AERONAUTICS

SIXTH ANNUAL REPORT

OF THE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

1920

INCLUDING TECHNICAL REPORTS
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LETTER OF TRANSMITTAL.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
Washington, D. C., November 20, 1920.

The PRESIDENT:

In compliance with the provisions of the act of Congress approved March 3, 1915 (naval appropriation act, Public, No. 273, 63d Cong.), I have the honor to transmit herewith the Sixth Annual Report of the National Advisory Committee for Aeronautics, including a statement of its expenditures for the fiscal year ending June 30, 1920.

In addition to the exercise of its prescribed functions in the field of scientific research in aeronautics, the National Advisory Committee for Aeronautics has, during the past year, given special consideration to the question of organization of governmental activities in aeronautics, and has effected a coordination of views on this subject between the military and naval air services and other governmental agencies concerned. The agreements reached have been given definite expression in a draft of legislation providing for the establishment of a Bureau of Aeronautics in the Department of Commerce for the regulation and encouragement of commercial air navigation. In this connection attention is invited to that section of the report entitled "Organization of Governmental Activities in Aeronautics."

The attention of the President and of the Congress is especially invited to the closing section of the report, entitled "A National Aviation Policy," and the specific recommendations of the National Advisory Committee for Aeronautics therein set forth as to the legislative steps which in its judgment are necessary to carry such a national aviation policy into effect.

Respectfully submitted.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
CHARLES D. WALCOTT, *Chairman.*

LETTER OF SUBMITTAL.

To the Senate and House of Representatives:

In compliance with the provisions of the act of March 3, 1915, making appropriations for the naval service for the fiscal year ending June 30, 1916, I transmit herewith the Sixth Annual Report of the National Advisory Committee for Aeronautics for the fiscal year ended June 30, 1920.

The attention of the Congress is invited to the recommendation of the National Advisory Committee for Aeronautics for the establishment of a Bureau of Aeronautics in the Department of Commerce for the regulation and encouragement of commercial aviation. The national aviation policy as formulated by the National Advisory Committee for Aeronautics and the constructive recommendations therein set forth for the consideration of the Congress have the hearty approval of the departments concerned as well as myself.

WOODROW WILSON.

THE WHITE HOUSE,
7 December, 1920.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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EXECUTIVE COMMITTEE.

JOSEPH S. AMES, *Chairman*.
S. W. STRATTON, *Secretary*.

THURMAN H. BANE.
T. T. CRAVEN.
JOHN F. HAYFORD.
CHARLES F. MARVIN.
CHARLES T. MENOHER.
D. W. TAYLOR.
CHARLES D. WALCOTT.

SIXTH ANNUAL REPORT

OF THE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
Washington, D. C., November 20, 1920.

To the Congress:

In accordance with the provision of the act of Congress, approved March 3, 1915, establishing the National Advisory Committee for Aeronautics, the committee submits herewith its Sixth Annual Report. In this report the committe has described its activities during the past year, the technical progress in the study of scientific problems relating to aeronautics, the assistance rendered by the committee in the formulation of a policy regarding the organization of governmental activities in aeronautics, the coordination of research work in general, the examination of aeronautical inventions, and the collection, analysis, and distribution of scientific and technical data. This report also contains a statement of expenditures, estimates for the fiscal year 1922, and a discussion of a national aviation policy with certain specific recommendations for the consideration of Congress.

FUNCTIONS OF THE COMMITTEE.

The National Advisory Committee for Aeronautics was established by act of Congress, approved March 3, 1915. The organic act charges the committee with the supervision and direction of the scientific study of the problems of flight with a view to their practical solution, the determination of problems which should be experimentally attacked, their investigation and application to practical questions of aeronautics. The act also authorizes the committee to direct and conduct research and experimentation in aeronautics in such laboratory or laboratories in whole or in part as may be placed under its direction.

Supplementing the prescribed duties of the committee, its broad general functions may be stated as follows:

First. Under the law the committee holds itself at the service of any department or agency of the Government interested in aeronautics, for the furnishing of information or assistance in regard to scientific or technical matters relating to aeronautics, and in particular for the investigation and study of problems in this field with a view to their practical solution.

Second. The committee may also exercise its functions for any individual, firm, association, or corporation within the United States, provided that such individual, firm, association, or corporation defray the actual cost involved.

Third. The committee institutes research, investigation, and study of problems which, in the judgment of its members or of the members of its various subcommittees, are needful and timely for the advance of the science and art of aeronautics in its various branches.

Fourth. The committee keeps itself advised of the progress made in research and experimental work in aeronautics in all parts of the world, particularly in England, France, and Italy, and will extend its efforts in the securing of information from Germany, Austria, Canada, and other countries.

Fifth. The information thus gathered is brought to the attention of the various subcommittees for consideration in connection with the preparation of programs for research and experimental work in this country. This information is also made available promptly to the military and naval air services and other branches of the Government, and such as is not confidential is immediately released to university laboratories and aircraft manufacturers interested in the study of specific problems, and also to the public.

Sixth. The committee holds itself at the service of the President, the Congress, and the executive departments of the Government for the consideration of special problems which may be referred to it, such as organization of governmental activities in aeronautics, recommendations as to proper action under the Convention for the Regulation of International Air Navigation, questions of policy regarding the regulation and development of civil aviation, advanced education in aeronautical engineering, etc.

ORGANIZATION OF THE COMMITTEE.

The committee has 12 members, appointed by the President. The law provides that the personnel of the committee shall consist of two members from the War Department, from the office in charge of military aeronautics; two members from the Navy Department, from the office in charge of naval aeronautics; a representative each of the Smithsonian Institution, of the United States Weather Bureau, and of the United States Bureau of Standards; and not more than five additional persons acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences. All members as such serve without compensation.

During the past year Mr. Orville Wright was appointed by the President to membership on the committee to succeed Dr. John R. Freeman, resigned.

The full committee meets twice a year, the annual meeting being held in October and the semiannual meeting in April. The present report includes the activities of the committee between the annual meeting held on October 9, 1919, and that held on October 7, 1920.

The present organization of the committee is as follows:

Charles D. Walcott, Sc. D., chairman.
S. W. Stratton, Sc. D., secretary.
Joseph S. Ames, Ph. D.
Maj. Thurman H. Bane, United States Army.
Capt. T. T. Craven, United States Navy.
William F. Durand, Ph. D.
John F. Hayford, C. E.
Charles F. Marvin, M. E.
Maj. Gen. Charles T. Menoher, United States Army.
Michael I. Pupin, Ph. D.
Rear Admiral D. W. Taylor, United States Navy.
Orville Wright, B. S.

THE EXECUTIVE COMMITTEE.

For carrying out the work of the Advisory Committee the regulations provide for the election annually of an executive committee, to consist of seven members, and to include further any member of the Advisory Committee not otherwise a member of the executive committee, but resident in or near Washington and giving his time wholly or chiefly to the special work of the committee. The executive committee, as elected and organized on October 7, 1920, is as follows:

Joseph S. Ames, Ph. D., chairman.
S. W. Stratton, Sc. D., secretary.
Maj. Thurman H. Bane, United States Army.
Capt. T. T. Craven, United States Navy.
John F. Hayford, C. E.
Charles F. Marvin, M. E.
Maj. Gen. Charles T. Menoher, United States Army.
Rear Admiral D. W. Taylor, United States Navy.
Charles D. Walcott, Sc. D.

The executive committee, in accordance with the general instructions of the Advisory Committee, exercises the functions prescribed by law for the whole committee, administers the affairs of the committee, and exercises general supervision over all its activities. The executive committee held regular monthly meetings throughout the year, and in addition held three special meetings, on the following dates: October 9, 1919; March 1 and June 28, 1920.

The executive committee has organized the necessary clerical and technical staffs for handling the work of the committee proper. General responsibility for the execution of the programs and policies approved by the executive committee is vested in the executive officer, Mr. George W. Lewis. In the subdivision of general duties, he has immediate charge of the scientific and technical work of the committee, being directly responsible to the chairman of the executive committee, Dr. Joseph S. Ames. The assistant secretary, Mr. John F. Victory, has charge of administration and personnel matters, property, and disbursements, under the direct control of the secretary of the committee, Dr. S. W. Stratton.

SUBCOMMITTEES.

The executive committee has organized six standing subcommittees, divided into two classes, administrative and technical, as follows:

ADMINISTRATIVE.	TECHNICAL.
Personnel, buildings, and equipment.	Aerodynamics.
Publications and intelligence.	Power plants for aircraft.
Governmental relations.	Materials for aircraft.

The organization and work of the technical subcommittees are covered in the reports of those committees appearing in another part of this report. A statement of the organization and functions of the administrative subcommittees follows:

COMMITTEE ON PERSONNEL, BUILDINGS, AND EQUIPMENT.

FUNCTIONS.

1. To handle all matters relating to personnel, including the employment, promotion, discharge, and duties of all employees.
2. To consider questions referred to it and make recommendations regarding the initiation of projects concerning the erection or alteration of laboratories and the equipment of laboratories and offices.
3. To meet from time to time on the call of the chairman, and report its actions and recommendations to the executive committee.
4. To supervise such construction and equipment work as may be authorized by the executive committee.

ORGANIZATION.

Dr. Joseph S. Ames, chairman.
Dr. S. D. Stratton, vice-chairman.
Prof. Charles F. Marvin.
J. F. Victory, secretary.

COMMITTEE ON PUBLICATIONS AND INTELLIGENCE.

FUNCTIONS.

1. The collection, classification, and diffusion of technical knowledge on the subject of aeronautics, including the results of research and experimental work done in all parts of the world.
2. The encouragement of the study of the subject of aeronautics in institutions of learning.
3. Supervision of the office of aeronautical intelligence.
4. Supervision of the foreign office in Paris.
5. The collection and preparation for publication of the technical reports, technical notes, and annual report of the committee.

ORGANIZATION.

Dr. Joseph S. Ames, chairman.
Prof. Charles F. Marvin, vice-chairman.
Miss M. M. Muller, secretary.

COMMITTEE ON GOVERNMENTAL RELATIONS.

FUNCTIONS.

1. Relations of the committee with executive departments and other branches of the Government.
2. Governmental relations with civil agencies.

ORGANIZATION.

Dr. Charles D. Walcott, chairman.
Dr. S. W. Stratton.
J. F. Victory, secretary.

QUARTERS FOR COMMITTEE.

On January 12, 1920, pursuant to authorization by the Public Buildings Commission, the administrative offices of the National Advisory Committee for Aeronautics were moved from the Air Service Building, Fourth Street and Missouri Avenue NW., Washington, D. C., to the Navy Building, Seventeenth and B Streets NW., Washington, D. C. The technical work of the committee, conducted by or under the supervision of the various subcommittees, has been carried on in various governmental laboratories and shops, including the Bureau of Standards and the committee's own field station at Langley Field, Va., known as the Langley Memorial Aeronautical Laboratory, and also in various laboratories connected with institutions of learning whose cooperation in the conduct of scientific research in aeronautics has been secured.

THE LANGLEY MEMORIAL AERONAUTICAL LABORATORY.

In previous annual reports, the committee described the progress made in the development of its field station at Langley Field, Va., for the prosecution of scientific research in aeronautics. The station now comprises three principal units, namely, an aerodynamical laboratory or wind tunnel, an engine dynamometer laboratory, and a research laboratory building, the latter including administrative and drafting offices, machine and wood-working shops, and photographic and instrument laboratories. The research laboratory and the wind tunnel building are of permanent brick construction; the engine dynamometer laboratory is housed in a temporary four-section steel airplane hangar.

With the completion of the wind tunnel proper, in April, 1920, the committee sought the approval of the President to name its field station in honor of the late Dr. Samuel Pierpont Langley. With the approval of the President and the Attorney General, the field station was accordingly given the name "Langley Memorial Aeronautical Laboratory," and was formally opened as such, with appropriate exercises, on June 11, 1920. Special invitations to men prominent in the development of aviation in the United States were issued jointly by the committee and the Director of Air Service of the Army. The executive committee, the aerodynamics committee, and the power plants committee held meetings at the field in the morning, and in the afternoon the members, the invited guests, of whom a number had flown to the field from Washington and more distant points, and the officers of the field assembled in the wind tunnel building, where formal dedicatory remarks were made by Dr. Joseph S. Ames, as Chairman of the Executive Committee, by Maj. Gen. Charles T. Menoher, as Director of Air Service of the Army and member of the committee, and by Rear Admiral D. W. Taylor, as Chief Constructor of the Navy and member of the committee.

The Langley Memorial Aeronautical Laboratory occupies a plot of ground known as Plot 16, Langley Field, Va., the plot having been set aside for the committee's use by the Chief Signal Officer of the Army at the time the site was selected as a proposed joint experimental station and proving ground for the Army and Navy air services and the Advisory Committee. The use of that plot of ground was officially approved by the Acting Secretary of War on April 24, 1919. The three buildings at present constituting the Langley Memorial Aeronautical Laboratory have been erected by the committee pursuant to authority granted by Congress.

OFFICE OF AERONAUTICAL INTELLIGENCE.

The Office of Aeronautical Intelligence was established in the early part of 1918 as an integral branch of the committee's activities. Its functions are the collection, classification, and diffusion of technical knowledge on the subject of aeronautics to the military and naval air services and civil agencies interested, including especially the results of research and experimental work conducted in all parts of the world. It is the officially designated Government depository for scientific and technical reports and data on aeronautics. The principal sources of such technical information are the following: The technical subcommittees and their engineering staffs, the Engineering Division and the Information Group of the Army Air Service, the Naval Air Service, the Bureau of Standards, the Forest Service, educational institutions, individual professors and experimenters, foreign governmental and private laboratories, and university professors.

Promptly upon receipt, all reports are analyzed and classified, and brought to the special attention of the subcommittees having cognizance, and to the attention of other interested parties, through the medium of public and confidential bulletins. Reports are duplicated where practicable, and distributed upon request. Confidential bulletins and reports are not circulated outside of governmental channels.

To efficiently handle the work of securing and exchanging reports in foreign countries, the committee maintains a technical assistant in Europe, with headquarters in Paris. It is his duty to personally visit the Government and private laboratories, centers of aeronautical information, and private individuals in England, France, Italy, Germany, and Austria, and endeavor to secure for America not only printed matter which would in the ordinary course of events become available in this country, but more especially to secure advance information as to work in progress, and any technical data not prepared in printed form, and which would otherwise not reach this country.

The service rendered by the Office of Aeronautical Intelligence during the past year has increased by approximately 60 per cent, including increases in services rendered to the Naval Air Service of 45 per cent; other governmental agencies, 60 per cent; aircraft manufacturers, 100 per cent; educational institutions, 180 per cent.

The technical assistant in Europe, in addition to rendering periodical reports as to developments in aeronautics, based on close personal observation of conditions in European countries, has secured for the committee many valuable reports and documents, including a number of complete sets of reports of the scientific research and experimental work conducted in Germany during the war.

THE AERONAUTICAL BOARD OF THE ARMY AND NAVY.

The Aeronautical Board was appointed by the Secretary of War and the Secretary of the Navy, and is composed exclusively of Army and Navy officers. It has no official connection with the National Advisory Committee for Aeronautics, its functions being the consideration of military questions regarding the use of aeronautics in both services. The committee feels that there is a positive need for such a joint board; in fact, the present Aeronautical Board is a development of the Joint Army and Navy Technical Aircraft Board which was established during the war on the recommendation of this committee. There is no friction or duplication of functions whatsoever between the Aeronautical Board and this committee. On the contrary, a cordial contact has always existed where the work of the two organizations brought them together.

ORGANIZATION OF GOVERNMENTAL ACTIVITIES IN AERONAUTICS.

