspectors. The reason for this is that serious errors may accompany the full scale deflection of an instrument, even though nothing is visibly wrong on the ground. Such changes of calibration often arise from deterioration due to continuous vibration, the presence of dust or rust (the latter especially on seaplanes), and even from true progressive changes in the quality of the constituent material. These last, which are known as secular changes, may become apparent several years after the instrument has been manufactured; they have been demonstrated to occur not only in materials like fabric and rubber, but also in metallic diaphragms and steel springs.

Such calibration tests need not be as elaborate as those originally given. It is usually sufficient to determined the correction of the instrument at two points—the zero point and one point near the end of the working range. The temperature test, if it has really been made once, need not be repeated on this occasion. From the two readings taken an approximate percentage correction factor is available, although an average factor, based on a complete set of observations, is still better.

Unless the percentage correction is small, the instrument should be readjusted. This may at time be done sufficiently well by merely shifting the pointer; at other times it will be necessary to alter the movement internally, which should not be undertaken without expert knowledge. If only a small correction has been found, it is better to let it go or issue a correction card, for small mechanical readjustments are liable to slip back again or otherwise change during the next flight.

Instruments which are broken need not be discarded. If the original manufacturer is unable to handle repair business, the service should maintain some central salvaging station, equipped with expert personnel and facilities for such work. This was found to be a very necessary function of the supply services in France. American instruments were salvaged at Colombey-les-belles and at Romorantin; British instruments were sent back to Farnborough, where at the Royal Aircraft Establishment instrument salvaging was done on a very large scale in the most scientific manner.

The salvaging problem consists of taking a certain number of damaged instruments and reassembling them to provide a smaller number of good instruments. The percentage of instruments redeemed will, of course, be increased if, in addition to the wrecked instruments, spare parts from the factory are also kept on hand. The readjustment of the resulting instruments, including temperature compensation, forms an important part of the salvage problem. A further study of scientific expedients for quickly making the necessary adjustment and preserving a uniform scale ought to be seriously taken up. Some instruments are better adapted than others for readjustment; hence since it is the destiny of every instrument to be eventually readjusted, this consideration should be given some weight in selecting instruments for purchase.

Instrument salvaging is not only one of the essential problems of maintenance of equipment, but the tabulation of the defects thus brought to light should be of great scientific value as a basis for the future improvement of instruments.

PHYSICAL RESEARCH PROBLEMS.

The foregoing general problems have been taken up more or less in chronological order. First, an instrument has to be designed, and then it has to be manufactured, and so on along the line. This sequence begins and ends with the subject of physical research. Rational design, spoken of at the beginning, is an application of whatever physical laws and data are available at the time. Instrument development can not progress indefinitely without further installments of such research results.

Among the applications of physical research discussed in the subsequent papers are the following: Design of elastic system of precision altimeter; theory of bimetallic temperature compensation; compensation for angular acceleration; determination of the minimum number of data needed for defining the behavior of instruments with respect to imperfect elasticity; development of rate-of-climb indicators with high sensitivity and small lag; theory of dynamical ground speed indicators without mechanical integration; theory of the motion of a spinning top in an airplane going around a bank; design of a new type of gyroscopic mechanism with experimental determination of the requisite data on friction; and the development of an absolute method for testing oxygen apparatus without the need of flow-metering devices. Some of the more general problems along which, in the interest of instrument development, further progress is to be desired are: The laws of solid friction; fluid dynamics; synthetic development of liquids with a minimum temperature coefficient of viscosity; development of alloys having a minimum change of elasticity with temperature; and a more complete determination of the laws of elastic hysteresis.

No field of practical work could therefore be more fascinating to the student of theoretical or experimental physics, or more completely dependent on this branch of science, than that of aeronautic instruments.

BIBLIOGRAPHY.[3]

1892–93.

ABAQUE POUR LA DÉTERMINATION DU POINT À LA MER. MM. Favé et Bollet de L'Isle. Annales Hydrographique, 1892; and Revue Maritime, Jan., 1893.

1897.

FLEURIAIS ARTIFICIAL HORIZON. E. Caspani, Journal de Physique, 6: 229.

1900.

EIN NEUES BAROMETER ("LUFTDRUCKARÄOMETER"). Karl T. Fischer, Ill. Aeron. Mitt., 4, Nr. 3, Juli 1900: 68–70; also, Physikalische Zeitschrift, 1, Nr. 37, 1900: 394.

[3] Prepared in collaboration with Mr. John A. C. Warner, foreign representative of the Bureau of Standards during 1921; the French references having been obtained by Mr. Warner through courtesy of M. A. de Grammont de Gui[illegible]he and M. R. E. Badin, and the German contributions through Dr. E. Everling.

1903.

EIN NEUER REGISTRIERAPPARAT FÜR SONDIERBALLONS. Nach Assmann, Ill. Aeron. Mitt., 7, Nr. 4, April 1903: 122.

1904.

NOTICE SUR L'HORIZON GYROSCOPIQUE DE FLEURIAIS. Annales Hydrographique, 1904.

TASCHENBUCH ZUM PRAKTISCHEN GEBRAUCH FÜR FLUGTECHNIKER UND LUFTSCHIFFER. H. W. L. Moedebeck. 2. Aufl. Berlin W., 1904, W. H. Kühl.

1905.

VÉRIFICATION DES ALTITUDES BAROMÉTRIQUES PAR LA VISÉE DIRECTE DES BALLONS-SONDES. L. T. de Bort, Comptes-Rendus de l'Acad. d. Sci., 1905: 153–155.

1906.

ALTITUDE, AZIMUTH, AND GEOGRAPHICAL POSITION. G. W. Littlehales. Lippincott, 1906.

RECHERCHES SUR LES INSTRUMENTS ET LES MÉTHODES PROPRES POUR LA DÉTERMINATION DU POINT EN BALLON. Mémoires du IIIème Congrès international d'Aéronautique, 1906.

ASTRONOMISCHE ORTSBESTIMMUNG IM BALLON. Alfred Wegener, Ill. Aeron. Mitt., 10, Nr. 4, April 1906: 116–121; auch Astronomische Ortsbestimmungen des Nachts bei der Ballonfahrt vom 5. bis 7. April, 1906; Ebenda, Nr. 6, Juni 1906: 205–207.

1907.

UEBER EINE NEUE AUTOMATISCHE ABSTELLVORRICHTUNG DER SCHREIBFEDERN VON REGISTRIERAPPARATEN FÜR UNBEMANNTE FREIBALLONS UND EINE NEUE METHODE DER FIXIERUNG DER DIAGRAMME. R. Nimführ, Ill. Aeron. Mitt., 11, Nr. 3, März 1907: 78–81.

DIE ASTRONOMISCHE ORTSBESTIMMUNG IM BALLON UND IHRE BEDEUTUNG FÜR DIE LUFTSCHIFFAHRT. Ad. Marcuse, Ill. Aeron. Mitt., 11, Nr. 1, Jan. 1907: 20–25.

1908.

ANEROID BAROMETER FOR AERONAUTS. C. J. Asten, Airship. Lond., 37, 1908.

EIN BALLONVARIOMETER ZUR MESSUNG DER VERTIKALGESCHWINDIGKEIT. A. Bestelmeyer, Ill. Aeron. Mitt., 12, Nr. 21, 21. Okt. 1908: 656–657; auch Physikalische Zeitschrift, 9, 1908: 863.

DER KREISEL ALS RICHTUNGSWEISER AUF DER ERDE MIT BESONDERER BERÜCKSICHTIGUNG SEINER ANWENDBARKEIT IN LUFTSCHIFFEN. A. F. nach Anschütz-Kämpfe, Ill. Aeron. Mitt., 12, Nr. 25, Dez. 1908: 792–793.