During the past year the committee has on numerous occasions given consideration to the subject of organization of governmental activities in aeronautics. A number of bills had been introduced in Congress providing widely differing solutions of the question, and each of these bills was discussed by the committee. After the adjournment of Congress and throughout the summer and fall of 1920 the committee endeavored to coordinate the views of the various governmental agencies interested, and to develop a tentative draft of legislation giving definite expression to the agreements reached. In its consideration of each of the measures introduced the committee was guided by an intimate knowledge of the problems peculiar to the military and naval air services, by the necessity of providing for, and reckoning with, a healthy development of civil aviation, and by broad general considerations of sound governmental policy in regard to matters of organization and administration. Of all the bills analyzed by the committee, two were selected for more earnest consideration, and in each case this has led to agreement upon amendments which will, in the committee's judgment, render either measure, if enacted into law, operative with a minimum of friction, confusion, or waste, at the same time utilizing existing agencies to the best interests of good administration. An analysis of the two bills referred to, as modified by the committee, follows:

House bill 14061 was introduced into the House of Representatives by Mr. Kahn, May 13, 1920. With the modifications recommended by the National Advisory Committee for Aeronautics, it provides for the establishment of a Bureau of Aeronautics in the Department of Commerce, in charge of a Commissioner of Air Navigation whose duties will comprise the licensing of aircraft, pilots, and airdromes, the designation of flying routes, cooperation with the States and municipalities in the laying out of landing fields, and, in general, the promotion of all matters looking to the advancement of commercial aviation. The bill provides also that all rules and regulations governing air navigation, licenses, etc., shall be formulated by the Commissioner of Air Navigation, who shall submit the same to the National Advisory Committee for Aeronautics for consideration, criticism, and recommendation to the Secretary of Commerce, who, if the same meet with his approval, shall formally promulgate the same. The bill provides further that the Commissioner of Air Navigation shall be appointed a member of the National Advisory Committee for Aeronautics, and shall seek the approval of the committee in certain matters, such as the laying out of flying routes, etc., which may hold a vital interest for other departments of the Government. The committee believes that all such extensive plans should be carefully considered with a view to serving the national interests as far as possible; that the Commissioner of Air Navigation should have the benefit of the counsel and advice of the other governmental agencies concerned; and that the method proposed in this bill would be practicable and effective.

House bill 14137 was introduced in the House of Representatives by Mr. Hicks, May 19, 1920. With the modifications recommended by the National Advisory Committee for Aeronautics, it makes substantially the same provisions for the regulation and development of air navigation as the modified bill, H. R. 14061, described above, with several additions, viz.: That the various departments of the Government shall prepare programs for experimental research or development work in aeronautics, and for the purchase or construction of aircraft, engines, accessories, and hangars, and the acquisition of land for purposes in connection with aviation, and shall submit such programs to the National Advisory Committee for Aeronautics for consideration and recommendation before contracts are made or orders are placed for same; that for the purpose of preliminary correlation of estimates the various departments shall submit their estimates for all aviation purposes to the National Advisory Committee for Aeronautics for consideration and recommendation by the committee before the estimates are submitted to Congress, the comments and recommendations of the Advisory Committee to be transmitted to Congress along with the estimates.

The committee has been actuated in its suggested revision of these bills by a desire to produce practicable workable plans for improving the existing situation. The committee believes that the Hicks bill as modified is responsive to that sentiment in Congress which has sought to prevent duplication of expenditures and effort in the military and naval air services. The committee is not wholly convinced that the necessity for such legislation exists at the present time, nor that the method proposed would have the desired result. On the other hand, the committee is unanimous in supporting the Kahn bill as modified. The most urgent need at this time is the development of commercial aviation under Federal regulation. There has been some objection to placing the regulation of air navigation under the Department of Commerce, but the National Advisory Committee for Aeronautics believes it unnecessary and unwise to create another independent Government establishment for the exercise of such functions, and that by making the Commissioner of Air Navigation a member of the National Advisory Committee for Aeronautics, and requiring him to submit his plans to the committee, he can not fail to be guided in his actions by considerations of paramount national interests. The text of the two bills referred to, as modified by the National Advisory Committee for Aeronautics, follows:

H. R. 14061.

INTRODUCED IN THE HOUSE OF REPRESENTATIVES BY MR. KAHN, MAY 13, 1920.

A BILL To regulate air navigation within the United States and its dependencies, and between the United States or any of its dependencies and any foreign country or its dependencies.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That to provide for the regulation of air navigation and to render effective the provisions of any treaty or convention relating to air navigation that may hereafter be entered into by the United States, there is hereby established in the Department of Commerce a bureau to be known as the Bureau of Aeronautics, and a Commissioner of Air Navigation, who shall be the head thereof, who shall be appointed by the President, by and with the advice and consent of the Senate, and who shall receive a salary of $6,000 per annum. The Commissioner of Air Navigation shall be appointed by the President an additional member of the National Advisory Committee for Aeronautics.

SEC. 2. That there shall be in said bureau, an assistant commissioner of recognized technical ability, who shall be appointed by the President, by and with the advice and consent of the Senate and who shall receive a salary of $5,000 per annum. The assistant commissioner shall perform such duties as may be prescribed by the commissioner, or as may be required by law. There shall also be in said bureau a chief clerk, and such other clerical assistants, inspectors, experts, and special agents as may be required from time to time and authorized by Congress.

SEC. 3. That all rules and regulations hereinafter provided for, except as otherwise provided for in section 9 hereof, shall be formulated by the Commissioner of Air Navigation, who shall submit the same to the National Advisory Committee for Aeronautics for consideration, criticism, and recommendation to the Secretary of Commerce, who, if the same meet with his approval, shall formally promulgate the same. When approved and duly promulgated by the Secretary of Commerce such rules and regulations shall be legally binding and enforceable from the date of such promulgation, unless otherwise provided therein: *Provided,* That hereafter the National Advisory Committee for Aeronautics, in addition to the exercise of its present functions, is authorized to act in an advisory capacity in connection with the formulation and promulgation of such rules and regulations, and for the consideration of questions of policy affecting the development of civil or commercial aviation, including recommendations from time to time for amendments to this act or subsequent acts.

SEC. 4. That the Commissioner of Air Navigation shall, in accordance with section 3 hereof, formulate all necessary and proper rules and regulations respecting air navigation and air traffic, issuance of licenses for aircraft, aviators and aeronauts, rules of the air, the giving and heeding of signals, periodical and before-flight inspection of aircraft, the carrying of lights and signals, the landing at and departure from airdromes, using prescribed routes and avoiding prohibited areas, the carrying and lightening of ballast, the carryng and use of wireless telegraph and telephone instruments and other radio equipment, the carrying, keeping, and exhibiting of log books and other records, the landing for customs or immigration inspectors, and other matters for the safety and convenience of air navigation. Such rules and regulations shall prescribe air routes and prohibited areas over which aircraft shall not fly for military reasons or in the interest of public safety. Such rules and regulations shall include descriptions of, and, if necessary, maps showing such air routes and prohibited areas, and shall include all areas over which the Secretary of War or the Secretary of the Navy may request in writing the prohibition of the movement of aircraft. All aircraft engaged in air navigation within the jurisdiction of the United States or its dependencies, or coming into such jurisdiction from a foreign country or its dependencies, or upon the high seas as to such aircraft as are flying under a United States license, and as to aircraft over which the United States has jurisdiction on other grounds, are hereby required to conform to the rules and regulations duly promulgated in accordance with this act.

SEC. 5. That all airdromes within the jurisdiction of the United States and its dependencies are hereby required to conform to such rules and regulations regarding the placing and use of lights and signals, the size and marking of landing places, and other matters for the safety of air navigation as may be prescribed by the rules and regulations duly promulgated in accordance with this act.

SEC. 6. That all rules and regulations, as herein provided, shall be so formulated as to carry out the provisions of this act and subsequent acts and of any treaty or convention which may hereafter be entered into by the United States. The Secretary of Commerce may alter, modify, amend, or revoke such rules and regulations in the same manner as provided in section 3 for the promulgation thereof, subject to the provisions of this act and any subsequent act and the provisions of any treaty which has been or may hereafter be entered into by the United States.

SEC. 7. That it shall be the province and duty of the Bureau of Aeronautics, except as may be otherwise provided, to foster, develop, and promote all matters pertaining to civil or commercial aeronautics, including the collection and dissemination of information relating thereto, the administration of all rules and regulations provided for in this act, the regulation and arrangement of landing fields and airdromes, and the allotment of such funds as may be provided by law to aid the various States in the establishment of landing fields and airdromes.

SEC. 8. That the Commissioner of Air Navigation is authorized and directed to plan aerial routes throughout the United States and its possessions, and to this end shall cooperate with the various States, cities, and municipalities for the purpose of setting aside and establishing airdromes and landing fields to be used in common by Federal, State, municipal, commercial, and private aircraft under the rules and regulations to be duly promulgated in accordance with section 3 of this act: *Provided*, That such plans for aerial routes and the establishment of airdromes and landing fields shall be submitted to the National Advisory Committee for Aeronautics, and upon approval by said advisory committee shall be carried into effect by the Commissioner of Air Navigation to the extent of the appropriations available for such purpose.

SEC. 9. That for the purpose of encouraging the development of commercial aeronautics in the United States, full cooperation shall be given by the Bureau of Aeronautics to the owners or operators of private or commercial aircraft, and that the Secretary of War, the Secretary of the Navy, the Postmaster General, and the Secretary of Commerce shall furnish to any owner or operator of private or commercial aircraft landing on an airdrome or landing field under their respective jurisdictions, aviation fuel, oil, supplies, and necessary mechanical assistance of an emergency character, under such regulations as they may approve and promulgate for their respective services. The proceeds from such sales and assistance shall be deposited in the Treasury of the United States to the credit of the appropriations involved.

SEC. 10. That no aircraft shall be used or operated in air navigation within the United States or its dependencies, or between the United States and any of its dependencies, or between the United States or any of its dependencies and any foreign country or its dependencies, or on the high seas as to aircraft over which the United States has jurisdiction, except under and in accordance with a license granted by the Commissioner of Air Navigation to the owner of the aircraft. Aircraft so licensed shall not be used or operated in air navigation except in accordance with the rules and regulations duly promulgated in accordance with this act: *Provided*, That aircraft and operators of the same duly registered and licensed in other countries and only transitorily or periodically in the United States and its dependencies may be exempted by treaty or convention from the requirements as to securing a license provided for in this section and section 11 hereof, but shall be subject to all other sections of this act and the rules and regulations duly promulgated in accordance with this act so long as they are within the boundaries of the United States and its dependencies.

Such license for aircraft shall not be granted unless the owner is a citizen of the United States or of its dependencies, or if such owner be a company or corporation, then a company or corporation organized under the laws of the United States or some one of the States thereof, the president or chairman and the majority of the members of which company, or the president or chairman and a majority of the board of directors and the holders of a majority of the stock of which corporation, are citizens of the United States or of its dependencies, nor unless such aircraft shall be constructed in a manner suitable for the service in which it is to be employed and is in a condition to warrant the belief that it may be used for such service in air navigation with reasonable safety, such construction, including standards of both workmanship and material, and condition to be determined in accordance with the rules and regulations duly promulgated in accordance with this act.

The Commissioner of Air Navigation shall keep a record in which licensed aircraft shall be registered, and such record shall contain, in a statement made under oath, the name of the owner of the aircraft, a statement as to his citizenship, or, in the case of a company or corporation, the facts showing that it comes within the provisions of this section, the purpose for which the aircraft is to be used, and an accurate description of such aircraft.

Such license shall expire one year from the date of its issuance or upon a change of ownership of the aircraft, whichever may first occur, and shall not be renewed or extended, but upon expiration thereof in either of the manners mentioned the owner of the aircraft may apply for a new license upon complying with the laws and the rules and regulations duly promulgated in accordance with this act.

Any such license may be revoked at any time by the Commissioner of Air Navigation upon its being shown to his satisfaction that any of the facts and qualifications upon which the issuance of such license was based have ceased to exist or upon failure to comply with the existing laws and rules and regulations.

For the purpose of ascertaining the facts upon which to determine whether licenses shall be granted or revoked the Commissioner of Air Navigation shall have the right to conduct hearings, to summon witnesses, to administer oaths, and to inspect books and records, including the stock books of companies and corporations.

SEC. 11. That no person shall operate an aircraft engaged in air navigation as provided in section 10 of this act, except under and in accordance with a license granted by the Commissioner of Air Navigation, and the Commissioner of Air Navigation is authorized to grant such license in accordance with rules and regulations duly promulgated in accordance with this act.

Such license shall expire one year from date of its issuance unless sooner revoked by the Commissioner of Air Navigation upon its being shown to his satisfaction that any of the facts and qualifications upon which the issuance of such license was based have ceased to exist or upon failure to comply with the existing laws and rules and regulations, but upon the expiration of such license the holder thereof may apply for a new license by complying with the laws and rules and regulations duly promulgated in accordance with this act.

SEC. 12. No airdrome shall be operated except under and in accordance with a license granted by the Commissioner of Air Navigation to the owner of the airdrome in accordance with the rules and regulations duly promulgated in accordance with this act: *Provided*, That such owner shall be a citizen of the United States or of its dependencies, or, if such owner be a company or corporation, then a company or corporation organized under the laws of the United States or some one of the States thereof, the president or chairman and the majority of the members of which company, or the president or chairman of the board of directors and a majority of the board of directors and the holders of a majority of the stock of which corporation, are citizens of the United States or its dependencies, and upon its being shown that the airdrome is prepared to operate in accordance with the said rules and regulations. Such license shall expire upon a change of ownership of the airdrome and shall not be renewed or extended, but a new license may be issued upon compliance with the laws and rules and regulations duly promulgated in accordance with this act. Any such license may be revoked at any time by the Commissioner of Air Navigation upon its being shown to his satisfaction that any of the facts upon which the issuance of such license was based have ceased to exist, or upon failure to comply with existing laws and rules and regulations duly promulgated in accordance with this act.

SEC. 13. That the Commissioner of Air Navigation is authorized, subject to the approval of the Secretary of Commerce, to fix the fees and charges for the licenses which are authorized by this Act, which fees and charges shall be collected by the Commissioner of Air Navigation and covered into the Treasury of the United States to the credit of miscellaneous receipts.

SEC. 14. That any person, partnership, joint-stock company, association, or corporation operating aircraft or an airdrome over which the United States may have jurisdiction on any grounds, who shall violate any of the provisions of this act or of the rules and regulations duly promulgated in accordance with this act, or who shall aid or abet in such violation, or who shall obstruct or impede compliance with or the enforcement of the provisions of this act or of any such rules and regulations shall, upon conviction thereof, be fined not more than $1,000 or be imprisoned for not more than one year, or both, in the discretion of the court. In the event that such a violation shall be by a partnership, joint-stock company, association, or corporation, any officer, agent, or member thereof who is personally responsible for the violation shall be subject to the punishment herein prescribed. The Commissioner of Air Navigation may also, in case of a conviction, in his discretion, revoke or suspend for such length of time as he may deem proper any license issued by him to the owner or operator, or both, of the aircraft or airdrome involved in any such violation.

The jurisdiction of the Federal courts of offenses against the provisions of this act, or the rules and regulations made pursuant thereto, and the venue for the trial of the same shall be as prescribed by existing law for offenses triable before the Federal courts.

SEC. 15. That the provisions of this act authorizing the regulation of air navigation and airdromes, and the rules and regulations made pursuant thereto, and the provisions of this act relating to licensing of aircraft and airdromes and the operators of aircraft, and the rules and regulations made pursuant thereto, shall not apply to aircraft nor airdromes owned by the Government of the United States nor to the operators employed by any department or other governmental agency to operate or assist in the operation of aircraft owned by the Government of the United States, nor to aircraft built for the purpose of experiment and flown for the purpose of experiment or test within three miles of the airdrome or aircraft factory, nor to operators of aircraft within the precincts of an airdrome as defined in the said rules and regulations when such persons are under the instruction of a person duly licensed in accordance with the provisions of section 11 of this act, except that all aircraft and operators, Government or otherwise, are required to observe the rules and regulations for lights, signals, and rules of the air.