1909.

THERMOGRAPH ZUR REGISTRIERUNG DER FÜLLUNGSTEMPERATUR VON LUFTSCHIFFEN UND FREIBALLONS. K. V. Bassus, Ill. Aeron. Mitt., 13, Nr. 17, 25, Aug. 1909: 755–757.

DER PEILKOMPASS IM FREIBALLON. H. H. Kreitzinger, Ill. Aeron. Mitt., 13, Nr. 22, 3. Nov. 1909: 984–987.

UEBER DIE MAGNETISCHE ORTSEBESTIMMUNG IM BALLON. Bidlingmeier, Ill. Aeron. Mitt., 13, Nr. 22, 3. Nov. 1909: 975–983.

SAUERSTOFF- UND ATMUNGSVORRICHTUNGEN FÜR LUFTSCHIFFE. Werner Bleines, Ill. Aeron. Mitt., 13, Nr. 20 und 23, 6. Okt. und 17. Nov. 1909: 900–903 u. 1029–1040.

EIN VERFAHREN ZUR AUSWERTUNG ASTRONOMISCHER POSITIONS-BESTIMUNGEN. A. Brill, Ill. Aeron. Mitt., 13, Nr. 22, 3. Nov. 1909: 988–994; auch Ilas-Wochenrundschau, Nr. 4.

NEUER BEITRAG ZUR FRAGE DER ORTSBESTIMMUNG IM BALLON. Ad. Marcuse, Ill. Aeron. Mitt., 13, Nr. 22, 3. Nov. 1909: 984.

ANLEITUNG ZUR ASTRONOMISCHEN ORTSBESTIMMUNG IM BALLON. Ad. Marcuse. Berlin 1909, G. Reimer.

EIN BEITRAG ZUR FRAGE DER BALLONINSTRUMENTE. P. A. Meckel, Ill. Aeron, Mitt., 13, Nr. 26, 29. Dez. 1909: 1151–1152.

1910.

ZUR THEORIE DES BALLONVARIOMETERS. A. Bestelmeyer, Physikalische Zeitschrift, 11, 1910: 763–768.

UEBER STATISCHE UND DYNAMISCHE LUFTDRUCKMESSUNGEN. Böninger, Flugsport, 2, Nr. 2, 22. Jan. 1910: 35–42.

ZUR BENUTZUNG DES KOMPASSES IM BALLON. A. Bestelmeyer, Deutsche Zeitschrift für Luftschiffahrt, 14, Nr. 24, 30. Nov. 1910: 17–18.

EIN PEILKOMPASS FUR LUFTSCHIFFE. Anon., Flug- und Motortechnik, 4, Nr. 23, 10. Dez. 1910: 929–931.

LE POINT SANS L'HORIZON DE LA MER. Horizon Gyroscopique de l'Amiral Fleuriais. Revue Maritime, 1910.

UEBER EINE NEUE EINHEITLICHE METHODE ZUR NAUTISCHEN UND AERONAUTISCHEN ORTSBESTIMMUNG AUS GESTIRNSBEOBACHTUNGEN. A. Brill, F ankfurt a. M ; auch An nalen der Hydrographie und Maritimen Meteorologie, 1910. Nr. 11, und 191 Sonderabdruck. Berlin, 1911.

UEBER ORTSBESTIMMUNG BEI DER LUFTSCHIFFAHRT. Nach Marcuse, Flug- und Motortechnik, 4, Nr. 5, 10. März 1910: 169–170.

UEBER DAS REGISTRIEREN HORIZONTALER LUFTSCHWANKUNGEN BEI LUFTSCHIFFEN UND FLUGAPPARATEN. Emil Kraft v. Helmhacker, Flug- und Motortechnik, 4, Nr. 4 u. 5, 25. Febr. und 10. März 1910: 140–144 u. 170–172.

1911.

DETERMINATION OF THE ALTITUDE OF AEROPLANES. R. W. Willson. Proc. Am. Acad. Arts & Sci., 47: 22–43. 1911.

BAROMETRY AND AERONAUTIC INSTRUMENTS. Annual Report of Director Bureau of Standards, 1911: p. 12; 1912: pp. 13–14; 1913: p. 8; 1914: p. 19; 1915: pp. 20–21; 1916: p. 21; 1917: pp. 27–28; 1918: pp. 125–127; 1919: pp. 174–181; 1920: pp. 167–173.

DIE MECHANISCH-GRAPHISCHE LÖSUNG DES HÖHENPROBLEMS MIT DEM VOIGTSCHEN INSTRUMENT. H. Boykow, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 2, Nr. 9, 13. Mai 1911: 116–120.

DIE HÖHENMESSUNGEN BEI FLUGVERANSTALTUNGEN. A. Schmauss, Deutsche Zeitschrift für Luftschiffahrt, 15, Nr. 6, 22. März 1911: 11–16.

EIN VERBESSERTER BALLONAPPARAT, DAS VERTIKAL DOPPEL-ANEMOMETER. Anon., Deutsche Zeitschrift für Luftshiffahrt, 15, Nr. 5, 7. März 1911: 22–23.

MITTEILUNGEN DES LUFTSCHIFFBAU ZEPPELIN. I. Die ERMITTELUNGEN DER MOMENTANEN EIGENGESCHWINDIGKEITEN VON LUFTFAHRZEUGEN MIT HILFE DER PITOTSCHEN RÖHRE. A. Frhr. V. Soden und Cl. Dornier, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 2, Nr. 19, 14. Okt. 1911: 241–245.

DIE ANÉMO-BUSSOLE. Anon., Oesterr. Flug-Zeitschrift, 5, Nr. 1, 10. Jan. 1911: 20.

NAVIGATION MITTELS DERIVATORS. H. Boykow, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 2, Nr. 11, 10. Juni 1911: 145–147.

DIE ORIENTIERUNGSFRAGE. Anon., und "Orion," ein neuer Auswertungsapparat für astronomische Ortsbestimmung in der Luft und auf der See. E. Wippich, Der Motorwagen, 14, Nr. 10, 10. April 1911: 224–227 u. 227–228.

INSTRUMENT ZUR GRAPHISCHEN AUSWERTUNG ASTRONOMISCHER POSITIONSBESTIMMUNGEN NACH DER STANDLINIENMETHODE. A. Brill, Luftschiffahrt, Flugtechnik und Sport, Nr. 24, 31. August 1911; auch Deutsche Zeitschrift für Luftschiffahrt, 15, Nr. 17, 23. Aug. 1911: 18–21.

EIN BEITRAG ZUR ASTRONOMISCHEN ORTSBESTIMMUNG MIT DEM VOIGTSCHEN INSTRUMENT. W. Hormel, Deutsche Zeitschrift für Luftschiffahrt, 15, Nr. 5, 7. März 1911: 14–18.

ASTRONOMISCHE ORTSBESTIMMUNG IM LUFTFAHRZEUG. O. Voight, Vortrag vom 14. Jan. 1911.

ASTRONOMISCHE AERONAVIGATION. Anon., Österr. Flug-Zeitschrift, 5, Nr. 15, u. 16, 10 u. 25, August 1911: 403–406 u. 430–432.

BEMERKUNGEN ZUR ASTRONOMISCHEN ORTSBESTIMMUNG IM LUFTFAHRZEUG. Marcuse, Deutsche Zeitschrift für Luftschiffahrt, 15, Nr. 24, 29. Nov. 1911: 24–25.

PRAKTISCHE FLUGZEUG-NAVIGATION. H. Boykow, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 2, Nr. 5 u. 6, 11. u. 24. März 1911: 66–68 u. 77–79.

AERONAVIGATION. Hans Boykow, Oesterr. Flug-Zeitschrift, 5, Nr. 14, 25. Juli 1911: 374–476.

THE AERIAL AGE. Walter Wellman, A. R. Keller Co., New York.

1912.

BALLONVARIOMETER. A. Bestelmeyer, Deutsche Luftfahrer-Zeitschrift, 16, Nr. 25, 11. Dez. 1912: 615.

ANEROIDVARIOMETER ZUR FESTSTELLUNG DER VERTIKALGESCHWINDIGKEIT IM FREIBALLON. G. von dem Borne, Deutsche Luftfahrer-Zeitschrift, 16, Nr. 22, 24. Okt. 1912: 538.

BALLON-THERMOMETER. O. Ebersbach, Der Motorwagen, 15, Nr. 33, 30. Nov. 1912: 767–768.

GESCHWINDIGKEITSMESSUNGEN VON LUFTSCHIFFEN. E., Der Motorwagen, 15, Nr. 12, 30. April 1912: 314.

THEORIE EINES WINDSCHREIBERS. G. von dem Borne, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 3, Nr. 20, 26. Okt. 1912: 261 u. 264.

EIN EINFACHER WINDDRUCKSCHREIBER. G. von dem Borne, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 3, Nr. 14, 27. Juli 1912: 188–189.

UEBER KOMPASSE FÜR LUFTFAHRZEUGE. G. Gehlhoff, Deutsche Luftfahrer-Zeitschrift, 16, Nr. 15, 24. Juli 1912, 369–370.

EIN NEUER KOMPASS FÜR FLUGZEUGE. H. H. Kistzinger, Deutsche Luftfahrer-Zeitschrift, 16, Nr. 11, 29. Mai 1912: 278–279.

DER KOMPASS IM FLUGZEUG. R. Topp, Der Motorwagen, 15, Nr. 35, 20. Dez. 1912: 809–813.

TACHOMETER FÜR FLUGZEUGE. Anon., Flugsport, 4, Nr. 22, 23. Okt. 1912: 832–833.

ON GYROSCOPIC OSCILLATIONS. W. S. Franklin, Phys. Rev., 34: 48–52, 1912.

UEBER EIN NEUES INSTRUMENT FÜR ERMITTLUNG DES STEUERWINKELS UND DER RESULTIERENDEN GESCHWINDIGKEIT BEI FLUGZEUGEN UND UEBER DIE ANWENDUNG DER NOMOGRAPHIE FÜR LÖSUNG SOLCHER AUFGEBEN. K. Hoetken, Deutsche Luftfahrer-Zeitschrift, 16, Nr. 24, 27. Nov. 1912: 577–580.

INSTRUMENT ZUR GRAPHISCHEN AUSWERTUNG ASTRONOMISCHER POSITIONS-BESTIMMUNGEN NACH DER STANDLINIEN-METHODE. A. Brill. Frankfurt a. M., 1912, Hartmann & Braun.

INSTRUMENT ZUR AUSWERTUNG VON GESTIRNSHÖHENBEOBACHTUNGEN IN DER KARTE. A. Wedemeyer, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 3, Nr. 1, 13. Jan. 1912, S. 3/5.

ASTRONOMISCHE ORTSBESTIMMUNGEN MIT BESONDERER BERÜCKSICHTIGUNG DER LUFTSCHIFFAHRT. W. Leick. 8°. S. 130. Leipzig, Quelle u. Meyer, 1912.

ASTRONOMISCHE ORTSBESTIMMUNGEN MIT HILFE VON NOMOGRAMMEN. W. Leick, Zeitschrift für Flugtechnick und Motorluftschiffahrt, 3, Nr. 17, 14. Sept. 1912: 230–231.

ZUR FRAGE DER ORTSBESTIMMUNG NACH FIXSTERNEN MIT DEM LIBELLENQUADRANTEN. S. v. Kolbe, Deutsche Luftfahrer-Zeitschrift, 16, Nr. 5, 6. März 1912: 105–106.

EIN LIBELLENQUADRANT IN NEUER FORM FÜR ASTRONOMISCHE ORTSBESTIMMUNGEN (ZAHNBOGEN-HÖHENMESSER). E. Hartmann, Annalen der Hydrographie und Maritimen Meteorologie, 40, Nr. 9, 1912: 486–488; auch Deutsche Luftfahrer-Zeitschrift, 16, Nr. 20, 2. Okt. 1912: 495–496.

EIN LIBELLENQUADRANT IN NEUER FORM FÜR ASTRONOMISCHE ORTSBESTIMMUNGEN. W. Lindt, Deutsche Luftfahrer-Zeitschrift, 16, Nr. 11, 29. Mai 1912: 273–274; ferner Annalen der Hydrographie und Maritimen Meteorologie 40, Nr. 1, 1912.

ORIENTIERUNG UND NAVIGATION IM LUFTFAHRZEUG. H. Boykow, Deutsche Luftfahrer-Zeitschrift, 16, Nr. 22, 24. Okt. 1912: 530–534.

MITTEILUNGEN DES LUFTSCHIFFBAU ZEPPELIN-FRIEDRICHSHAFEN. V. TEMPERATURMESSUNGEN DES FÜLLGASES UND DER LUFT IM Z-SCHIFF UND DEREN BEDEUTING FÜR DIE HÖHENNAVIGATION. Gludd u. Fhr. V. Soden, Zeitschrift fur Flugtechnik und Motorluftschiffahrt, 3, Nr. 7, 13. April, 1912: 97–101.

1913.

THE MEASUREMENT OF TRUE STATIC PRESSURE IN A MOVING FLUID—APPLICATION TO AN AEROPLANE BAROGRAPH. A. F. Zahm, Journal of the Franklin Institute, v. 175, 503–509, Jan., 1913.

ANEROIDVARIOMETER ZUR FESTSTELLUNG DER VERTIKALGESCHWINDIGKEIT IM BALLON. G. von dem Borne, Österr. Flug-Zeitschrift, 7, Nr. 4, 25. Febr. 1913: 91.

ENREGISTREMENT DE LA VITESSE RELATIVE DES AEROPLANES. A. Toussaint et G. Lepére, Bull. de l'Institut Aérotcehde l'Univ. de Paris, fasc. 3, 1913.

EXPÉRIENCES SUR L'AJUTAGE DE VENTURI. A. TOUSSAINT ET G. Lepére, Bull. de l'Institut Aérotech. de l'Univ. de Paris, fasc. 3, 1913.

DER LUFTGESCHWINDIGKEITSMESSER DER SIEMENS UND HALSKA A.-G. (VORTRAG). H. Gerdien, Verhandlungen der Gesselschaft Deutscher Naturforscher und Ärzte, 85. Versammlung zu Wien, 2. Teil, 1. Hälfte, 1913: 234–238.

PREISAUSSCHREIBEN FÜR EINEN WETTBEWERB UM EINEN AUFZEICHNENDEN BESCHLEUNIGUNGSMESSER FÜR FLUGZEUGE. Anon., Zeitschrift für Flugtechnik und Motorluftschiffahrt, 4, Nr. 14, 26. Juli, 1913: 199–200.

THE THEORY OF THE EARTH INDUCTOR AS AN INCLINOMETER. N. E. Dorsey, Terrestrial Magnetism & Atmospheric Electricity, 18, 1913: 1–38.

BEMERKUNGEN ZU DEM BERICHT ÜBER KOMPASS-BEOBACHTUNGEN IM LUFTSCHIFF "HANSA." Karl Bamberg, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 4, Nr. 21, 15. Nov. 1913: 292.

ZUR DÄMPFUNGSFRAGE BEI LUFTFAHRZEUGKOMPASSEN. H. Boykow, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 4, Nr. 18, 27. Sept. 1913: 248–250.