SEC. 16. That such portions of the air as are navigable by aircraft and all aircraft navigating the air are hereby declared to be within the admiralty jurisdiction of the Federal courts; and the district courts of the United States shall have jurisdiction of all cases involving air navigation and aircraft, with the right of appeal as in other cases, in accordance with existing laws or such laws as may be hereafter enacted, saving to suitors in all cases the right of a common-law remedy where the common law is competent to give it. The maritime law and all existing acts and acts hereafter enacted relating to water craft and water navigation shall be held to govern aircraft and air navigation in so far as applicable thereto and except as modified by this act and subsequent acts, and by the rules and regulations made pursuant thereto, and by the treaties or conventions that may hereafter be entered into by the United States, and the rules and regulations made pursuant thereto.

SEC. 17. That the Commissioner of Air Navigation shall submit estimates for appropriations through the Secretary of Commerce. He shall be charged with the duty of examining all money accounts covering disbursements of funds appropriated for the Bureau of Aeronautics, with the examination of all property accounts covering all aeronautical property in the custody of the Bureau of Aeronautics, and shall have power to prescribe, institute, and enforce such system of money and property accountability as in his judgment will best safeguard the interests of the United States.

SEC. 18. That for the purposes of this act, not chargeable to existing appropriations, including personal services in the field and in the District of Columbia, there is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be available immediately, the sum of $100,000.

SEC. 19. That this act shall take effect from and after the date of its passage, and all acts or parts of acts contrary to the provisions of this act or inconsistent therewith be, and the same are hereby, repealed.

SEC. 20. That the Commissioner of Air Navigation shall annually, at the close of each fiscal year, make a report to the Secretary of Commerce, giving an account of all moneys received and disbursed by him and describing the work done by the bureau, and the Secretary of Commerce shall transmit the report to Congress with the annual report of the Department of Commerce.

SEC. 21. That if any section or provision of this act shall be held to be invalid, it is hereby provided that all other sections and provisions of this act which are not expressly held to be invalid shall continue in full force and effect.

H. R. 14137.

INTRODUCED IN HOUSE OF REPRESENTATIVES BY MR. HICKS, MAY 19, 1920.

A BILL To create a Bureau of Aeronautics in the Department of Commerce, and providing for the organization and administration thereof.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That to provide for the regulation of air navigation and to render effective the provisions of any treaty or convention relating to air navigation that may hereafter be entered into by the United States there is hereby established in the Department of Commerce a bureau to be known as the Bureau of Aeronautics, and a Commissioner of Air Navigation, who shall be the head thereof, who shall be appointed by the President, by and with the advice and consent of the Senate, and who shall receive a salary of $6,000 per annum. The Commissioner of Air Navigation shall be appointed by the President an additional member of the National Advisory Committee for Aeronautics.

SEC. 2. That there shall be in said bureau an assistant commissioner of recognized technical ability, who shall be appointed by the President, by and with the advice and consent of the Senate, and who shall receive a salary of $5,000 per annum. The assistant commissioner shall perform such duties as may be prescribed by the commissioner or as may be required by law. There shall also be in said bureau a chief clerk and such other clerical assistants, inspectors, experts, and special agents as may be required from time to time and authorized by Congress.

SEC. 3. That all rules and regulations herein provided for, except as otherwise provided for in section 12 hereof, shall be formulated by the Commissioner of Air Navigation, who shall submit the same to the National Advisory Committee for Aeronautics for consideration, criticism, and recommendation to the Secretary of Commerce, who, if the same meet with his approval, shall formally promulgate the same; when approved and duly promulgated by the Secretary of Commerce, such rules and regulations shall be legally binding and enforceable from the date of such promulgation unless otherwise provided therein: *Provided,* That hereafter the National Advisory Committee for Aeronautics, in addition to the exercise of its present functions, is authorized to act in an advisory capacity in connection with the formulation and promulgation of such rules and regulations, for the consideration of questions of policy affecting the development of civil or commercial aviation, including recommendations from time to time for amendments to this act or subsequent acts, and for the coordination of the aeronautical activities of the various departments of the Government.

The said National Advisory Committee for Aeronautics shall have authority to consider and recommend to the heads of departments concerned, on questions of policy regarding the development of civil aviation, with particular reference to education, preliminary training, commercial production of aircraft, establishment, elimination, and consolidation of all flying fields and air stations, and all other matters in connection therewith.

SEC. 4. That hereafter the War, Navy, and other departments of the Government shall prepare programs for experimental research and development work in aeronautics, and for the purchase or construction of air craft, engines, accessories, and hangars, and the acquisition of land for purposes in connection with aviation, and shall submit same to the said advisory committee for consideration and recommendation before contracts are made or orders are placed for the purchase, manufacture, or construction of the same.

SEC. 5. That the National Advisory Committee for Aeronautics shall have authority to recommend to the heads of the departments concerned the tarnsfer of aircraft and aircraft equipment and accessories from one department to another for the civil uses of the Government. The heads of the various departments concerned are authorized to make such transfers of aircraft, equipment, and accessories when recommended by the said advisory committee.

SEC. 6. That the said advisory committee shall consider and report upon any question dealing with aviation referred to it by the President or by any of the departments, and shall initiate, report, and recommend to departmental heads desirable undertakings or developments in the field of aviation, and each department shall furnish the said advisory committee such information as to its aviation activities as may be requested.

SEC. 7. That the Commissioner of Air Navigation shall, in accordance with section 3 hereof, formulate all necessary and proper rules and regulations respecting air navigation and air traffic, issuance of licenses for aircraft, aviators, and aeronauts, rules of the air, the giving and heeding of signals, periodical and before-flight inspection of aircraft, the carrying of lights and signals, the landing at and departure from airdromes, using prescribed routes and avoiding prohibited areas, the carrying and lightening of ballast, the carrying and use of wireless telegraph and telephone instruments and other radio equipment, the carrying, keeping, and exhibiting of log books and other records, the landing for customs or immigration inspections, and other matters for the safety and convenience of air navigation.

Such rules and regulations shall prescribe air routes and prohibited areas over which aircraft shall not fly, for military reasons or in the interest of public safety. Such rules and regulations shall include descriptions of, and, if necessary, maps showing such air routes and prohibited areas, and shall include all areas over which the Secretary of War or the Secretary of the Navy may request in writing the prohibition of the movement of aircraft. All aircraft engaged in air navigation within the jurisdiction of the United States or its dependencies or coming into such jurisdiction from a foreign country or its dependencies, or upon the high seas as to such aircraft as are flying under a United States license, and as to aircraft over which the United States has jurisdiction on other grounds, are hereby required to conform to the rules and regulations duly promulgated in accordance with this act.

SEC. 8. That all airdromes within the jurisdiction of the United States and its dependencies are hereby required to conform to such rules and regulations regarding the placing and use of lights and signals, the size and marking of landing places, and other matters for the safety of air navigation as may be prescribed by the rules and regulations duly promulgated in accordance with this act.

SEC. 9. That all rules and regulations as herein provided shall be so formulated as to carry out the provisions of this act and subsequent acts and of any treaty or convention which may hereafter be entered into by the United States. The Secretary of Commerce may alter, modify, amend, or revoke such rules and regulations in the same manner as provided in section 3 for the promulgation thereof, subject to the provisions of this act and any subsequent act and the provisions of any treaty which has been or may hereafter be entered into by the United States.

SEC. 10. That it shall be the province and duty of the Bureau of Aeronautics, except as may be otherwise provided, to foster, develop, and promote all matters pertaining to civil or commercial aeronautics, including the collection and dissemination of information relating thereto; the administration of all rules and regulations provided for in this act; the regulation and arrangement of landing fields and airdromes; and the allotment of such funds as may be provided by law to aid the various States in the establishment of landing fields and airdromes.

SEC. 11. That the Commissioner of Air Navigation is authorized and directed to plan aerial routes throughout the United States and its possessions and to this end shall cooperate with the various States, cities, and municipalities for the purpose of setting aside and establishing airdromes and landing fields to be used in common by Federal, State, municipal, commercial, and private aircraft under the rules and regulations to be duly promulgated in accordance with section 3 of this act: *Provided*, That such plans for aerial routes and the establishment of airdromes and landing fields shall be submitted to the National Advisory Committee for Aeronautics and, upon approval by said advisory committee, shall be carried into effect by the Commissioner of Air Navigation to the extent of the appropriations available for such purpose.

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SEC. 12. That for the purpose of encouraging the development of commercial aeronautics in the United States full cooperation shall be given by the Bureau of Aeronautics to the owners or operators of private or commercial aircraft, and that the Secretary of War, the Secretary of the Navy, the Postmaster General, and the Secretary of Commerce shall furnish to any owner or operator of private or commercial aircraft landing on an airdrome or landing field under their respective jurisdictions aviation fuel, oil, supplies, and necessary mechanical assistance of an emergency character under such regulations as they may approve and promulgate for their respective services; the proceeds from such sales and assistance shall be deposited in the Treasury of the United States to the credit of the appropriations involved.

SEC. 13. That no aircraft shall be used or operated in air navigation within the United States or its dependencies, or between the United States and any of its dependencies, or between the United States or any of its dependencies and any foreign country or its dependencies, or on the high seas as to aircraft over which the United States has jurisdiction, except under and in accordance with a license granted by the Commissioner of Air Navigation to the owner of the aircraft. Aircraft so licensed shall not be used or operated in air navigation except in accordance with the rules and regulations duly promulgated in accordance with this act: *Provided*, That aircraft and operators of the same duly registered and licensed in other countries and only transitorily or periodically in the United States and its dependencies, may be exempted by treaty or convention from the requirements as to securing a license provided for in this section and section 14 hereof, but shall be subject to all other sections of this act and the rules and regulations duly promulgated in accordance with this act so long as they are within the boundaries of the United States and its dependencies. Such license for aircraft shall not be granted unless the owner is a citizen of the United States or of its dependencies, or if such owner be a company or corporation, then a company or corporation organized under the laws of the United States or some one of the States thereof, the president or chairman and the majority of the members of which company, or the president or chairman and a majority of the board of directors and the holders of a majority of the stock of which corporation, are citizens of the United States or of its dependencies, nor unless such aircraft shall be constructed in a manner suitable for the service in which it is to be employed and is in a condition to warrant the belief that it may be used for such service in air navigation with reasonable safety, such construction, including standards of both workmanship and material, and condition to be determined in accordance with the rules and regulations duly promulgated in accordance with this act.

The Commissioner of Air Navigation shall keep a record in which licensed aircraft shall be registered, and such record shall contain, in a statement made under oath, the name of the owner of the aircraft, a statement as to his citizenship, or, in the case of a company or corporation, the facts showing that it comes within the provisions of this section, the purpose for which the aircraft is to be used, and an accurate description of such aircraft.

Such license shall expire one year from the date of its issuance or upon a change of ownership of the aircraft, whichever may first occur, and shall not be renewed or extended, but upon expiration thereof in either of the manners mentioned the owner of the aircraft may apply for a new license upon complying with the laws and the rules and regulations duly promulgated in accordance with this act.

Any such license may be revoked at any time by the Commissioner of Air Navigation upon its being shown to his satisfaction that any of the facts and qualifications upon which the issuance of such license was based have ceased to exist or upon failure to comply with the existing laws and rules and regulations.

For the purpose of ascertaining the facts upon which to determine whether licenses shall be granted or revoked, the Commissioner of Air Navigation shall have the right to conduct hearings, to summon witnesses, to administer oaths, and to inspect books and records, including the stock books of companies and corporations.

SEC. 14. That no person shall operate an aircraft engaged in air navigation as provided in section 13 of this act except under and in accordance with a license granted by the Commissioner of Air Navigation, and the Commissioner of Air Navigation is authorized to grant such license in accordance with the rules and regulations duly promulgated in accordance with this act.

Such license shall expire one year from date of its issuance unless sooner revoked by the Commissioner of Air Navigation upon its being shown to his satisfaction that any of the facts and qualifications upon which the issuance of such license was based have ceased to exist, or upon failure to comply with the existing laws and rules and regulations, but upon the expiration of such license the holder thereof may apply for a new license by complying with the laws and rules and regulations duly promulgated in accordance with this act.

SEC. 15. That no airdrome shall be operated except under and in accordance with a license granted by the Commissioner of Air Navigation to the owner of the airdrome in accordance with the rules and regulations duly promulgated in accordance with this act: *Provided*, That such owner shall be a citizen of the United States or of its dependencies; or if such owner be a company or corporation, then a company or corporation organized under the laws of the United States, or some one of the States thereof; the president or chairman and the majority of the members of which company, or the president or chairman of the board of directors and a majority of the board of directors and the holders of a majority of the stock of which corporation, are citizens of the United States or its dependencies; and upon its being shown that the airdrome is prepared to operate in accordance with the said rules and regulations. Such license shall expire upon a change of ownership of the airdrome and shall not be renewed or extended, but a new license may be issued upon compliance with the laws and rules and regulations duly promulgated in accordance with this act. Any such license may be revoked at any time by the Commissioner of Air Navigation upon its being shown to his satisfaction that any of the facts upon which the issuance of such license was based have ceased to exist or upon failure to comply with existing laws and rules and regulations duly promulgated in accordance with this act.

SEC. 16. That the Commissioner of Air Navigation is authorized, subject to the approval of the Secretary of Commerce, to fix the fees and charges for the licenses which are authorized by this act, which fees and charges shall be collected by the Commissioner of Air Navigation and covered into the Treasury of the United States to the credit of miscellaneous receipts.

SEC. 17. That any person, partnership, joint-stock company, association, or corporation operating aircraft or an airdrome over which the United States may have jurisdiction on any grounds, who shall violate any of the provisions of this act or of the rules and regulations duly promulgated in accordance with this act, or who shall aid or abet in such violation, or who shall obstruct or impede compliance with or the enforcement of the provisions of this act, or of any such rules and regulations, shall, upon conviction thereof, be fined not more than $1,000 or be imprisoned for not more than one year, or both, in the discretion of the court. In the event that such a violation shall be by a partnership, joint-stock company, association, or corporation, any officer, agent, or member thereof who is personally responsible for the violation shall be subject to the punishment herein prescribed. The Commissioner of Air Navigation may also, in case of a conviction, in his discretion, revoke or suspend for such length of time as he may deem proper any license issued by him to the owner or operator, or both, of the aircraft or airdrome involved in any such violation.

The jurisdiction of the Federal courts of offenses against the provisions of this act or the rules and regulations made pursuant thereto and the venue for the trial of the same shall be as prescribed by existing law for offenses triable before the Federal courts.

SEC. 18. That the provisions of this act authorizing the regulation of air navigation and airdromes, and the rules and regulations made pursuant thereto, and the provisions of this act relating to licensing of aircraft and airdromes and the operators of aircraft, and the rules and regulations made pursuant thereto, shall not apply to aircraft nor airdromes owned by the Government of the United States nor to the operators employed by any department or other governmental agency to operate or assist in the operation of aircraft owned by the Government of the United States nor to aircraft built for the purpose of experiment and flown for the purpose of experiment or test within three miles of the airdrome or aircraft factory nor to operators of aircraft within the precincts of an airdrome as defined in the said rules and regulations when such persons are under the instruction of a person duly licensed in accordance with the provisions of section 14 of this act, except that all aircraft and operators, Government or otherwise, are required to observe the rules and regulations for lights, signals, and rules of the air.