BERICHT ÜBER KOMPASSBEOBACHTUNGEN IM LUFTSCHIFF "Hansa." Meldau u. J. Möller, Mitteilungen des Luftschiffbau Zeppelin. VIII. Bericht über Astronomische und Magnetische Ortsbestimmungsversuche an Bord des Luftschiffes "Hansa." J. Möller, Mitteilungen des Luftschiffbau Zeppelin, IX. Zeitschrift für Flugtechnik und Motorluftschiffahrt, 4, Nr. 18, 27. Sept. 1913: 243–245 bezw. 245–246.

UEBER EINEN NEUREN KREISELKOMPASS. Th. Bruger, Jahrbuch der Wissenschaftliche Gesellschaft für Flugtechnik (bis 1914) 1, 1912–13. Berlin, 2. Lief., 1913: 125–129.

DER BETTER SAUERSTOFF IN SEINEN BEZIEHUNGEN ZUR LUFTFAHRT DRÄGER-HEFTE. I. W. Haase-Spe, Nr. 11, Mai 1913: 81, 84–87.

ERMITTELUNG DER NAVIGATIONSDATEN IM LUFTSCHIFF. H. Boykow, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 4, Nr. 20, 25. Okt. 1913: 273–279.

ÄUSSERUNG ZU DEM AUFSATZ DES HERRN DR. H. H. KRITZINGER ZUR THEORIE DES LIBELLENQUADRANTEN: V. Kobbe, Deutsche Luftfahrer-Zeitschrift, 17, Nr. 10, 14. Mai 1913: 236.

ZUR THEORIE DES LIBELLENQUADRANTEN. H. H. Kritzinger, Deutsche Luftfahrer-Zeitschrift, 17, Nr. 4 u. 10, 19. Febr. u. 14. Mai 1913: 85–87 u. 236.

LIBELLENHORIZONT UND LIBELLENSEXTANT. K. Schwarzschild, Zeitschirft für Flugtechnik und Motorluftschiffahrt, 4, Nr. 13, 12. Juli 1913: 177–180.

STERNZEIT-TRANSFORMATOR. A. Schütze, Annalen der Hydrographie und Maritimen Meteorologie, Febr. 1913.

ORT- UND ZEITBESTIMMUNGEN. Grosse, Deutsche Luftfahrer-Zeitschrift, 17, Nr. 10, 14. Mai 1913: 235–236.

WISSENSCHAFTLICHE INSTRUMENTE. Anon., Deutsche Luftfahrer-Zeitschrift, 17, Nr. 5, 5. März 1913: 103–114.

EINE AUSSTELLUNG VON MESSAPPARATEN. R. Wachsmuth, Jahrbuch der Wissenschaftliche Gesellschaft für Flugtechnik (bis 1914) 1, 1912–13. Berlin, 2. Lief., 1913: 133–151.

PHYSIKALISCHE UNTERSUCHUNGEN IM FREIBALLON I. A. Wigand u. G. Lutze, unter Mitarbeit von E. Everling, und G. Jenrich, Abhandlungen der Naturforschenden Gesellschaft. Halle a. S., n. F., Nr. 2, 1913: 39.

LUFTSCHIFFNAVIGATION IM NEBEL. H. Boykow, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 4, Nr. 15, 16. Aug. 1913: 206–208.

1914.

THE TESTING OF BAROMETERS. Bureau of Standards Circular No. 46, 1914: 12.

EIN FLUGGESCHWINDIGKEITSMESSER MIT LUFTDRUCK UND TEMPERATURKOMPENSATION. G. Fuhrmann, Jahrbuch der Deutsche Versuchsanstalt für Luftfahrt, 1, 1912–13. Berlin, 1914: 232–236.

EIN APPARAT ZUR UNTERSUCHUNG DES WINDSTRUKTUR (ANEMOKLINOGRAPH) DER SIEMENS UND HALSKA A.-G. H. Gerdien, Jahrbuch der Wissenschaftliche Gesellschaft für Flugtechnik (bis 1914) 2, 1913–14. Berlin, 1914, 1. Lief., 67–78; Diskussion: 79–80.

PREISAUSSCHREIBEN FÜR EINEN WETTBEWERB UM EINEN AUFZEICHNENDEN BESCHLEUNIGUNGSMESSER FÜR FLUGZEUGE. (Reissner), Jahrbuch der Wissenschaftliche Gesellschaft für Flugtechnik (bis 1914), 1913–14, Berlin, 1. Lief., 1914: 31–34.

DISCUSSION OF THE ACTION OF DIFFERENT TYPES OF AIR SPEED INDICATOR. L. Bairstow, British Adv. Com. for Aero., 1913–14: 461–466.

MESURES SUR AÉROPLANES EN VOL AU MOYEN D'APPAREILS ENREGISTREURS. A. Toussaint, G. Lepére & Gouin, La Technique Aéronautique, Mars 1, 15, et Avril 1, 1914.

RECHERCHES EXPÉRIMENTALS SUR LES MOULINETS ANÉMOMÉTRIQUES. M. C. E. Brazier, Annales du Bureau Central Météorologique de France (mémoires).

NEUE AUFZEICHENDE KRAFTMESSGERÄTE UND EINIGE MESSUNGEN IM FLUGZEUG. W. Hoff u. F. Bendemann, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 5, Nr. 1 u. 2, 17. u. 31. Jan. 1914: 3–5 u. 17–22.

FLUGRICHTUNGSKOMPASS, SYSTEM WÄLLER. Gustav E. Macholz, Osterr. Flug-Zeitschrift, 8, Nr. 3–4, Febr. 1914: 42–43.

GYROSTATS AND GYROSTATIC ACTION. A. Gray, Smithsonian Report for 1914: 193–208 (Publication 2327).

REPORT ON GYROSCOPIC THEORY. Greenhill, British Adv. Com. for Aero., Reports and Memos. No. 146, 1914: 277.

DER RIPOGRAPH. R. Katzmayr, Österr. Flug-Zeitschrift, 8, Nr. 22–23, 1. Dez. 1914: 360–361.

PHYSIKALISCHE UNTERSUCHUNGEN IM FREIBALLON II. G. Lutze u. E. Everling, unter Mitarbeit von A. Wigand u. G. Jenrich, Abhandlungen der Naturforschenden Gesellschaft. Halle a. S., n. F., Nr. 3, 1914: 79.

BERICHT DES AUSSCHUSSES FÜR MESSWESEN. Jahrbuch der Wissenschaftliche Gesellschaft für Flugtechnik (bis 1914) 2, 3. Lief., 1913–14: 223–236.

KRITISCHER BERICHT DES PRÜFUNGSAUSSCHUSSES ZUR BEURTEILUNG VON ERFINDUNGEN. v. Parseval, Jahrbuch der Wissenschaftliche Gesellschaft für Flugtechnik (bis 1914) 2, 1913–14. Berlin, 3. Lief., 1914: 193–195.

1915–16.

ANEROID BAROMETER INVESTIGATIONS. M. D. Hersey, Phys. Rev., 6, 1915: 75–76.

INVESTIGATION OF PITOT TUBES. W. H. Herschel (Pt. I) and E. Buckingham (Pt. II), Report No. 2, Nat. Adv. Com. for Aero., First Annual Report, 1915: 77–110.

KOMPASSTÖRUNGEN IM NEBEL. Wilhelm Krebs, Der Motorwagen, 18, Nr. 1, 10. Jan. 1915: 12–13.

REPORT ON THE ACCURACY WITH WHICH THE TEMPERATURE ERRORS IN DETERMINING HEIGHTS BY THE BAROMETER MAY BE CORRECTED. G. I. Taylor, British Adv. Com. for Aero., 1915–16: 576–578.