SEC. 19. That such portions of the air as are navigable by aircraft and all aircraft navigating the air are hereby declared to be within the admiralty jurisdiction of the Federal courts; and the district courts of the United States shall have jurisdiction of all cases involving air navigation and aircraft, with the right of appeal as in other cases, in accordance with existing laws or such laws as may be hereafter enacted, saving to suitors in all cases the right of a common-law remedy where the common law is competent to give it. The maritime law and all existing acts and acts hereafter enacted relating to water craft and water navigation shall be held to govern aircraft and air navigation in so far as applicable thereto, and except as modified by this act and subsequent acts, and by the rules and regulations made pursuant thereto, and by the treaties or conventions that may hereafter be entered into by the United States, and the rules and regulations made pursuant thereto.

SEC. 20. That all estimates of funds necessary to meet the requirements of all services and departments of the Government for the development, production, operation, and maintenance of aircraft, aircraft material and accessories, including fields, shops, airdromes, and all other facilities connected therewith, shall be submitted to the National Advisory Committee for Aeronautics for consideration and recommendation before they are submitted to Congress, and any recommendations or suggestions made by the said advisory committee shall be transmitted to the Congress with the estimates by not later than the 15th day of October of each year.

SEC. 21. That the Commissioner of Air Navigation shall submit estimates for appropriations through the Secretary of Commerce after compliance with the provisions of section 20 of this act. He shall be charged with the duty of examining all money accounts covering disbursements of funds appropriated for the Bureau of Aeronautics, with the examination of all property accounts covering all aeronautical property in the custody of the Bureau of Aeronautics, and shall have power to prescribe, institute, and enforce such system of money and property accountability as in his judgment will best safeguard the interests of the United States.

SEC. 22. That for the purposes of this act, not chargeable to existing appropriations, including personal service in the field and in the District of Columbia, there is hereby appropriated, out of any money in the Treasury not otherwise appropriated, to be available immediately, the sum of $100,000.

SEC. 23. That this act shall take effect from and after the date of its passage, and all acts or parts of acts contrary to the provisions of this act or inconsistent therewith be, and the same are hereby, repealed.

SEC. 24. That the Commissioner of Air Navigation shall annually, at the close of each fiscal year, make a report to the Secretary of Commerce, giving an account of all moneys received and disbursed by him and describing the work done by the bureau, and the Secretary of Commerce shall transmit the report to Congress with the annual report of the Department of Commerce.

SEC. 25. That if any section or provision of this act shall be held to be invalid, it is hereby provided that all other sections and provisions of this act which are not expressly held to be invalid shall continue in full force and effect.

CANADA'S COURTESY REGARDING AMERICAN AIR PILOTS.

In June, 1920, the committee received through the State Department information to the effect that the Canadian Air Board had promulgated regulations permitting United States qualified aircraft and pilots to fly in Canada until November 1, 1920, on the same basis as if the United States had established air regulations as contemplated under the Convention for the Regulation of International Air Navigation. The committee, by resolution adopted at the July meeting, recommended that the State Department express the appreciation of the Government of the United States for the courtesy of the Canadian Government in this matter, and, in view of the fact that the Congress of the United States was not then in session and would not meet until December, 1920, further recommended that the State Department inquire if the Canadian Government would be willing to extend by six months from November 1, 1920, the period during which United States pilots and aircraft would be permitted to fly in Canada under the existing conditions. The State Department acted upon these recommendations, and as a result the Canadian Government has extended its courtesies to American pilots and aircraft until June 1, 1921. The entire incident, however, serves to emphasize the need for Federal legislation for the regulation of air navigation, as recommended in another part of this report.

INTERNATIONAL CONVENTION ON AIR NAVIGATION.

During the past year the committee has given consideration to a number of questions dealing with the subject of international air navigation referred to it by the State Department, and in each case has submitted its recommendations to the State Department. The questions considered by the committee have been mainly those arising under the pending International Convention on Air Navigation and a few miscellaneous questions in regard to the general subject of international air navigation.

In regard to the Convention on International Air Navigation, the committee formulated and recommended to the State Department reservations which were accepted by the department and communicated as instructions to the American ambassador to France for his official notation at the time of signing the convention preliminary to ratification by the Government of the United States. The committee has also considered reservations formulated by Canada and submitted recommendations to the State Department as to concurrence and nonconcurrence therewith on the part of the United States.

CIVIL USE OF GOVERNMENT LANDING FIELDS.

In June, 1920, the Aeronautical Board sought the advice of the committee as to the governmental policy to be followed in regard to the question of permitting the use of Government landing fields and facilities by private or commercial aircraft. The meeting at which this subject was discussed was held at Langley Field, Va., in connection with the formal opening of the Langley Memorial Aeronautical Laboratory, at which many persons prominent in aeronautical development were present, a number of whom had flown to the field from Washington and more distant places.

The committee at that meeting adopted a resolution stating that, "It is the sense of the National Advisory Committee for Aeronautics that each governmental agency having airdromes or landing fields under its jurisdiction should be authorized by law to furnish to owners or operators of private or commercial aircraft, landing on or near such airdromes or landing fields, aviation fuel, oil, supplies, and necessary mechanical assistance at cost plus 10 per cent, under such regulations and restrictions as may be approved from time to time by the heads of the departments concerned;" and that "Private or commercial aircraft should not be allowed to use Government airdromes or landing fields as home stations, and that only mechanical assistance or repairs of an emergency nature should be furnished at Government airdromes or landing fields, such as are necessary to permit an aircraft to resume its journey."

These principles have been embodied in a draft of proposed legislation for the regulation of air navigation, referred to in another part of this report.

PROTECTION OF AIRCRAFT INDUSTRY FROM UNFAIR FOREIGN COMPETITION.

A bill was introduced in the House of Representatives during the last session by Representative Tilson, known as the "anti-dumping bill" (H. R. 14287), the principal object of which was the prevention of unfair foreign competition in the sale of airplanes imported into the United States. At the time there was some question as to the facts in the matter, the merits of the bill, and the need for such legislation. After the adjournment of Congress, the bill not having been passed, the committee recommended to the Secretary of Commerce that the Bureau of Foreign and Domestic Commerce be authorized to make a thorough investigation with a view to determining all the facts bearing upon the advisability of the proposed legislation, in order that the Secretary of Commerce might be able to present to Congress at its next session the facts as determined by the investigation, together with his recommendations. This the Secretary of Commerce, under date of June 21, 1920, agreed to do.

DEVELOPMENT OF RIGID AIRSHIPS.

The National Advisory Committee for Aeronautics at the semiannual meeting of the full committee had under consideration the question of the development of rigid airships, which the committee considers essential for our national defense. The Army and Navy had agreed that until standard types were developed in this country, the work of development should rest with the Navy. The proper development of this type of aircraft for military purposes will unquestionably lead to the development of commercial types, but it is felt that the Government must take the lead by first developing rigid airships for military purposes.

The committee at that time submitted a special report to the President recommending that adequate provision be made in the then pending naval appropriation bill for the construction of rigid airships and suitable hangars, and that a continuing building program for this type of aircraft be authorized, extending over a period of years. The committee at this time reiterates this recommendation, and expresses its belief that this experimental development is of vital importance to the effectiveness of the Army and Navy in time of war, and particularly to the military and naval air services as combatant arms.

PRODUCTION OF HELIUM.

At the semiannual meeting of the full committee, held in April, 1920, consideration was given to the question of the production of helium. Helium has such advantages over any other known gas as to make its use imperative for military and naval airships in time of war, provided it can be made available in sufficient quantity. In letters to the Secretary of War, the Secretary of the Navy, and the Secretary of the Interior, the committee stated that it is necessary to encourage the economical production of helium in order that an increased demand may bring about a greater increase in the supply, a simplification of the processes of extraction, and a lessening of the cost of production. The committee especially invited their attention to the necessity for thoroughly investigating all sources from which helium may be extracted or secured, and recommended that every practicable effort be made both to increase production and to decrease cost, having due regard for conservation of the sources of supply for military purposes.

EDUCATION IN ADVANCED AERONAUTICAL ENGINEERING.

At the semiannual meeting of the full committee in April, 1920, consideration was given to the question of education in advanced aeronautical engineering. This meeting was attended by all the members of the committee connected with universities: Drs. Ames, Durand, Hayford, and Pupin, and it is deemed worthy of special notice that each of these members individually expressed his approval of the resolution which was adopted at that meeting in the following terms:

Whereas it is deemed essential to the development of aviation in America for military and naval purposes that advanced instruction in aeronautical engineering be given to military and naval officers at a competent educational institution; and

Whereas the public demand for such instruction will in all probability not be sufficient to justify or permit the offering of such advanced courses in more than one institution at the present time; and

Whereas such an advanced course is now being given at the Massachusetts Institute of Technology; and

Whereas it is deemed further essential that actual experience with aerodynamic research should form a part of such advanced instruction: Therefore be it

Resolved, That the National Advisory Committee for Aeronautics hereby recommends to the Secretary of War and to the Secretary of the Navy the adoption of a continuing policy for the instruction of officers in advanced aeronautical engineering, and that for the next three years classes of 15 Army officers and 15 Navy officers be detailed annually to take such instruction in advanced aeronautical engineering at the Massachusetts Institute of Technology at the expense of the War and Navy Departments, respectively.

Resolved further, That, in connection with the course in advanced aeronautical engineering, the National Advisory Committee for Aeronautics cooperate in every way with the Massachusetts Institute of Technology by offering to its faculty and students the facilities for investigations in aerodynamics and experimental work on actual airplanes at the committee's research laboratory, Langley Field, Va.

Resolved further, That the National Advisory Committee for Aeronautics offer to give at various engineering universities courses of lectures in advanced aeronautical engineering by members of its engineering staff.

Resolved further, That the National Advisory Committee for Aeronautics recommend that educational institutions generally not consider the establishment of courses in aeronautical engineering at the present time, as it is the opinion of the committee that the demand for such instruction outside of the Government service is not sufficient, and competent instructors for such courses are not available.

This resolution was transmitted to the Secretary of War and to the Secretary of the Navy. The War Department, acting on the committee's recommendation, secured the necessary authority from Congress to detail 25 officers for special instruction at the Massachusetts Institute of Technology. It is understood that the Navy has not secured similar authority. The committee therefore strongly recommends to Congress that similar authority be given for the detail of naval officers for such special training. At the present time both services are weak in respect to the number of officers sufficiently educated in aeronautical engineering. The committee considers that the diligent prosecution of a continuing program of education will be of great value within a few years in the development of military and naval aviation.

NOMENCLATURE FOR AERONAUTICS.

The National Advisory Committee for Aeronautics, to secure uniformity with reference to aeronautical terms in official documents of the Government, and, so far as possible, in technical and other commercial publications, has prepared a report on nomenclature for aeronautics, in classified and dictionary forms, and including a list of symbols used. This report was issued during the past year under the title "Report No. 91, Nomenclature for Aeronautics." It supersedes Report No. 25, on the same subject, which appeared in the Fourth Annual Report of the committee.

The subcommittee on aerodynamics had charge of the preparation of the nomenclature for aeronautics, and was materially assisted by the Interdepartmental Conference on Aeronautical Nomenclature and Symbols, which was especially organized by the executive committee, with the approval of the War and Navy Departments, for the purpose of giving proper representations to all technical divisions of the Army Air Service and the bureaus of the Navy Department.

The first meeting of the interdepartmental conference was held on October 23, 1919; the second meeting, on January 15, 1920, at which meeting the nomenclature was unanimously approved and recommended to the subcommittee on aerodynamics, with the reservation that stability terms and power plant terms be given further and special consideration.

The stability terms were accordingly referred for special consideration to Messrs. E. B. Wilson. J. C. Hunsaker, A. F. Zahm, E. P. Warner, and H. Bateman, and the power plant terms were referred to the subcommittee on power plants for aircraft. The complete report was adopted by the subcommittee on aerodynamics on March 8, 1920, and recommended to the executive committee for approval and publication.

Upon recommendation of the subcommittee on aerodynamics, the executive committee of the National Advisory Committee approved the nomenclature for publication as a technical report on April 1, 1920.

BIBLIOGRAPHY OF AERONAUTICS.

During the past year, the committee has continued the bibliography of aeronautics. The first work on this subject was prepared by Mr. Paul Brockett, of the Smithsonian Institution, and included the period up to 1910. The committee has prepared a bibliography of aeronautics from 1910 to 1916 in one volume, and a bibliography for the years 1917, 1918, and 1919 has been prepared in one volume. The bibliography for each year in the future will be prepared annually.

DISTRIBUTION OF METEOROLOGICAL INFORMATION BY WIRELESS.

The State Department, under date of June 5, 1920, referred to the committee for consideration and recommendation a copy of a note from the British ambassador, together with a copy of a report from an international commission which had been considering methods for the distribution of meteorological information by wireless telegraphy under the provisions of article 35 and Annexe G of the proposed Convention on International Air Navigation.

After consideration of this question at two meetings the committee reported to the Secretary of State that the proposal as submitted by the British ambassador appeared to be satisfactory in general, but that it would be impracticable to carry out the entire program in detail, the principal difficulty centering around the proposal to take observations at hours corresponding to 1, 7, 13, and 19 Greenwich mean time. At the present time observations are taken in the United States only at hours corresponding to 1 and 13 G. M. T. After taking up the matter with the Navy Department the committee, in its special report, also recommended that Annapolis be designated as the station for the dissemination of such reports for North America.

AEROLOGICAL WORK OF THE WEATHER BUREAU.

At the regular meeting of the executive committee of the National Advisory Committee for Aeronautics held on December 18, 1919, consideration was given to the increasing needs of aviation for improvements and extensions in the making of meteorological observations in the free air, and the issuance of forecasts and warnings for the promotion of safety of aerial navigation over the land and the oceans. Work of this character was at that time being conducted by the Weather Bureau under an appropriation of $100,000, which was originally granted by Congress in 1917 upon the recommendation of the National Advisory Committee for Aeronautics.

The organic act defining the duties and functions of the Weather Bureau clearly required it to perform this service. The making of local meteorological observations by the Army at certain military posts and by the Navy at base stations and aboard ships was necessary for local needs and obviated the maintenance by the Weather Bureau of stations at those points which would otherwise have been necessary.

The executive committee accordingly authorized the submission of a special report to the Committee on Agriculture of the House of Representatives in which the committee stated that there was no duplication of work or expenditure in these activities, the work of the Army and Navy in this connection being wholly supplementary and complementary to that of the Weather Bureau, their observations being telegraphed to the Weather Bureau daily for its use in conjunction with reports from over 200 stations of its own. In this special report the executive committee strongly recommended the appropriation of additional funds by Congress to extend this feature of the Weather Bureau's activities in order to meet the requirements of aviation and to safeguard lives and property engaged in aerial navigation.

REPORT OF THE COMMITTEE ON AERODYNAMICS.

Following is a statement of the organization and functions of the committee on aerodynamics:

ORGANIZATION.

Dr. John F. Hayford, Northwestern University, chairman.
Dr. Joseph S. Ames, Johns Hopkins University, vice chairman.
Maj. T. H. Bane, United States Army.
Dr. L. J. Briggs, Bureau of Standards.
Maj. V. E. Clark, United States Army.
Commander J. C. Hunsaker, United States Navy.
Franklin L. Hunt, Bureau of Standards.
Prof. Charles F. Marvin, Chief Weather Bureau.
Edward P. Warner, Massachusetts Institute of Technology, secretary.
Dr. A. F. Zahm, United States Navy.

FUNCTIONS.

1. To aid in determining the problems relating to the theoretical and experimental study of aerodynamics to be experimentally attacked by governmental and private agencies.
2. To endeavor to coordinate, by counsel and suggestion, the research and experimental work involved in the investigation of such problems.
3. To act as a medium for the interchange of information regarding aerodynamic investigations in progress or proposed.
4. The committee may direct and conduct research and experiment in aerodynamics in such laboratory or laboratories as may be placed (either in whole or in part) under its direction.
5. The committee shall meet from time to time on call of the chairman, and report its actions and recommendations to the executive committee.

The committee on aerodynamics, by reason of the representation of the Bureau of Standards, the Army, the Navy, technical institutions, and the industry, is in close contact with aerodynamical research and development work being carried on in the United States. Its representation enables it, by counsel and suggestion, to coordinate the experimental research work involved in the investigation of aerodynamical problems, and to influence the direction of the proper expenditure of energy toward those problems which seem of greatest importance.

The committee has direct control of aerodynamical research conducted at the Langley Memorial Aeronautical Laboratory and also directs propeller research conducted at Leland Stanford Junior University under the supervision of Dr. W. F. Durand, and through its membership it keeps in close touch with the work being carried on at the Bureau of Standards, at McCook Field by the engineering division of the Army Air Service, and at the Washington Navy Yard by the Bureau of Construction and Repair, United States Navy.

Two new wind tunnels have been completed and put in operation in the United States within the past year. A new 5-foot wind tunnel at the Langley Memorial Aeronautical Laboratory has gone into service and has already run at speeds slightly in excess of 110 miles per hour. It is anticipated that speeds of 140 miles per hour will be attained with a new propeller which will be better suited to the characteristics of the electric motor employed. The other new wind tunnel of the year is that constructed by the Curtiss Engineering Corporation at Garden City and is of the true Eiffel type.

The committee on aerodynamics, in directing the research work at the Langley Memorial Aeronautical Laboratory, has adopted a definite policy with reference to research work to be conducted at this laboratory. The policy adopted confines the work to three general problems, and, in order to obtain results which will be of general use, experiments are to be conducted in such a manner that general conclusions and, if possible, general theories may result from them. The following three general problems covering the work of the aerodynamical laboratory for the coming year have been adopted:

(*a*) Comparison between the stability of airplanes, as determined from full-flight test and as determined from calculations based on wind tunnel measurements.

The committee will endeavor to determine the characteristics and peculiarities of certain existing airplanes, and attempt to account for these by calculations based on wind tunnel work. The matter of control will also fall under this heading. The first work conducted will probably be confined to the explanation of the theory of small oscillations and its verification with full-scale work. Later, a study of maneuverability and controllability will follow, as it is felt that in the present state of the art there is not available to airplane designers a rational method of predicting the maneuverability of airplanes from the drawings of the airplanes or from wind tunnel experiments with models.

(*b*) Similar comparison between the performance of airplanes full-scale and the calculations based on wind tunnel experiments.

A great deal of attention has been given by the British to the prediction of performance based on aerodynamic data, but there is still a gap between model and full-scale results which can not be bridged until we have more information. The performance is intimately connected with the propeller, and it is the intention of the committee to have all propeller research conducted at the Aerodynamical Laboratory of Leland Stanford Junior University under the direction of Dr. Durand. An effort will be made to tie in the results obtained at Leland Stanford with the performance work being done at Langley Field. Experiments will also be conducted on models of well-known airplanes to better understand the landing and starting characteristics of airplanes and to determine exactly what it is that makes certain airplanes require a long run.

(*c*) General aerofoil problem, including control surfaces, with particular reference to thick sections and combinations and modifications of such sections.

The committee is to undertake a systematic investigation of thick wing sections, after a thorough analysis of what has been done in this matter, and to duplicate some of the experiments already performed. After the determination of what properties of thick wing sections are of interest, work will then be carried along with a view to systematic variation of the variables which determine the aerodynamic properties of a series. Determination will also be made of the relation between aerodynamic properties of such standard aerofoils and aerofoils of similar profile but of different aspect ratio and taper. It is also desirable to know biplane and other interference effects when the aerofoils are used in combination. A careful study will also be made of recent work, by which it appears possible to predict from a knowledge of the lift coefficient the properties of aerofoils in combination and of different aspect ratio, as well as the influence of a boundary.

Such problems arising in connection with the Army and Navy programs of development as fit in logically with the above program will be referred to the committee on aerodynamics, and the research work covering the problems will be conducted at the Langley Memorial Aeronautical Laboratory.

At the Langley Memorial Aeronautical Laboratory a large number of experiments have been carried on with model wind tunnels in the past year to determine the best form for steadiness of flow and efficiency of operation. The effect of various shapes of cones, experimental chambers, and types of propellers, honeycombs, and diffusers were thoroughly studied. A special recording air-speed meter and recording yaw meter were designed in order to study the steadiness of flow, and it was found that the tunnel with a continuous throat was superior to the open or Eiffel type of tunnel both in efficiency and steadiness of flow. It was also demonstrated that a honeycomb placed in the entrance cone is of the greatest value in straightening the air flow, but a diffuser placed in the return circuit was apparently of little value.

The National Advisory Committee's 5-foot wind tunnel was completed in the spring of 1920 and has been in continuous operation since. This tunnel is designed from the data obtained in the model experiments and is very satisfactory both in efficiency and steadiness of flow. The 10-foot four-bladed propeller is driven by a 200-horsepower variable-speed electric motor. The power for this motor is obtained from gasoline-driven generating sets, and the control system is very convenient, the motor being started and stopped simply by pushing a button in the experimental chamber, and the speed being controlled by a rheostat from the same place.

The balance used in this tunnel is of the modified N. P. L. type, and was constructed in the shop of the National Advisory Committee at Langley Field. Unlike the usual balance, the weight is supported on a ball bearing socket, rather than a conical pivot, as this device considerably reduces the friction and will carry a much larger load. It is also possible with this balance to simultaneously read the lift, drag, and pitching moment. As the N. P. L. type of balance is not suited to holding tapered wings, and as a large amount of work of this kind is planned for the future, a simple wire type of balance is being constructed at the present time, similar to that used in the wind tunnel at Göttingen.

It has been the practice in the past when setting up a model to align the chord of the wing with the wind by placing a thin wooden batten on the wing and comparing this batten with a straight line on the floor of the tunnel. But as this method is rather laborious and inaccurate, a new type of aligning apparatus has been designed for this tunnel, consisting essentially of a mechanism for reflecting a beam of light from a plain mirror which is attached parallel to the chord of the wing, so that by rotating the wing the reflected beam of light is brought to a cross line on a small target on the side of the experimental chamber. In this way a wing can be lined up with an accuracy of 0.01° in a very few seconds. As the air speeds used in this wind tunnel are considerably higher than those usually encountered, a special type of manometer was constructed to obviate the necessity of having an extremely long inclined tube. This gauge changes the head of liquid and at the same time the inclination of the tube, so that the fluctuations of the liquid are approximately equal at any speed. A multiple manometer has also been constructed for pressure distribution work on models, containing 20 glass tubes, the inclination of which can be adjusted to any desired angle.

A thorough investigation has been made of the problem of spindle interference and the best manner of protecting the spindle by a fairwater. Different types and lengths of fairwater were tested in order to determine which condition would give the least total interference. An accurate determination of the effective resistance of the spindle was made for various lengths of spindle and for various air speeds so that a complete set of data is available for use on any model tests for the future. In order to provide data for stability calculations a wing was tested through an angle of 360°, and a model of an airplane was tested in the same way. In order to determine the scale corrections for model airplanes a model of the JN4H was constructed with great accuracy, and all details of the airplane were reproduced in the model, including the radiator and motor, but the wires were omitted as it was thought that their resistance could be determined better from tests of the full-sized wires. This model was tested at speeds of 30, 60, and 90 miles per hour in order to determine the corrections that must be applied to it in order to give the full-flight performance which was carefully determined on the full-sized machine.

FREE FLIGHT.

The machines available for the committee's use at the Langley Memorial Aeronautical Laboratory consist of two JN4H training machines and one DH4. During the summer the machines have been in the air about 60 hours. Numerous small changes have been made on these machines during the different tests, including changing the stagger, changing the angle of the tail plane, and changing the position of the center of gravity by adding weight at the front or rear of the fuselage. A large number of special instruments have been designed and constructed at Langley Field for research in full flight. An accelerometer has been developed for obtaining the loads on an airplane during stunts and landings, and satisfactory results have been obtained with it, which are of considerably greater accuracy than those obtained by other types of instruments. Instruments were also developed for recording the position of and the force on all three controls of the airplane, and valuable results have been obtained with these instruments. For obtaining the pressure distribution on the tail of the full-sized machine a special multiple manometer was constructed having 110 glass manometer tubes, all of which could be photographed at one time by an automatic film camera placed in the fuselage. As this instrument will only determine accurately the pressure distribution in steady flight, another manometer is now being constructed consisting of a large number of small diaphragm gauges which will record continuously on a moving film so that the rise and fall of the pressure at various points on the tail surfaces can be recorded during any stunt maneuver.

An air-speed meter and yaw meter have been constructed, working on the optical recording principle, having the actual period of the instrument high and its friction small, so that air-speed records can be obtained of any small or high period fluctuations in the wind velocity. To determine the angular rotation of the airplane during flight, in order to study its stability properties, a kymograph was constructed consisting of a narrow slit which focused the image of the sun on moving bromide paper, and another instrument of the same type has been constructed working on the gyroscopic principle. For obtaining the full-flight lift and drag coefficient a special longitudinal inclinometer was constructed which would give a large scale deflection and would be convenient and accurate to read.

The investigations undertaken consist of the determination of the lift and drag coefficients of the JN4H in free flight, and it is found possible by careful piloting to flay the machine at or slightly beyond the burble point. A thorough experimental investigation has been made of the static longitudinal stability of the airplane and a great many factors have been altered on the full-sized machine, such as changing the angle of the tail plane, changing the center of gravity of the machine, changing the section of the tail plane, and inclining the angle of the propeller axis. A study was made of the angle of attack and the air speed at the wing tips during spins and loops. This was accomplished by placing vanes and air-speed meters at the wing tips and photographing them during the maneuver by means of a camera gun and then plotting the curve of angle and speed against time from the photographs so obtained.

A very extensive investigation of the pressure distribution over the tail of an airplane in free flight has been undertaken. The pressure at 110 points on the left and right hand sides of the tail have been taken independently and the total pressure determined from these two curves. By means of photographic recording methods the time taken for making this investigation in the air is brief, but the computation and plotting of the results are laborious and require a long time for their completion. Runs were made with three positions of the center of gravity and two angles of setting of the stabilizer, as well as one run with celluloid over the crack between the stabilizer and the elevator. In all cases the pressure found over the tail was extremely low and in steady flight the load on the tail would be found very small compared with the load resulting from accelerated flight. A large number of records have been taken with the recording accelerometer designed by the N. A. C. A., these records being taken in the JN4H and several other machines during various stunts and landings. It was found that the maximum acceleration experienced in any stunt was during a roll, where the acceleration reached a maximum of 4.2 g. In order to determine the characteristics of an airplane during circling flight a record of the forces on all three controls was made doing banks of various angles up to 60° and side slips up to 20° of yaw.

The wind tunnel at Leland Stanford Junior University has again been occupied entirely with propeller tests. The results of the research work conducted this year are contained in technical report No. 109. Preparations are being made for tests on propellers at large angles of yaw, which will give data for the analysis of helicopters traveling horizontally.

Dr. George de Bothezat, aerodynamical expert of the National Advisory Committee for Aeronautics, has carried on at McCook Field, with the cooperation of the Engineering Division of the Army Air Service, a special investigation for the measurement of aerodynamic performance. The report on this investigation has been completed and approved as technical report No. 97, entitled "General Theory of the Steady Motion of an Airplane." This investigation involved the design and construction of a new type of barograph. Also in connection with his investigation of airplane performance, Dr. de Bothezat has designed a torque meter and a rate-of-climb meter, which are under construction. The torque meter is a very simple design, and present indications are that it will be a most serviceable and efficient instrument. The rate-of-climb meter is not based on a new principle; it is simply a new construction and design embodying the experience obtained in the use of other instruments.

The research work conducted by the Bureau of Construction and Repair of the Navy Department is carried on at the aerodynamical laboratory of the Washington Navy Yard and at the naval aircraft factory, Philadelphia Navy Yard. At the Washington Navy Yard two wind tunnels are in operation, and during the year a large number of airplanes and seaplane models have been given routine tests, and tests on many new aerofoil sections have also been made. Special attention has been given to testing streamline forms and struts. Yawing tests were conducted on the EP and the IE envelopes, which are formed from mathematical curves and have very low resistance. The tests indicate that the yawing moment about the center of gravity of a bare streamlined form varies but little from one shape to another. In connection with the tests on struts, it was shown that the Navy I strut has approximately 15 per cent less resistance than that given for the "Best" strut by the National Physical Laboratory. Wind tunnel tests were also conducted on two airship cars, one of faired contour and the other with facets of the same general contour, the results of which show the great value of fairing. The resistance of the faired car was 15 per cent less than that of the unfaired.

In connection with the wind tunnel at the Washington Navy Yard, a new aerodynamic balance of great interest has been developed. The balance is so designed that all adjustments of weights to bring the balance into equilibrium are automatic, and the time required for testing and the number of skilled operators are thus much decreased.

The Bureau of Construction and Repair has also undertaken the development and construction of the following instruments:

A precision recording barograph intended for use in airplane trials, and especially for measuring the landing angle of airplanes, for which no wind tunnel test is available. This instrument will have a range of from 0 to 5,000 feet, and will incorporate the desirable features of the present Bureau of Standards precision altimeter.

Two thermometer altimeters and density indicators. These instruments will combine a thermometric element with a pressure element in such a manner as to show at all times the altitude corrected for temperature.

Two instruments intended to measure quantitatively the permeability of gas cells of envelopes without the removal of samples. The construction of these instruments has been suggested by the technical staff of the Bureau of Standards. This instrument is to take the form of a cup of suitable area which is pressed against the envelope at the point where the permeability is to be determined. A current of air is either sucked or driven through the cup, sweeping it out at a known rate. The mixture of gas and air from the cup is then passed through a thermal conductivity cell, and the proportion of hydrogen contained in the mixture is determined from the thermal conductivity of the mixture.

In the high-speed wind tunnel at McCook Field, which is operated under the direction of the technical staff of the Army Air Service, work has been continued along the same general lines as those indicated in technical report No. 83. During the year it is contemplated that tests will be conducted to determine the flow around a sphere and around biplane combinations. It is hoped thus to determine how nearly the action of the visible vapor particles indicate the true air flow about a body, and to visualize the flow around combinations of more than one supporting surface so as to determine the nature of the interference between the upper and lower surfaces should be of the greatest interest. It is also hoped to photograph the vapor action about a sphere over as large an air-speed range as possible. The sphere is to be supported in a manner to produce a minimum disturbance due to the support, and the photographs obtained are to be compared with existing photographs of flow about spheres and with the theoretical streamlines.

It is also hoped that tests will be conducted to determine the effect of rake and tapered wing tips on air flow, as this information may make it possible to further improve the airplane form and nature of taper in wings.

Performance tests are also conducted at McCook Field, and the committee on aerodynamics has requested that special tests be made on longitudinal stability to obtain an index of the dynamic longitudinal stability of the various airplanes used by the Army. The work already done by the staff of the National Advisory Committee for Aeronautics at Dayton with the cooperation of the Engineering Division of the Air Service on five airplanes is but a beginning of longitudinal stability investigation. It is desirable to obtain readings of stick forces and elevator angles on every type of machine in the Army's possession, and to have curves plotted in the same way as in National Advisory Committee's report No. 96.

The investigations carried on at the two wind tunnels of the Bureau of Standards under the direction of Dr. L. J. Briggs have consisted largely in instrument calibration and testing. The principal research has been in connection with the resistance of spheres and projectiles.