CALIBRATION OF TUBE ANEMOMETERS AT HIGH VELOCITIES. J. R. Pannell, British Adv. Com. for Aero., 1915–16: 529–533.

ON SOME PROPOSED ELECTRICAL METHODS OF RECORDING GAS FLOW IN CHANNELS AND PIPES BASED ON THE LINEAR HOT WIRE ANEMOMETER. L. V. King, Journal Franklin Institute, Aug. 1916: 191.

GESCHWINDIGKEITSMESSER FÜR FLUGZEUGE. Anon., Mitteilungen des K. K. Österr. Aero-Clubs 1916; abgedruckt im Bulletin des Schweiz. Aero-Clubs, Okt. 1916: 152–154.

ZUR GESCHWINDIGKEITSMESSUNG IM LUFTFAHRZEUG. Anon., Bulletin des Schweiz. Aero-Clubs, Nov. 1916: 162.

THE MAGNETIC COMPASS FOR AIR NAVIGATION. Creagh-Osborne. Glasgow, James Brown & Son.

REPORT ON THE ERRORS OF COMPASSES ON AEROPLANES. K. Lucas, British Adv. Com. for Aero., 1915–16: 554–566.

COMPASS DEVIATION IN AIRCRAFT. British Adv. Com. for Areo., 1915–16: 533–536.

COMPASS DEVIATION DUE TO VIBRATION AND FRICTION. A. Mallco, British Adv. Com. for Aero., 1915–16: 536–538.

COMPASS DEVIATION DUE TO VIBRATION WITHOUT FRICTION. G. Greenhill, British Adv. Com. for Aero., 1915–16: 539–553.

ON A NEW TYPE OF MAGNETIC COMPASS FOR USE ON AEROPLANES. K. Lucas, British Adv. Com. for Aero., 1915–16: 567–575.

ELEKTRISCHES FERNTHERMOMETER ZUR MESSUNG DER KÜHLWASSER-TEMPERATUR IN EXPLOSIONSMOTOREN, IN FLUGZEUGEN UND AUTOMOBILEN. Otto Hauser, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 7, Nr. 7–8, 29. April 1916: 49–50.

Eine Vereinfachte Atmungsmaske für Flugzeuge. E. Everling. Deutsche Luftfahrer-Zeitschrift 20, Nr. 3–4, Febr. 1916: 35–36.

The Oscillations of an Aeroplane in Flight. K. Lucas, British Adv. Com. for Aero., Report, 1915–16: 267–277.

General Specifications for Aeronautic Instruments. Report No. 8, Nat. Adv. Com. for Aeronautics, Second Annual Report, 1916: 25–28.

1917.

Aerial Navigation over Water. Elmer A. Sperry, Trans. Soc. Automotive Engs., Sec. 1, 1917: 153.

Creep Errors in Altimeters Due to Hysteresis. T. G. Hull, British Adv. Com. for Aero., Report, 1916–17: 668–670.

A Barothermograph for Use on Aeroplanes. Aeroplane Testing Squadron, British Adv. Com. for Aero., Report, 1916–17: 673–674.

A Rate-of-Climb Indicator. Commanding Officer, Testing Squadron, Royal Flying Corps, British Adv. Com. for Aero., Report, 1916–17: 699–701.

A Method of Measuring the Speed of an Aeroplane at a Height. Commandant, Central Flying Station, British Adv. Com. for Aero., 1916–17: 744–751.

Die Messung von Flugzeuggeschwindigkeiten. E. Jacobi. Technische Berichte der Flugzeugmeisterei bezw. II, Nr. 1, 20. Dez. 1917: 99–110.

Behaviour of Levels when Subject to Vibration. A. Mallock, British Adv. Com. for Aero., Report, 1916–17: 671–672.

The Northerly Turning Error of the Magnetic Compass. F. A. Lindemann, British Adv. Com. for Aero., Report, 1916–17: 678–698.

Turn Indicators for Aeroplanes. F. A. Lindemann, British Adv. Com. for Aero., Reports and Memoranda, No. 525, Dec. 1917: 1–8.

Tachometer mit Ablesevorrichtung. Wilke, Zeitschrift des Vereines deutscher Ingenieure, 61, 31. März 1917: 297.

A Petrol Flowmeter for use on Aeroplanes. Aeroplane Testing Squadron, British Adv. Com. for Aero., Report; 1916–17: 675–677.

Flossendruckmessungen. E. Everling, M. Iklé und E. Sieber, Technische Berichte der Flugzeugmeisterei bezw. der Inspektion der Fliegertruppen I, Nr. 6, 15. Okt. 1917: 302–312.

Vorläufiges Ergebnis der Versuchsflüge mit der Messnabe. E. Everling, Technische Berichte der Flugzeugmeisterei bezw. der Inspektion der Fliegertruppen I, Nr. 2, 1. April 1917: 54–56.

Altitude Azimuth and Hour Angle Diagram. G. W. Littlehales, Proceedings U. S. Naval Inst., Nov. 1917.

Die Physikalischen Grundlagen der Höhennavigation. K. Bassus. München, 1917.

Das Verhalten des Flugzeuges im Fluge. E. Everling und W. Zabel, Technische Berichte der Flugzeugmeisterei bezw, der Inspektion der Fliegertruppen I, Nr. 6, 15. Okt. 1917: 313–318.

Die Messung von Flugleistungen in England. E. Everling, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 8, Nr. 19–20, 21–22 und 23–24, 27. Okt., 29. Nov. u. 29. Dez. 1917: 154–155, 163–166, u. 182–185.

Das Wesen und die Eigenschaften der Radioaktiven Leuchtfarben. P. Ludewig, Österr. Flug-Zeitschrift, 11, Nr. 1–2, Jan. 1917: 23–24.

Die Skalenberechnung zum Deutschen Bombenvisier für Flugzeuge. O. Prochnow, Technische Berichte der Flugzeugmeisterei bezw. der Inspektion der Fliegertruppen II, Nr. 1, 20. Dez. 1917: 135–141.

1918.

Altimètres à Cadrans et Baromètres Enregistreurs. Gourdou, Bull. du S. T. Aéron. No. 4, Septembre.

Fehler in den Angaben von Aneroidbarometern. Wilh. Schmidt, Österr. Flug-Zeitschrift 12, Nr. 15–16, Aug. 1918: 170–171.

Tests of Swivelling Pressure Heads. Aerodynamics Staff of R. A. E., British Adv. Com. for Aero., Reports and Memoranda No. 567, Oct., 1918: 1–4.

A Hot-Wire Anemometer which is Sensitive over a Large Range of Wind Speed. A. Fage, British Adv. Com. for Aero., Reports and Memoranda No. 556, Nov., 1918: 1–8.

Development of Air Speed Nozzles. A. F. Zahm, Report No. 31, Nat. Adv. Com. for Aeronautics, Fourth Annual Report, 1918: 322–334.

Neuere Geschwindigkeitsmessungen. V. Heidelberg und A. Hölzel, Technische Berichte der Flugzeugmeisterei bezw. der Inspektion der Fliegertruppen III, Nr. 5, 1918: 174–179.

Ein Neues Instrument zur Geschwindigkeitsmessung auf Flugzeugen. W. Hort, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 9, Nr. 11–12, 28. Juni 1918: 67–71.

Flugzeukompasswesen und Flugsteuerkunde. W. Immler, Berlin-Charlottenburg, 2, 1918.

Der Flugzeugkompass. Anon., aus "Ueberall," Ill. Zeitschrift für Heer und Marine, Juli 1918; Die Deutsche Luftwaffe, Nr. 10, 1918: 833–839.