The work of the Aeronautic Instruments Section of the Bureau of Standards comprises the investigation, experimental development, and testing of aircraft instruments; also the development of methods of testing, fundamental researches on the physical principles involved in such instruments, and the study of their behavior in actual service.

The more important investigations which have been undertaken by the section during the past year are as follows:

An investigation has been completed and prepared for publication through the National Advisory Committee for Aeronautics on the effect on the performance of Venturi tube air-speed indicators of changes in atmospheric pressure. The results show that in certain instruments commonly used a correction should be applied for the viscosity of the air, a factor which has not hitherto been taken into account. This is of special interest in dirigible work where the air speeds may be low, and also in aircraft performance tests where exceptional precision is required.

An altimeter of exceptional accuracy designed and made at the Bureau of Standards has been completed and submitted to the Army. Another model with additional improvements has recently been designed and is under construction.

At the request of the National Advisory Committee for Aeronautics a fundamental investigation of the factors determining the behavior of flexible diaphragms as used in aeronautic instruments has been undertaken. The irreversible effects which cause the lag in diaphragm instruments has been formulated mathematically. The relation between force and deflection for diaphragms of different sizes, thickness, and materials has been studied graphically, practical methods for spinning diaphragms and building up diaphragm boxes have been investigated, and the possibilities of mechanical seasoning by repeated stress considered.

An improved rate of climb indicator, which indicates directly the rate of climb of aircraft in hundreds of feet per minute, has been completed and tested, and specifications have been prepared for the Army to use in the manufacture of a number of these instruments.

Information regarding instruments available for aerial navigation in cloudy weather or at night or for long-distance flights has been compiled at the request of the National Advisory Committee for Aeronautics and the Air Mail Service by the Aeronautic Instruments Section. This work will be continued and the development of new instruments undertaken.

Other investigations have been the development of a motion-picture apparatus for recording instrument readings during the flight of an airplane; a study of the errors in instruments used for determining the direction of aircraft, such as gyroscopic and liquid inclinometers and banking indicators, gyroscopic and magnetic compasses and turn indicators, a systematic investigation of commercial sphygmomanometers; a paper on the results of investigations on German instruments; a statistical study of the causes of failure in aeronautic instruments.

Assistance has been given the Air Service, the Aero Club of America, and others interested during the past year in the world's altitude competition for airplanes. Instruments have been calibrated and the best procedure for determining the altitude attained formulated.

REPORT OF COMMITTEE ON POWER PLANTS FOR AIRCRAFT.

Following is a statement of the organization and functions of the committee on power plants for aircraft:

ORGANIZATION.

Dr. S. W. Stratton, chairman.
Commander A. K. Atkins, United States Navy, vice chairman.
Henry M. Crane, Wright Aeronautical Corporation.
Harvey N. Davis, Harvard University.
Dr. H. C. Dickinson, Bureau of Standards, acting secretary.
L. M. Griffith, Langley Memorial Aeronautical Laboratory.
Capt. G. E. A. Hallett, United States Army.
G. W. Lewis, National Advisory Committee for Aeronautics.
J. G. Vincent, Packard Motor Car Co.

FUNCTIONS.

1. To aid in determining the problems relating to power plants for aircraft to be experimentally attacked by governmental and private agencies.
2. To endeavor to coordinate, by counsel and suggestion, the research and experimental work involved in the investigation of such problems.
3. To act as a medium for the intercharge of information regarding aeronautic power-plant investigations in progress or proposed.
4. The committee may direct and conduct research and experiment on aeronautic power-plant problems in such laboratory or laboratories, either in whole or in part, as may be placed under its direction.
5. The committee shall meet from time to time on call of the chairman and report its actions and recommendations to the executive committee.

By reason of the representation of the Army, the Navy, and the industry upon this subcommittee, it has been possible to maintain close contact with the research and development being carried on in this country and to exert an influence toward the expenditure of energy on those problems whose solution appears of the greatest importance, as well as to avoid waste due to unnecessary repetition of research. The activities of this committee can be advantageously considered under the following main classes of problems relating to aircraft power plants:

New engine types.
Performance characteristics of aircraft engines.
Supercharging compressors.
Improvement of engine details.
Cooling problems.
Radiating systems.
Carburetion systems.
Ignition systems.
Fuels and combustion.
Lubricants and lubrication.
Cylinder pressure indicators.
Miscellaneous problems.
Extension of laboratory facilities.

NEW ENGINE TYPES.

Owing to the disadvantages of high fire risk, high fuel cost, carburetion and ignition difficulties. low service reliability, and specific power limitation of the four-cycle engine, constantly increasing interest has been shown in the fuel injection engine of both automatic and electric ignition types. The two-cycle fuel injection automatic ignition engine appears especially promising. The problems incident thereto are being energetically studied abroad and some work is being done in this country. In particular, the Bureau of Engineering of the Navy Department has recently approved a fuel injection research program to be carried out at the Langley Memorial Aeronautical Laboratory, as the development of a successful engine of the fuel injection type is of especial interest to the Navy in connection with the power plants of large airships.

The program for the immediate future covers the study of the phenomena of fuel injection by means of a special glass-walled pressure chamber, in which many of the engine operating conditions may be simulated, equipped with apparatus for taking very high-speed photographs of the events occurring in the pressure chamber. The results are to be applied to an experimental engine and a study made of the possibilities of the double-piston two-cycle engine in this connection. The problem of altering standard carbureted four-cycle engines will receive attention as well.

The direct air-cooled engine offers important possible advantages which have been studied by foreign laboratories and to a small extent by those in this country, largely in connection with the general problem of radiation. In connection with direct fuel injection, the air-cooled engine is especially interesting as looking toward the increase of thermal efficiency and the reduction of engine weight.

The program provides for the continuation of the research into the problem of direct transfer of heat from cylinder walls to air, and, if possible, the extension of the results to the development of efficient cylinder forms.

The development of a radial engine of the air-cooled type has received the serious attention of research laboratories of both Great Britain and France. In this country very little has so far been done along this line, but the Air Service of the Army at McCook Field is now undertaking the problem, and at the present time is developing at two outside laboratories radial air-cooled engines.

The Army Air Service has nearing completion an 18-cylinder engine of 600 to 700 horsepower.

The development of an engine particularly suitable for a power unit for the operation of lighter-than-air craft is now being carried on by the Navy Department. To further this work and obtain an engine of general characteristics, and still allow leeway for individual design of detail, the Bureau of Engineering has let contracts to three separate engine manufacturers. The general specifications call for an engine with six cylinders in line, of approximately 300 horsepower, the main characteristics of which will be low fuel and oil consumption, together with a high degree of reliability. One engine of this class being constructed is of the Ricardo type, as it is hoped that by the use of the Ricardo principle of construction the life and reliability of the engine will be greatly increased.

PERFORMANCE CHARACTERISTICS OF AIRCRAFT ENGINES.

An investigation of the performance characteristics of aircraft engines, with special reference to conditions met with in flight, is being carried on in the altitude chamber of the Bureau of Standards. The purpose of the investigation is to secure information to be used in the selection of engines for specific purposes, and in improving the design of power plants. In conducting this research work, observations of the performance characteristics by means of the altitude laboratory equipment were made to supply information on a variety of subjects; such observations were made on a number of typical engines covering the following subjects:

(*a*) Conditions attendant upon supercharging (with special reference to Liberty engine).

(*b*) Study of indicated horsepower under altitude conditions.

(*c*) Study of relations between air to fuel ratio and maximum power at full and part throttle.
(*d*) Effect of intake air temperature, jacket-water temperature, etc., on performance.
(*e*) Study of mechanical losses.
(*f*) Comparison of performance of different types of spark plugs in operation.

SUPERCHARGING COMPRESSORS.

The General Electric exhaust turbine-driven centrifugal compressor as developed by the Air Service and Dr. S. A. Moss has been continuously perfected until it may be considered as a proved device. It is, in fact, being ordered in appreciable numbers for the equipment of the Liberty-12 engine. The gain in power output at high altitudes is sufficient to much more than offset the added weight.

The Sturtevant centrifugal-blower type, driven by gears and belt from the engine crankshaft, has been developed so far as to demonstrate its value, and its application to the Liberty-12 is now in progress. The gear-driven centrifugal compressor is being investigated and the Air Service has partly developed a hydraulic clutch for the same to eliminate the destructive effect of the very high inertia of the rotor.

The positive gear-driven centrifugal-fan type eliminates the high inertia forces by reason of the very low inertia of the rotor. This type was partially investigated by the engineering division of the American Expeditionary Forces in Paris during the last months of the war, and its further investigation has been undertaken by this committee at Langley Field.

The postive blower of the Root type is also being studied by the committee at the Langley Field laboratory, an experimental model having been built to supercharge the Liberty-12 up to 20,000 feet altitude. This device, as also the fan type above mentioned, are being subjected to performance tests on the dynamometer and will later be tested in flight if advisable.

The program of the committee for the immediate future involves the closest contact with all progress in this field, with a view to the early solution of the problem of the most desirable form of compressor and drive. The investigation in our own laboratory will be pushed forward as fast as possible consistent with accurate results.

IMPROVEMENT OF ENGINE DETAILS.

Little research has been carried out during the past year under this head. Perhaps the most important item is the study of the use of Monel metal for exhaust valves, the results of which indicate conclusively that this metal has quite favorable thermal properties and is on the whole well adapted for this purpose. Some work has also been done upon the effect of varying width of exhaust-valve seat upon the valve-head temperature. The "mercury-cooled" exhaust valve was developed by private laboratories and their conclusions have to a certain extent been checked by other laboratories, indicating that this valve does maintain a lower head temperature than the ordinary valve, provided the thermal capacity of the stem and contacting guide is sufficient to transfer the heat which the mercury carries from the exhaust-valve head to the stem. Some attention has also been paid to the question of reducing the temperature of the piston head, although sufficient data has not as yet been secured to justify any general conclusion.

The program for the future emphasizes the necessity for the energetic study of the piston head temperature, inasmuch as this is likely to prove one of the limitations to the continuous increase of brake mean effective pressure, and is of especial importance in connection with the two-cycle engine. Provision is also made for the continuation of the study of exhaust-valve temperatures and the thermal resistance of such constructional expedients as threaded joints in the combustion-chamber walls.

COOLING PROBLEMS.

The problem including water cooling and direct-air cooling of aircraft engines has been undertaken to complete the unfinished portion of the research on cooling radiators and to secure data desired for the design of direct air-cooled engines by means of fundamental laboratory experiments, mathematical analysis of these researches, and observations made in flight to check the foregoing. This work is to be undertaken by—

(*a*) Tests of new designs of radiator cells as developed.
(*b*) Study of heat and temperature distribution in model air-cooled cylinders by laboratory method and in cylinders of engines under operating conditions.
(*c*) Pressure and temperature gradients in air tubes of radiators.
(*d*) Mathematical analysis of results of the foregoing.
(*e*) Flight tests of radiators of standard and special construction to verify laboratory and mathematical study.

RADIATION SYSTEMS.

During the past year the testing of sample radiator cores has continued, together with the application of the results to full-size radiators. At the same time the results of previous work in this field have been collated and placed in such form as to be of direct value to the designing engineer. The results of research have to a large extent been checked by tests carried out by the Air Service at McCook Field.

The program provides for the continuation of the testing of interesting radiator core samples, as well as for the extension of the laboratory work and the verification of the fundamental relations. The scientific development of the direct air-cooled engine in reality comes under this same class, since the problems are quite similar to those of radiation involved in the water-cooled engine radiator, except that the temperature gradients are greatly increased. The fundamental data secured in the study of water radiators is of the greatest value in connection with the study of direct air-cooled engine cylinder.

CARBURETION SYSTEMS.

During the past year the problem of automatic carburetor compensation for altitude has received additional study and some work has been done in connection with its development in free flight tests. However, the growing importance of the supercharger has to a certain extent lessened the importance of this problem. A mathematical study has been made of the laws of flow of air and fuel in carburetors as affected by changes in altitude, and this is available as a foundation for the further development of automatic or inherent compensation means. The problems of the atomization and mixing characteristics of aircraft carburetors have received some additional experimental study, but the subject is so involved that it has not as yet been possible to develop any satisfactory foundation for the scientific comparison of the experimental results from different carburetors. These problems are interrelated to those of the optimum fuel to air ratios and the modifying effects of differing inlet manifold forms. An effort is being made to lay a proper foundation for the study of all of these problems, and it is believed that fundamental information will shortly be available. The data yielded by the testing of aircraft engines in the altitude chamber has been supplemented by tests of the carburetors alone in the carburetor test plant.

The program provides for the continuation of research in all of these problems, and in addition to study the question of the most advantageous form of poppet valves and ports as viewed from the standpoints of charging efficiency and minimum interference with mixture conditions.

The program also provides for a study of carburetion and manifolding for the purpose of securing fundamental data on the metering characteristics of aircraft carburetors with special reference to their performance at low-air densities. This will require also a study of the physical constants of aircraft fuels, such as vapor pressure, vapor volume, viscosities, etc., and of pulsating flow of manifolds. This work is to be carried on by—

(*a*) Study of various types of carburetors and the carburetor metering devices in the carburetor test plant.

(*b*) Subsequent checks on their performance when mounted on engines in the altitude laboratory.

(*c*) Study of physical constants of fuels by means of physical-chemical laboratory equipment, which has been developed for the purpose.

(*d*) Further mathematical analysis of the problem of melting at different air densities.

(*e*) Laboratory experiments to determine the effects of pulsating air flow on metering of fuel.

IGNITION SYSTEMS.

The work performed in this field has consisted largely of the more or less routine testing of new forms of spark plugs and spark-plug insulators. The mathematical theory of the electrical side of the ignition system has been worked out in detail and checked by laboratory experiments. The use of a series gap in the ignition secondary has received some additional attention and apparatus has been assembled for the continuation of research in this field.

The program for the future provides for the study of the effect of spark quality and intensity on the engine performance, the effect of the electrode temperature upon the breakdown voltage of the spark plug gap, as well as a continuation of the research into the auxiliary spark gap. The program also provides for the study of problems of ignition to secure information on the relative performance of different types of ignition systems, including spark plugs, magnetos, battery systems, etc., and the research will include:

(*a*) Laboratory and engine tests of spark plugs.

(*b*) Study of the effect of spark quality and intensity on engine performance.

(*c*) Study of the breakdown volume of spark gaps in normal operation.

(*d*) Further verification of the mathematical theory of the magneto.

Much of this work can be conveniently performed in connection with the research on the propagation of flame.

FUELS AND COMBUSTION.

During the past year experiments have been made with a number of compounded fuels, intended to reduce the tendency to knocking characteristics of the ordinary aviation gasoline. The results have demonstrated that there are a number of such compound fuels which will permit of a very considerable elevation of the compression ratio and compression temperature without difficulty. The effect of the admixture with gasoline or benzol, alcohol, or other substances, hydrocarbon or not, is now reasonably well known. It is possible to specify the proportions of a compound fuel to withstand any reasonable compression ratio, without developing disagreeable knocking conditions. The future program provides only for the testing of such fuel blends as may be introduced from time to time, it being considered that the fuel injection type of engine will ultimately eliminate the necessity for such compounded fuels as are now necessarily used in the very high compression carbureted engine.

The measurement of the rate of flame propagation in aircraft engine cylinders has been continued during the past year, through the medium of a specially equipped single cylinder Liberty engine. While the results of the investigation indicate a velocity of flame propagation in the order of 20 to 40 feet per second for ordinary operating conditions, it is felt that the data secured is not yet sufficient to justify the issuance of a general report upon the subject. To a large extent, this work is tied up with the investigation of the problem of detonation of charge, and the general problem of the chemical relations due to combustion. It is felt that investigation of all three general phases should be conducted simultaneously, in order that the resulting information may be of a fundamental instead of a particular nature. The program provides for the continuation of this work during the coming year, as it is believed that these are subjects of which too little is now known, in view of their vital bearing upon the desired continuous increase of brake mean effective pressure and thermal efficiency.