Drehzahl- und Fahrtfernanzeiger für Flugzeuge und Luftschiffe. Wilke, Der Motorwagen 21, Nr. 34–36, 10. u. 31. Dez. 1918: 461–463 u. 492–494.

GYROSTATICS AND ROTATIONAL MOTION. Andrew Gray, MacMillan & Co., Ltd., London, 1918: 530.

UNTERSUCHUNGEN ÜBER FLIEGKRAFT-TACHOMETER NACH DEM DREHPENDELPRINZIP. Wilke, Zeitschrift des Vereines deutscher Ingenieure, 62, 16. u. 23. Nov. 1918: 801 u. 829.

VORRICHTUNG ZUM EICHEN VON ASPIRATOREN AUF IHRE FÖRDERMENGE. Schmidt, Zeitschrift für Instrumentenkunde, 38, Nov., 1918: 180–181.

L'INHALATION D'OXYGÈNE DANS LES VOLS À HAUTE ALTITUDE. Garsaux, Bull. de la S. T. de l'Aéro. Militaire No. 2, Juillet.

NAVIGATION UND SEEMANNSCHAFT IM SEEFLUGZEUG. Th. E. Sönnichsen. Berlin W., 62, R. C. Schmidt u Co., 1918.

THE SEARCH FOR INSTRUMENTAL MEANS TO ENABLE NAVIGATORS TO OBSERVE THE ALTITUDE OF A CELESTIAL BODY WHEN THE HORIZON IS NOT VISIBLE. Proceedings U. S. Naval Institute, v. 44, No. 8, Aug., 1918.

ALTITÜDE AZIMUTH AND LINE OF POSITION TABLES. U. S. Hydrographic Office Publication No. 200.

THE CHART AS A MEANS OF FINDING GEOGRAPHICAL POSITION BY OBSERVATIONS OF CELESTIAL BODIES IN AERIAL AND MARINE NAVIGATION. G. W. Littlehales, Proc. U. S. Naval Inst., Mar., 1918.

SIMPLIFIED NAVIGATION FOR SHIPS AND AIRCRAFT. C. L. Poor. New York: Century Co. (126 pp.+), 1918.

DIE MESSNABE FÜR FLUGZEUGE. W. Steiber, Technische Berichte der Flugzeugmeisterei bezw. der Inspektion der Fliegertruppen III, Nr. 6, 1918: 221–229.

"LA NATURE" BORDINSTRUMENTE DER DEUTSCHEN FLUGZEUGE. Lefranc, Flugsport 10, Nr. 23, 6. Nov. 1918: 553–560.

UEBER FLUGTECHNISCHE INSTRUMENTE. K. Bennewitz, Technische Berichte der Flugzeugmeisterei bezw. der Inspektion der Fliegertruppen III, Nr. 5, 1918: 160–165.

FREE FLIGHT INVESTIGATIONS. Annual Report of Director, Bureau of Standards, 1918: 128.

SELF-LUMINOUS MATERIALS. N. E. Dorsey, Natl. Adv. Com. for Aeronautics, Fourth Annual Report, 1918: 339–349.

1919.

LES ALTIMÈTRES. L. Condroyer, Bulletin, S. T. Aé., 19 Février 1919.

ALTIMÈTRE À PRESSION STATIQUE. Goffin, "Aeronautics," Sept. 19.

ATMOSPHÈRE STANDARD. Toussaint, L'Aéronautique, October.

UEBER ANEROIDE. E. Warburg und W. Heuse, Zeitschrift für Instrumentenkunde, Febr. 1919: 41; abstracted in Technical Note No. 72, N. A. C. A.

DIE WAHRE NEIGUNG VON FLUGZEUGEN. E. Everling, Der Motorwagen, 22, Nr. 28, 10. Okt. 1919: 531–533.

UEBER EIN NEUES INSTRUMENT ZUM BESTIMMEN DER VERTIKALGESCHWINDIGKEIT. A. Gockel, Bulletin des Schweiz. Aero-Clubs, 13, 1919: 101–102.

THE RELATION OF WIND TO DISTRIBUTION OF BAROMETRIC PRESSURE. Sir Napier Shaw, Manual of Meteorology, part IV.

DER HÖHENREGULATOR. Popper-Lynkeus u. Löwy, Physikalische Zeitschrift, 20, 1. Okt. 1919: 433–439.

INDICATEURS DE VITESSE RELATIVE. L. Condroyer, Bull. de la S. T. Aé. Militaire, No. 28, Juin.

GENERAL INVESTIGATION OF AIR SPEED INDICATORS. F. L. Hunt, Technology Press, June, 1919 (abstract of investigations submitted: 1–5).

NOTES ON THE DESIGN OF A RECORDING THREE-DIMENSIONAL ACCELEROMETER FOR USE IN AEROPLANES. G. F. C. Searle, British Adv. Com. for Aero., Reports and Memoranda, No. 627: 1–16, June, 1919.

UEBER DIE BESTIMMUNG DER INKLINATION MIT DEM INDUKTIONS INKLINATOR. W. Uljanin, Terrestrial Magnetism, 24: 113–117. 1919.

ZWEI STAUGERÄTE. Holm. Physikalische Zeitschrift, 20, 15. Jan. 1919: 27–30.

UNTERSUCHUNG EINES STAUGERÄTES ENGLISCHER HERKUNFT. R. Katzmayr, Oesterr. Flug-Zeitschrift, 13, Nr. 2, Febr. 1919: 25–27.

BEMERKUNGEN ZUM ARTIKEL: ZUR STÖRUNGSTHEORIE DES KREISELPENDELS VON R. GRAMMEL. H. Boykow, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 10, Nr. 11–12, 28. Juni 1919: 124–125. Erwiderung dazu. R. Grammel, Ebenda: 125.

ZUR STÖRUNGSTHEORIE DES KREISELPENDELS. R. Grammel, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 10, Nr. 1–2, 25. Jan. 1919: 1–12.

UEBER GEODÄTISCHE ANWENDUNGEN DES KREISELS. Alfred Lechner, Oesterr. Flug-Zeitschrift, 13, Nr. 1, Jan. 1919: 5–10.

TECHNISCHE ANWENDUNGEN DER KREISELBEWEGUNG. H. Lorenz, Erweiterter Sonderabdruck aus der Zeitschrift des Vereines deutscher Ingenieure, 63, 6. u. 13. Dez. 1919: 64, 17. Jan. 1920: 1224–1231, 1250–1257 u. 68–69.

DER KREISEL ALS LOTSE IM LUFTMEER. A. Neuburger, Motor, März, April 1919: 135 u. 203; auch Deutsche Optische Wochenschrift, Nr. 43–44; 1919: 309–312.

REGISTRIERENDER FLÜSSIGKEITSKOMPASS ALS FAHRTRICHTUNGS-KONTROLL-APPARAT. Anon., Flugsport, 11, Nr. 19, 17. Sept. 1919: 675–676.

GENERAL INVESTIGATION OF OXYGEN INSTRUMENTS. F. L. Hunt, Technology Press, June, 1919 (abstract of investigations submitted: 6–8).

DER DRÄGER-SAUERSTOFF-APPARAT FÜR HÖHENFLÜGE. C. W. Vogelsang, Automobil- und Flugverkehr, 24. Sept. 1919: 239–240.

RICHTUNGSBESTIMMUNGEN IM LUFTFAHRZEUG MITTELS DRAHTLOSER TELEGRAPHIE. Thieme, Luftfahrt, 23, Febr. 1919: 21.

CALCULATIONS IN AERIAL PHOTOGRAPHY. L. P. Clerc, British Journal of Photography, 66, 1919: 295–299.

REPORT ON THE NAVIGATION OF AIRCRAFT BY SEXTANT OBSERVATIONS. H. N. Russell, Proc. Astron. Soc. Pacific, 31, 1919: 129–149.

LE POINT ESTIMÉ EN NAVIGATION AÉRIENNE. L. Dunoyer, l'Aéronautique, Septembre: 133.

VARIATION IN DIRECTION OF PROPAGATION OF LONG ELECTRO-MAGNETIC WAVES. Lt. Comdr. A. Hoyt Taylor, U. S. N. R. F., Bureau of Standards Scientific Paper No. 353.

PRINCIPLES OF RADIO TRANSMISSION AND RECEPTION WITH ANTENNA AND COIL AERIALS. J. H. Dellinger, Bureau of Standards Scientific Paper No. 354.

WIRELESS NAVIGATION FOR AIRCRAFT. J. Robinson, Electrician, vol. 83, Oct. 1919: 420.

DIE MESSNABE FÜR SCHRAUBEN- UND MOTORPRÜFUNGEN IM FLUGE. O. Enoch, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 10, Nr. 19, 15. Okt. 1919: 208–215.

DIE MESSNABE UND DAS SCHWUNGRAD DES MOTORS. E. Everling, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 10, Nr. 17–18, 27. Sept. 1919: 181–182.

SPANNSEILDEHNUNGSMESSER. R. Katzmayr, Oesterr. Flug-Zeitschrift, 13, Nr. 9, Sept. 1919: 142–143.

INSTRUMENTE. F. Schieferl, Oesterr. Flug-Zeitschrift 13, Nr. 5, Mai 1919: 65–69.

INSTRUMENTENKUNDE DES FLIEGERS. R. Thebis u. G. Römmler, Berlin W., 1919.

EINE METHODE ZUR MESSUNG DER SICHT. A. Wigand, Physikalische Zeitschrift, 20, 1. April 1919: 151–160; auch, Annalen der Hydrographie und maritimen Meteorologie, Mai-Juni 1919: 134–140.

LES MÉTHODES ET LES CALCULS D'ESSAIS DES AVIONS NOUVEAUX. Bull. de la S. T. de l'Aéro. Militaire, No. 26, Mai 1919.

AIRCRAFT INCIDENCE METER. A. F. Zahm, Aeronautics, Nov. 12, 1919.

1920.

THE ALTITUDE EFFECT ON AIR SPEED INDICATORS. M. D. Hersey, F. L. Hunt, and H. N. Eaton, Report No. 110 (27 pp.), preprint from Sixth Annual Report, Nat. Adv. Com. for Auro., 1920.

SUR LA VITESSE DU VENT AUX DIFFÉRENTES ALTITUDES. Toussaint, L'Aéronautique, Decembre.

MITTEILUNGEN ÜBER FORTSCHRITTE AN METEOROLOGISCHEN BEOBACHTUNGSINSTRUMENTEN. Georgi, Jahrbuch der Wissenschaftliche Gesellschaft für Luftfahrt (seit 1914) 5, 1920, Berlin 1920: 35–36. (Kurzer Auszug.)

INSTRUMENTE FÜR GESCHWINDIGKEITS- BEZW. VOLUMENMESSUNG GASFÖRMIGER UND TROPFBARFLÜSSIGER KÖRPER. P. Biber, Zeitschrift für Feinmechanik, 28, 1919; 29, 1920: 71–74, 81–84, 89–91, 97–98, 105–107, 113–114, 120–122, 129–131, 136–137, 146–147, 152–154, 161–163, 169–171, 178–180, 184–185, 3–5, 13–14 (Nr. 1 und 2); auch als Sonderdruck, Berlin Nikolassee, 1921.

DIE WILDSCHE WINDMESSTAFEL. Georgi, Flugsport, 12, 29. Sept. 1920: 460–461; ferner, 27. Okt.: 512.

UEBER EINEN NEUEN LUFTGESCHWINDIGKEITSMESSER (I). H. Gerdien u. R. Holm, Veröffentlichungen aus dem Siemens-Konzern 1, Nr. 1, 1920: 107–121.

UEBER DIE NACHEILUNG DER ZWANGLÄUFIGEN GESCHWINDIGKEITSMESSER. W. Hort, Zeitschrift für technische Physik, Nr. 11, 1920: 243–246.

ACCELERATION IN FLIGHT. F. H. Norton and E. T. Allen, Report No. 99, preprint from Sixth Ann. Rep. Nat., Adv. Com. for Aero., 1920.

SPECIAL INCLINOMETERS AND INDICATORS. Prepared in the Office of the Director of Air Service, Aviation and Aircraft Journal, 9, 1920: 322.

WAS MUSS MAN WISSEN, UM EINEN LUFTFAHRERKOMPASS ZU KOMPENSIEREN. H. Wilke, Schweizer Luftfahrt 2, 10. April 1920.

DER FERNKOMPASS. W. Friedensburg, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 11, Nr. 15, 15. Aug. 1920: 217–220.

LE COMPAS DE NAVIGATION. L'Aéronautique, Février.

INDICATEURS DE VIRAGE. Aeronautics, Flight (1919).

DER KREISEL IM FLUGZEUG. H. Boykow, Der Luftweg, 4, Nr. 26/27, 23. Sept. 1920: 7–8.

NEUZEITLICHE BORDGERÄTE ZUR FLUGORIENTIERUNG. Drexler (Bericht über Vortrag), Nachrichten für Luftfahrer, 1, Nr. 4, 29. Okt. 1920: 70–71.

DER KREISEL, SEINE THEORIE UND SEINE ANWENDUNGEN. R. Grammel, Braunschweig, 1920.

FLUGZEUG-STEURZEIGER. A. Neuburger, Verkehrstechnik, 1, 5. Febr. 1920: 51–53.

ZUR STÖRUNGSTHEORIE DES KREISELPENDELS. M. Schuler, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 11, 15. Mai 1920: 129.

DER DREXLER-STEURANZEIGER, EIN UNENTBEHRLICHES KREISELGERÄT FÜR DAS FLIEGEN IN WOLKEN, BEI NACHT UND NEBEL. Wertheim, Flugsport, 12, 3. März 1920: 104–114.

BENZINSTANDMESSER. Anon., Ill, Flug-Welt, 2, Nr. 4, 18. Febr. 1920: 116.

FLUGZEUG-KONTROLLUHR (DRP 324-284). Anon., Industrie und Handelszeitung, 3. Okt. 1920.

LE CERCLE CALCULATEUR DE ROUTES ET DE VITESSES. Duval, L'Aéronautique, Sept.

LE CORRECTEUR DE ROUTE. Lt. de vaisseau Le Prieur, L'Aéronautique, No. 18, Nov.–Dec. 1920: 227.

LE DERIVOMÈTRE BRION. L'Aéronautique, Mars 1920.

Nouvelle Méthode de Navigation Aérienne à l'Estime. Y. Le Prieur, L'Aéronautique, Décembre.

Traité Pratique de Navigation Aérienne. L. Hébrard et A. B. Duval, L'Aéronautique, 1920–21.

Die Instrumentellen Hilfsmittel des Fliegens. H. Boykow (Bericht über Vortrag), Nachrichten für Luftfahrer, 1, Nr. 8, 26. Nov. 1920: 122.

Messverfahren zur Untersuchung von Lüftanlagen auf Schiffen. Freudenthal, Zeitschrift des Vereines deutscher Ingenieure, 64, 15. Mai 1920: 371–374.

Efficiency of Small Bearings in Instruments of the Type Used in Aircraft. F. H. Norton, Report No. 94 (10 pp.), preprint from Sixth Ann. Rep., Nat. Adv. Com. for Aero., 1920.