This work is being continued at the Bureau of Standards, and in conducting the tests it is hoped that data bearing on the following items of special importance will be obtained:

(*a*) The relation between rate of combustion and pressure distribution in engine cylinders.

(*b*) The velocities of propagation of flame in engine cylinders and in explosive mixtures as measured by laboratory methods, with special reference to the relative velocities for different fuels and different mixture ratios.
(*c*) Measurements of the apparent flame temperatures in engine cylinders under various conditions of operation by direct observation and spectrum analysis, if possible.
(*d*) The ignition temperatures for mixtures of fuel and air under various conditions.
(*e*) Analysis of the intermediate products of combustion secured by means of a sampling valve at different points in the combustion cycle.

LUBRICANTS AND LUBRICATION.

During the past year a series of tests were run for the military authorities to determine the relative merits of oils refined from different types of crude, giving results of a comparative nature only. Very little work has been done upon the fundamentals of cylinder lubrication, so that the real reason for the slight superiority of one oil over another has not as yet been determined. The future program provides for the comprehensive investigation of lubrication phenomena and the properties of oils suitable for aircraft engine lubrication, especially important because existing specifications do not guarantee an oil that will always answer the requirements.

CYLINDER PRESSURE INDICATORS.

A very satisfactory step-by-step diaphragm type indicator has been perfected during the past year and a number of instruments built and used in the regular work of the laboratory. The characteristics of preignition or knocking, as well as the normal operating cycles, have been studied with these instruments and pressures have been recorded of nearly 1,000 pounds per square inch. This instrument has also been developed in an automatic form, in which the balancing of the pressures on the two sides of the diaphragm is automatically provided for. This modification permits of more rapid operation and is probably the type which will be settled on for further development in the laboratory. Two other types of indicators are in the preliminary stage and will be further investigated. The program provides for the continuous perfection of such instruments in order that the study of the pressure changes in the cylinder may be carried out with the greatest degree of accuracy. It is intended that such studies shall form a part of all important investigations involving the operation of aircraft engines.

MISCELLANEOUS PROBLEMS.

Owing to the pressure of more important work, practically nothing has been done during the past year with reference to the development of mufflers for aeronautic engines, except as is necessarily involved in the general problem of the condensation of water from the exhaust gas. Considerable experimental work has been done on the latter problem and the general requirements have been roughly determined. Apparatus has been designed for the continuation of these experiments under free flight conditions upon the power plants of dirigibles.

The program provides that this work shall be continued and also for the further development of mufflers for those installations which do not involve water condensation.

EXTENSION OF LABORATORY FACILITIES.

During the past year the new engine laboratory has been completed at the Bureau of Standards, thus making available to the committee extensive facilities for the conduct of its work. A total of six dynamometers are at present provided, and these are so arranged in connection with the altitude chambers that engines as large as 800 horsepower may be tested therein. A complete complement of auxiliary equipment is included, and the installation as a whole is extremely convenient.

During the year some progress was made in the installation of the committee's own dynamometer laboratory equipment at its Langley Field laboratory. The small amount of available funds has, however, so limited the size of the staff that the work of installation is not yet complete. For the same reason it has not been possible to carry out much actual research work in this laboratory, the work so far accomplished being largely in the nature of preliminary investigations to serve as a basis for the research being conducted on the two types of supercharger. It is expected that the funds available for this laboratory during the forthcoming year will permit the very considerable extension of the staff and the conduct of work on a scale commensurate with the amount of apparatus available. The equipment consists mainly of five dynamometers ranging from 2 to 450 horsepower capacity, together with a certain amount of auxiliary apparatus. The equipment is temporarily housed in a standard Army steel hangar, a building not at all suited for the purpose, and it is hoped that in the near future it will be possible to replace this with a permanent building of more substantial construction.

The engine laboratory facilities of the United States Army Air Service station at McCook Field have been increased so that that organization is well provided with means for the conduct of the experimental development of power plants.

The Navy Department maintains a small dynamometer laboratory in the navy yard at Washington the equipment of which has been augmented by making available two electric dynamometers coupled together. This laboratory has been largely engaged on the problem of water recovery from the exhaust.

REPORT OF COMMITTEE ON MATERIALS FOR AIRCRAFT.

Following is a statement of the organization and functions of the committee on materials for aircraft:

ORGANIZATION.

Prof. Charles F. Marvin, chairman.
Dr. G. K. Burgess, Bureau of Standards, vice chairman.
Capt. H. W. Flickinger, United States Army.
Dr. Henry A. Gardner, Institute of Industrial Research.
Prof. George B. Haven, Massachusetts Institute of Technology.
Commander J. C. Hunsaker, United States Navy.
Dr. Zay Jeffries, Aluminum Co. of America.
Prof. William Walker, Massachusetts Institute of Technology.
Prof. E. P. Warner, Massachusetts Institute of Technology.
Prof. H. L. Whittemore, Bureau of Standards, acting secretary.

FUNCTIONS.

1. To aid in determining the problems relating to materials for aircraft to be experimentally attacked by governmental and private agencies.

2. To endeavor to coordinate, by counsel and suggestion, the research and experimental work involved in the investigation of such problems.

3. To act as a medium for the interchange of information regarding investigations of materials for aircraft, in progress or proposed.

4. The committee may direct and conduct research and experiment on materials for aircraft in such laboratory or laboratories, either in whole or in part, as may be placed under its direction.

5. The committee shall meet from time to time on call of the chairman and report its actions and recommendations to the executive committee.

The committee on materials for aircraft, through its personnel acting as a medium for the interchange of information regarding investigations on materials for aircraft, is enabled to keep in close touch with research in this field of aircraft development.

Much of the research, especially in the development of light alloys, must necessarily be conducted by the industries interested in the particular development, and both the Aluminum

Co. of America and the American Magnesium Corporation are represented on the committee. In order to cover effectively the large and varied field of research on materials for aircraft three subcommittees were formed, as follows:

Subcommmittee on metals (Dr. G. K. Burgess, chairman).

Subcommittee on woods and glues (Prof. H. L. Whittemore, chairman).

Subcommittee on coverings, ropes, and protective coatings (Dr. Henry A. Gardner, chairman).

Most of the research in connection with the development of materials for aircraft is financed directly by the Bureau of Construction and Repair of the Navy Department and the Engineering Division of the Army Air Service.

The Bureau of Construction and Repair not only conducts research at its aerodynamical laboratory at the Washington Navy Yard and at the naval aircraft factory in Philadelphia, but also apportions and finances research problems to the Bureau of Standards, the Langley Memorial Aeronautical Laboratory, the Institute of Industrial Research, and the Forest Products Laboratory.

SUBCOMMITTEE ON METALS.

In a report of the progress that has been made in regard to the manufacture and utility of light alloys it is well to state that much of this progress is the result of investigations either started during the war and completed since the armistice or of work that has been a natural consequence of experience gained during the war. Of those light aluminum alloys which can be worked, duralumin or material of similar composition, because of its inherent possibilities, is probably the most widely used and naturally has received the most attention at the hands of the investigators. Dr. Merica and his associates at the Bureau of Standards have greatly increased the knowledge of the manufacture and heat treatment of duralumin, as reported in Bureau of Standards Scientific Paper No. 347. This paper shows that it is advisable to preheat the ingots previous to rolling somewhat higher than was customary, namely, to preheat to 500° C. and then roll to 450° C. The best quenching temperature was found to lie between 510° and 515° C., and quenching should be in hot water. The mechanical properties of the finished material are quite dependent upon the artificial aging process, but for most purposes it was found best to age at 100° C. for about five to six days. A theory of the mechanism of the hardening of duralumin was developed, which has been further amplified by Dr. Zay Jeffries.

Duralumin may be drop-forged as well as rolled, and some interesting tests on drop-forged connecting rods are given by Rollason, who found that the aluminum alloy rods withstood impact fatigue better than ordinary steel forgings.

Gibson has also investigated the fatigue resistance of various duralumins and concludes that, weight for weight, forged and heat-treated duralumin is equal to, if not superior to, forged steel in its fatigue-resisting properties. He also states that under certain limitations as to stresses involved that it is comparable with steel on a volume-for-volume basis.

As an example of the increasing use of duralumin there might be cited the all-metal airplanes, such as the Larsen or others similar to the German Junker models. These airplanes use duralumin for wing surface coverings in place of fabric as well as for structural members. For the latter purpose seamless tubing is essential, although to date satisfactory sources of supply have not become available in the United States.

Many of the light casting alloys have been studied by Merica and Karr, as reported in Bureau of Standards Technologic Paper No. 139, and they determined the tensile properties, hardness, resistance to corrosion, and resistance to the action of alternating stresses of a number of compositions. The effect of various additional elements, such as copper, zinc, manganese, magnesium, and nickel were studied, and these investigators showed that certain of the casting alloys were also subject to beneficial results from heat treatment. This practice was commended to the manufacturers of castings for realization of its commercial possibilities.

Jeffries and Gibson also investigated the effect of heat treatment upon cast aluminum alloys and suggested that more uniform results could be obtained by heating the castings in a bath of fused niter followed by quenching in oil, thus reducing to a minimum the tendency for the atmosphere to permeate and oxidize the interior of porous castings.

R. J. Anderson has published several articles on aluminum castings and foundry practice, particularly with a view to producing sound castings, free from blowholes and hard spots.

The metallography of aluminum and its alloys has also received some attention; Merica, Waltenberg, and Freeman studied aluminum and its alloys with copper and with magnesium. The various constituents were identified and the temperature solubility curves of $CuAl_2$ and of Mg_4Al_3 determined. Anderson studied the metallography of commercial aluminum and aluminum in ingot form and compared the microstructure, macrostructure, and fracture of tough and brittle ingots.

For a comprehensive investigation of the constitution and positive identification of the constituents in aluminum it is necessary to start with pure aluminum. The best aluminum now obtainable is seldom better than 99.8 per cent pure. Efforts to produce aluminum of greater purity have not been successful thus far.

The corrosion of the rolled light alloys was investigated by Merica, Waltenberg, and Finn, using three ternary series, Al–Mg–Cu, Al–Mg–Mn, and Al–Mg–Ni. The alloys of the Al–Mg–Mn series resisted corrosion in general better than the others. Hard-rolled commercial aluminum corrodes much more than any of the alloys, annealed aluminum was more resistant to corrosion than the hard-rolled aluminum, but did not compare favorably with the alloys. Bureau of Standards Technologic Paper No. 132 also gives the mechanical properties of the various alloys in the cold-rolled, annealed, and heat-treated conditions.

The Bureau of Standards, in cooperation with the Navy Department, also conducted tests on the corrosion of aluminum and its alloys by sea water, both unprotected and with various protective coatings. Presence of oil on the water where the plates were exposed lends some doubt to the results, but the indications were that unprotected duralumin has practically the same resistance to corrosion as that which has been protected. Other findings were practcially as above.

Among the new light alloys which have been brought out, "Dow metal" is quite interesting. This alloy is said to contain over 90 per cent magnesium and to have a specific gravity of 1.79. Castings have a tensile strength of from 22,000 to 25,000 pounds per square inch; yield point, 12,000 to 14,000 pounds per square inch; elongation, 3.5 per cent in 2 inches; reduction of area, 3.5 per cent; and Brinell hardness of 55 to 75. The sand castings are subject to heat treatment, such procedure increasing the tensile strength to 30,000 pounds per square inch and elongation and reduction of area to 6 per cent each. The alloy may also be worked, drop forgings having a tensile strength of 50,000 pounds per square inch and Brinell hardness of 70. No data are given in the literature on this alloy as to the method of casting which heretofore has been a great drawback in producing magnesium rich alloys, due to the affinity of magnesium for oxygen, nitrogen, etc.; Waltenberg and Coblentz in preparing aluminum magnesium alloys resorted to vacuum casting in order to produce sound material.

In this connection, in an article by Thomas on the casting of elektronmetall containing about 80 per cent magnesium and the balance aluminum and zinc, it is stated that great care must be exercised in selecting the sand for molding and that the molds must be thoroughly dried to get rid of all moisture. The alloy is melted in wrought-iron or cast-steel crucibles, as magnesium will take up the silica of graphite crucibles. The crucibles are covered with an iron cover to reduce oxidation, the pouring temperature must be closely controlled (just above melting point) and the melt poured directly after reaching the proper temperature. The alloy is brittle down to 100° C. and the casting must not be disturbed until cold. He gives illustrations of very sound castings produced in this manner.

The naval aircraft factory conducted a test of the comparison of the effect of punched and drilled rivet holes on the physical properties of duralumin sheet, and to determine whether punching is harmful to the material. The general conclusion of this investigation is that rivet holes made by punching will not weaken duralumin sheets more than those made by drilling, and comparative tests made on duralumin sheets in the four states in which it is likely to be handled showed the punched specimens to be slightly stronger than the drilled specimens.

The Bureau of Construction and Repair of the Navy has also authorized an investigation of the strength and fatigue value of duralumin as affected by heat treatment and working. This investigation will be conducted at the Bureau of Standards along lines that have been proposed by the committee on materials for aircraft.

A special report is being prepared by A. M. Hunt, director of research of the American Magnesium Corporation, Niagara Falls, N. Y., on the present status of magnesium alloys, with special reference to their possible use in connection with aircraft.

The Engineering Division of the Air Service of the Army is making extensive preparations to carry on experiments in connection with the development of aluminum and magnesium alloys for use in the construction of aircraft.

SUBCOMMITTEE ON WOODS AND GLUES.

Most of the research in connection with the development of woods and glues to be used in construction of aircraft is carried on at the forest-products laboratory at Madison, Wis. The forest-products laboratory is developing for the Bureau of Construction and Repair a 17-foot strut for a Navy flying boat, and is also engaged in the development of a streamline strut and the determination of the dimensions of wide struts of uniform strength. Tests have also been made upon airship girders. Improvement has been made in the formula for a waterproof glue developed by the forest-products laboratory for use in gluing wood. Increasing or decreasing greatly the proportion of sodium silicate shortens the life of the glue, although this has little effect on the strength or water resistance. The life of the glue is less the greater the amount of lime content. Water resistance increases with the increase of the amount of lime; very rapidly at first, but later more slowly. With very high lime content the water resistance falls off slightly.

Weathering tests were also conducted on all-veneer wing sections. The all-veneer wing used was built and previously tested by sand loading, and was cut into five sections and covered with varnish and aluminum leaf for protection. The usefulness of both veneers appeared to be equal, but the surface of the one protected by aluminum leaf was in better condition than the one protected by spar varnish.

Strength tests were also conducted on screw fastenings of plywood, with the result that it was found that round-head screws with washers give about the same strength at flat-headed screws of the same size without washers. The tests resulted in recommendations for screw sizes, margin, and spacing for use with various species and thicknesses of plywood.

The Bureau of Construction and Repair also authorized the investigation of the strength of plywood. The object of these tests was to secure comparative data on properties of different species, effect of varying ratio of thickness of core to total panel thickness, and the effect of low density species in core to high density species on faces. Stiffness in bending, tensile strength, resistance to splitting, and toughness increase with the increase of the density of the plywood, and column bending and tensile strength of 3-ply wood are greater when force is applied perpendicular. Strength and stiffness in column bending decrease as the number of plies increase when the force is applied parallel to the grain and increase when force is applied perpendicular to the grain.

SUBCOMMITTEE ON COVERINGS, DOPES, AND PROTECTIVE COATINGS.