Aeronautic Instruments: General Principles of Construction, Testing, and Use. M. D. Hersey (with Discussion by Prof. S. H. Anderson, Com. G. C. Westervelt, Dr. F. A. Carpenter, Prof. A. McAdie, Mr. E. A. Sperry, Lieut. A. F. Hegenberger, Rear-Adml. J. A. Hoogewerff, Prof. T. D. Cope), Trans. Am. Soc. Mech. Engs., 42, 1920: 81–118.

Design of Instruments for the Navigation of Aircraft. G. M. B. Dobson, Geographical Journal, Vol. LVI, No. 5, Nov., 1920: 370. Royal Geographical Society of London.

Methods of Measurement. L. Bairstow, Chapter III, 73–115, Applied Aerodynamics, New York; Longmans Green & Co., 1920.

A Primer of Air Navigation. H. E. Wimperis. London, Constable, 1920: 128.

Aerial Navigation. J. E. Dumbleton. London. Crosby, Lockwood & Son, 1920: 168.

Flying the Atlantic in Sixteen Hours. Sir Arthur Whitten Brown. Frederick A. Stokes Co.

The Prospective Utilization of Vessel-to-Shore Radio-Compass Bearings in Aerial Navigation. G. W. Littlehales, Journal American Society of Naval Engineers, vol. 32, No. 1, Feb., 1920.

Direction and Position Finding. H. J. Round, Journal Institution of Electrical Engineers (British), 58, Mar., 1920: 224–257.

1921.

Altimètre. Gourdou et Lesseurre, tomé I, 93. Rapports du Premier Congrès International de la Navigation Aérienne, Paris, 15–25 Novembre, Ed. Blondel la Rougery, 7, rue St. Lazare, Paris.

The Testing of Aneroid Barometers at the Laboratory of the Dominion Lands Survey. Bull. 42: 1–9 (Ottawa).

Das Messen der Wahren Neigung. E. Everling, Das Weltall, 21, Nr. 9–10 u. 11–12, Febr., März 1921: 67–73.

Neigungs- und Kurvenmessung bei Flugzeugen. E. Everling, Der Motorwagen, 24, Nr. 24, 31. August 1921: 481–493.

Methodik Aerophysikalischer Flüge. A. Wigand. I. Ein Flugzeug-Meteorograph, A. Wigand und A. Wieneke, Methodik aerophysikalischer Flüge II. Die Anbringung von Meteorographen im Flugzeuge, A. Wigand, und A. Wieneke, Methodik aerophysikalischer Flüge II. Temperaturmessungen im Flugzeuge, Beiträge für Physik der freien Atmosphäre, 9, Nr. 4, 1921: 137–147, 148–162, 163–175.

Étude d'une Girouette à Applications Multiples. Louis Constantin, tome II, 91. Rapports du Premier Congrès International de la Navigation Aérienne. Paris, 15–25 Novembre; Ed. Blondel la Rougery, 7, rue St. Lazare, Paris.

On the Theory of Air Speed Indicators. Mayo Dyer Hersey, tome II, 79. Rapports du Premier Congrès International de la Navigation Aérienne. Paris, 15–25 Novembre; Ed. Blondel la Rougery, 7, rue St. Lazare, Paris.

N. A. C. A. Recording Air Speed Meter. F. H. Norton, Aerial Age Weekly, Vol. 14, No. 7: 151–154. Technical Note No. 64, N. A. C. A.

Ein Manometer für Aufzeichnung der Fluggeschwindigkeiten. C. Wieselsberger, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 12, Nr. 1, 15 Jan. 1921: 4–6.

Der Flügel-Beanspruchungsmesser von Klemperer. E. M., Der Luftweg, 5, 7. April 1921: 105–106.

Druckmessungen am Fliegenden Flugzeug. A. Pröll, Zeitschrift für Flugtechnik und Motorluftschiffahrt, 12, Nr. 12, 30. Juni 1921: 177–180.

Neuzeitliche Bordgeräte zur Flugorientierung. F. Drexler, Berichte und Abhandlungen der Wissenschaftliche Gesellschaft für Luftfahrt (seit 1914), Nr. 4, April 1921: 14. (Kurzer Bericht.)

Anschütz Artificial Horizon. A. Gradenwitz, Aeronautics, 20, June 2, 1921: 390–391.

Les Indicateurs Gyroscopiques de Virage. Raoul Badin, tome I, 96. Rapports du Premier Congrès International de la Navigation Aérienne, Paris, 15–25 Novembre. Ed. Blondel la Rougery, 7, rue St. Lazare, Paris.

Indicateur de Virage. A. de Grammont de Guiche, tome II, 87. Rapports du Premier Congrès International de la Navigation Aérienne, Paris, 15–25 Novembre. Ed. Blondel la Rougery, 7, rue St. Lazare, Paris.

Inhalateur d'Oxygen. Gourdou et Lesseurre, tome II, 170. Rapports du Premier Congrès International de la Navigation Aérienne, Paris, 15–25 Novembre. Ed. Blondel la Rougery, Editeur, 7, rue St. Lazare, Paris.

L'Echelle Rectiligne et les Appareils à Sensibilité Constante. Barbillon, L'Aéronautique, Mars.

Pratique de la Navigation Aérienne. Hébrard et Duval, L'Aéronautique, Février, Mars, Avril.

Old and New Problems of Aeronautic Instruments. M. D. Hersey, Jour. Wash. Acad. Sci., 11, 1921: 22–23.

Aeronautic Instruments. C. E. Mendenhall, Jour. Franklin Institute, 191, 1921: 57–86.

The Aveline Automatic Pilot. Aerial Age, 12, 1921: 656–658; 667.

Radio Communication with Postal Aeroplanes. J. L. Bernard and L. E. Whittemore, Aerial Age, 13, 1921: 105–106.

Position Plotting by Radio Bearings. Elmer B. Collins, Proc. U. S. Naval Inst., vol. 47, No. 2, Feb. 1921.

The Radio Direction Finder and Its Application to Navigation. F. A. Kolster and G. W. Dunmore. (Forthcoming Bureau of Standards publication.)

Appareils de Repèrage de la Position d'un Aéronef. Capitaine Volmerange, tome I, 87. Rapports du Premier Congrès International de la Navigation Aérienne, Paris, 15–25 Novembre. Ed. Blondel la Rougery, 7, rue St. Lazare, Paris.

La Navigation à l'Estime. Pierre Maffert, tome II, 73. Rapports du Premier Congrès International de la Navigation Aérienne, Paris, 15–25 Novembre. Ed. Blondel la Rougery, 7, rue St. Lazare, Paris.

Le "Toposcope" (Chercheur de Point). Détermination graphique due point en avion indépendant du cap et chemin parcouru. Capitaine Vucetic, tome II, 96. Rapports du Premier Congrès International de la Navigation Aérienne, Paris, 15–25 Novembre. Ed. Blondel la Rougery, 7, rue St. Lazare, Paris.

Graphiques pour la Détermination des Routes Orthodromiques sur la Projection de Mercator. Comptes-rendus de l'Academie des Sciences, Janvier 31, 1921.

Progrès Techniques en 1920 dans la Navigation Aérienne. Capitaine A. Volmerange, L'Aéronautique, No. 19–20, Janvier 1921: 319.

Correcteur de Routes Coutinho-Sacadura. Capitaine de Corvette Sacadura-Cabral, tome II, 112. Rapports du Premier Congrès International de la Navigation Aérienne, Paris, 15–25 Novembre. Ed. Blondel la Rougery, 7, rue St. Lazare, Paris.

Die Instrumentelle Unterstützung des Fliegens. H. Boykow, Zeitschrift für technische Physik, 2, Nr. 9, Sept. 1921: 238–244.

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