The Bureau of Construction and Repair is developing a substitute for goldbeater's skin. It is intended to use this material in the construction of gas cells for rigid airships, and possibly in the construction of envelopes for nonrigid airships. The material has properties approaching the properties which made goldbeater's skin of value, namely, high resistance to the passage of hydrogen gas, and lightness. It is capable of being produced in sheets of large area, and cemented with comparative ease.

The Bureau of Construction and Repair has requested the Bureau of Standards to develop a cement for the attaching of goldbeater's skin to cotton cloth. The material should resist the action of moisture, and at the same time remain permanently flexible and adherent. It is intended to replace the rubber cement at present in use. The latter is understood to have a slow deteriorating effect on goldbeater's skin. The new cement should have no deteriorating effect, and if possible actually have a preservative action.

The Bureau of Standards is also developing a substitute for rubber proofing in balloon fabrics. It is believed that other substances may have the properties of being impermeable to hydrogen in equal or better degree than rubber, and may also be made flexible and capable of application in very much the same manner as that used with rubber.

TECHNICAL PUBLICATIONS OF THE COMMITTEE.

During the past year, the committee on publications and intelligence has recommended the publication of 28 technical reports, a summary of which follows. The reports cover a wide range of subjects on which research has been conducted under the supervision and cognizance of the various subcommittees, each report being approved by the subcommittee interested and recommended for publication to the executive committee. The technical reports presented represent fundamental research in aeronautics carried on at different aeronautical laboratories in this country, including the Langley Memorial Aeronautical Laboratory, McCook Field, the Aeronautical Laboratory at the Washington Navy Yard, the Bureau of Standards, and the Leland Stanford Junior University.

Considerable technical information is obtained by the committee that is of immediate interest to those interested in experimental and research problems in connection with aeronautics. To make this information immediately available, the National Advisory Committee for Aeronautics has authorized the committee on publications and intelligence to issue a series of "Technical Notes." In accordance with this authorization, the committee has issued 16 technical notes, on subjects that were of immediate interest, not only to research laboratories, but also to airplane manufacturers. A list of the technical notes issued during the year follows the general summary of the technical reports.

The first annual report of the National Advisory Committee for Aeronautics contained technical reports Nos. 1 to 7; the second annual report, Nos. 8 to 12; the third annual report, Nos. 13 to 23; the fourth annual report, Nos. 24 to 50; the fifth annual report, Nos. 51 to 82; and since the preparation of the fifth annual report, the committee has issued the following technical reports, Nos. 83 to 110:

Report No. 83, entitled "Wind Tunnel Studies in Aerodynamic Phenomena at High Speed," by F. W. Caldwell and E. N. Fales, Engineering Division, Air Service, McCook Field.—A great amount of research and experimental work has been done and fair success obtained in an effort to place airplane and propeller design upon an empirical basis. However, one can not fail to be impressed by the apparent lack of data available toward establishing flow phenomena upon a rational basis, such that they may be interpreted in terms of the laws of physics.

With this end in view it was the object of the authors to design a wind tunnel differing from the usual type especially in regard to large power and speed of flow. This involved features whose suitability could not be predicted; for, after all available information has been secured on full-size and model wind tunnels in various parts of the world, there remains much obscurity about the air flow phenomena. It is the assumption of Dr. George de Bothezat that the type of air flow which establishes itself is governed by the stresses set up in the air passing the aerofoil. The stresses increase as the velocity rises, and it is easy to conceive that a given type of flow is possible only so long as the shearing stresses developed in the fluid do not exceed a certain magnitude which depends on the value of the viscosity coefficient.

Experimental investigation of the flow has heretofore been rather unsuccessful because of lack of adequate methods. The writers laid out the design of the McCook Field wind tunnel to investigate the scaling effect due to high velocities of propeller aerofoils. During the course of the experiments, however, it was found impossible to visualize the air flow. The velocities of the air flow obtained by the writers offers a solution to one of the fundamental problems of aerodynamics, namely, the quantitative empirical measurement of the phenomena of fluid dynamics pertaining to flight and air flow. The method described in the report for visualizing air flow depends upon the fact that the moisture in the air condenses as a fog when the temperature is reduced to the dew point, provided that there is a solid or liquid nucleus to start the condensation. In the McCook Field wind tunnel the temperature drop is brought about through expansion of the air during acceleration due to a drop of pressure of 100 inches of water. The relative humidity of the atmosphere can be artificially raised if too low, and the necessary nucleus for condensation is provided by the model tested. Flow vortices become readily visible, and the report contains many photographs showing the air flow past an aerofoil under different conditions.

Report No. 84, entitled "Data on the Design of Plywood for Aircraft," by Armin Elmendorf, Forest Service.—This report gives the results of investigations made by the Forest Products Laboratory of the United States Forest Service at Madison, Wis., for the War and Navy Departments. Sufficient discussion on the mechanical and physical properties of plywood is included so that the data may be intelligently used. The data, although primarily intended for aircraft design, have a broader field of application. The report makes available data which will aid the designer in determining the plywood that is best adapted to various aircraft parts. The results expressed in the report were determined through a comprehensive test of the mechanical and physical properties of plywood and of the way these properties vary with the density, number, thickness, and arrangement of the plies and the direction of grain of the plies.

Report No. 85, entitled "Moisture Resistant Finishes for Airplane Woods," by M. E. Dunlap, Forest Service.—This report describes briefly a series of experiments made at the Forest Products Laboratory, Madison, Wis., to determine the comparative moisture resistance of linseed oil, impregation treatments, condensation varnishes, oil varnishes, enamels, cellulose varnishes, rubber, electroplated and sprayed metal coatings, and metal-leaf coatings when applied to wood.

All coatings except the rubber and electroplated metal coatings, which were not developed sufficiently to make them practical, admitted moisture in varying degrees. The most effective and at the same time most practical coating was found to be that of aluminum leaf.

Tests were made by applying coatings to panels of yellow birch, care being taken that the panels were carefully smoothed and the corners rounded. In general, a coat of filler was first applied, followed by three coats of the coating material being studied; and in some cases the material applied required special methods of application. After the panels had dried thoroughly they were subjected to an atmosphere of the humidity of 95 to 100 per cent for 17 days.

Report No. 86, entitled "Properties of Special Types of Radiators," by S. R. Parsons, Bureau of Standards.—This report discusses the general performance characteristics of three special classes of radiators: Those with flat-plate water tubes, fin and tube types, and types that whistle in an air stream. Curves and tables show the performance of representative radiators of each class and compare the flat-plate and whistling types. Empirical equations are given for estimating the performance of flat-plate radiators of various dimensions.

The report also contains a brief discussion, with curves, showing the effect of yawing on the properties of a radiator.

It was found that a careful distinction should be made between radiators whose water tubes are smooth and other types using perforated plates or deep and narrow tubes placed in rows one behind the other. Holes in water tubes or spaces between them in the direction of the air flow caused a great increase in head resistance and a decrease in mass flow of air, although the heat transfer per square foot of cooling surface was increased by the great turbulence caused by the use of perforations. The net result was a decrease in the figure of merit. The same result has been found in the case of turbulent vanes in cellular radiators, and, indeed, no type of radiator is known to the writer in which an artificial increase of turbulence is not accompanied by a decrease in the figure of merit.

Report No. 87, entitled "Effects of Nature of Cooling Surface on Radiator Performance," by S. R. Parsons and R. V. Kleinschmidt, Bureau of Standards. This report discusses the effects of roughness, smoothness, and cleanness of cooling surfaces on the performance of aeronautic radiators, as shown by experimental work, with different conditions of surface, on (1) heat transfer from a single brass tube and from a radiator; (2) pressure drop in an air stream in a single brass tube and in a radiator; (3) head resistance of a radiator; and (4) flow of air through a radiator. It is shown that while smooth surfaces are better than rough, the surfaces usually found in commercial radiators do not differ enough to show marked effect on performance, *provided the surfaces are kept clean.*

An accumulation of oil and dust on the surface will have a very harmful effect on the performance of the radiator. The heat transfer from an ordinary smooth surface may be increased 17 per cent in a good air flow by giving the surface a high polish, or it may be decreased 10 per cent or more by smoking the surface, and the figure of merit of the radiator then may be somewhat increased by polishing the surface, 6 to 10 per cent being observed in one case.

In general, the performance of a radiator may be improved by polishing the surfaces; and if they are fairly smooth and clean, a high polish is required to produce an appreciable change in the property of the radiator, and there is a question whether or not such a method of improvement is practicable.

Report No. 88, entitled "Pressure Drop in Radiator Air Tubes," by S. R. Parsons, Bureau of Standards. This report describes a method for measuring the drop in static pressure in air flowing through a radiator and shows (1) a reason for the discrepancy noted by various observers between head resistance and drop in pressure; (2) a difference in degree of contraction of the jet in entering a circular cell and a square cell; (3) the ratio of internal frictional resistance to total head resistance for two representative types; (4) the effect of smoothness of surface on pressure gradient; and (5) the effects of supplying heat to the radiator on pressure gradient.

The fact that the pressure gradients are found to be approximately proportional to the square of the rate of flow of air appears to indicate turbulent flow, even in the short tubes of the radiator.

It was found that in general the drop in the static pressure in the air stream through a cellular radiator and the pressure gradient in the air tubes are practically proportional to the square of the air flow in a given air density; that the difference between the head resistance per unit area and the fall of static pressure through the air tubes in radiators is apparent rather than real; and that radiators of different types differ widely in the amount of contraction of the jet at entrance. The frictional resistance was found to vary considerably, and in one case to be two-thirds of the head resistance in the type using circular cells and one-half of the head resistance of the radiator type using square cells of approximately the same dimensions.

Report No. 89, entitled "Comparison of Alcogas Aviation Fuel with Export Aviation Gasoline," by V. R. Gage, S. W. Sparrow, and D. R. Harper, of the Bureau of Standards.—Mixtures of gasoline and alcohol when used in internal-combustion engines designed for gasoline have been found to possess the advantage of alcohol in withstanding high compression without "knock," while retaining advantages of gasoline with regard to starting characteristics. Tests of such fuels for maximum power-producing ability and fuel economy at various rates of consumption are thus of practical importance, with especial reference to high-compression engine development.

Aviation alcogas, prepared by the Industrial Alcohol Co., of Baltimore, Md., for trial by the Navy Department and by the latter submitted to the Bureau of Standards for test, was a mixture apparently of about 40 per cent alcohol, 35 per cent gasoline, 17 per cent benzol, and 8 per cent other ingredients. This is not the alcogas prepared for commercial or passenger car use. The exact composition and methods of manufacture are a trade secret.

The tests made for the Navy Department consisted in a direct comparison, in a 12-cylinder Liberty engine, between alcogas and standard "X" (export grade) aviation gasoline with respect to maximum power obtainable and fuel consumption with the leanest mixture giving maximum power. The tests were made in the altitude laboratory at the Bureau of Standards, where controlled conditions simulate those of any altitude up to 30,000 feet. The speed range covered was from 1,400 to 1,800 revolutions per minute and the altitude range from ground level to 25,000 feet. Two series of comparisons were made, one with 5.6 compression ratio pistons and one with 7.2 compression ratio pistons.

The results of the tests showed the following performance of alcogas in comparison with X gasoline as a standard:

(1) At 5.6 compression the same maximum power production at ground level and a general average of 4 per cent more power at altitude, the maximum difference being about 6 per cent at 6,400 feet and 1,800 revolutions per minute.

(2) At 7.2 compression an average and fairly uniform increase of 4 per cent in power at altitude, no comparative figure for X gasoline at ground level being determined with this compression.

(3) A fuel consumption per brake horsepower of from 10 per cent to 15 per cent more by weight to secure this maximum power at any altitude or speed with either compression ratio. Owing to 12 per cent higher density of alcogas, the fuel consumption in terms of volume per brake horsepower is practically the same as with X gasoline.

(4) Thermal efficiency superior by about 15 per cent. A pound of alcogas contains about 22 per cent less heat units than a pound of gasoline, so that in securing more power with 15 per cent greater weight of fuel it is evident that the available energy of alcogas is more fully utilized than that of gasoline.

Report No. 90, entitled "Comparison of Hecter Fuel with Export Aviation Gasoline," by H. C. Dickinson, V. R. Gage, and S. W. Sparrow, of the Bureau of Standards.—Aviation engine developments for attaining higher power at altitude are following two principal lines, supercharging and increase in compression ratio. For the latter fuels have been demanded which are capable of operating under compressions too high for gasoline. Among the fuels which will operate at compression ratios up to at least 8.0 without preignition or "pinking" is Hecter fuel, whence a careful determination of its performance is of importance.

The Hecter fuel supplied by the Bureau of Mines for use in these tests was a mixture of 30 per cent benzol (C_6H_6) and 70 per cent cyclohexane (C_6H_{12}), having a low freezing point, and distilling from first drop to 90 per cent at nearly a constant temperature, about 20° C. below the average distillation temperature ("mean volatility") of the X gasoline.

This comparison of the performance of the two fuels in an aviation engine was made in the altitude chamber at the Bureau of Standards, duplicating altitude conditions up to about 25,000 feet, except that the temperature of the air entering the carburetor was maintained nearly constant at about 10° C. A Liberty 12-cylinder aviation engine was used, supplied with special pistons giving a compression ration of 7.2 (the compression pressure measured by check-valve gauge was 170 pounds per square inch). Stromberg carburetors were used and were adjusted for each change of fuel, speed, load, and altitude so as to give the maximum possible power with the least fuel for this power. The tests covered a speed range of 1,400 to 1,800 r. p. m.

The results of these experiments show that the power developed by Hecter fuel is the same as that developed by export aviation gasoline at about 1,800 r. p. m. at all altitudes.

At lower speeds differences in the power developed by the fuels become evident. At 1,400 r. p. m. and 25,000 feet Hecter gives a little less power than X gasoline, at 15,000 feet about the same, and at 6,000 feet perhaps 6 per cent more. Comparisons at ground level were omitted to avoid any possibility of damaging the engine by operating with open throttle on gasoline at so high a compression. The fuel consumption per unit power based on weight, not volume, averaged more than 10 per cent greater with Hecter than with X gasoline, considering all conditions. The thermal efficiency of the engine when using Hecter is less than when using gasoline, particularly at higher speeds, a generalization of the difference for all altitudes and speeds being 8 per cent. The general deduction from these facts is that more Hecter is exhausted unburnt. Undoubtedly Hecter can withstand high compression pressures and temperatures without preignition. This characteristic was proved by operating the engine (compression ratio 7.2) with full throttle at 1,500 r. p. m. on the ground, carburetor air temperature 42° C. (107.6° F.) and jacket-water temperature, leaving engine, at 90° C. (194° F.). No signs of preignition or "pinking" were noted.

Report No. 91, "Nomenclature for Aeronautics," by the National Advisory Committee for Aeronautics.—This nomenclature and list of symbols were approved by the executive committee of the National Advisory Committee for Aeronautics, for publication as a technical report, on April 1, 1920, on recommendation of the subcommittee on aerodynamics.

The purpose of the committee in the preparation and publication of this report is to secure uniformity in the official documents of the Government and, as far as possible, in technical and other commercial publications. This report supersedes all previous publications of the committee on this subject.

The subcommittee on aerodynamics had charge of the preparation of the report. It was materially assisted by the Interdepartmental Conference on Aeronautical Nomenclature and Symbols, organized by the executive committee, with the approval of the War and Navy Departments, for the purpose of giving adequate representation to the divisions of the Army Air Service and to the bureaus of the Navy Department most concerned. The first meeting of the interdepartmental conference was held on October 23, 1919, and the second meeting on January 15, 1920, at which meeting this report was unanimously approved and recommended to the subcommittee on aerodynamics, with the reservation that stability terms and power-plant terms be given further and special consideration.

The stability terms were accordingly referred for special consideration to Messrs. E. B. Wilson, J. C. Hunsaker, A. F. Zahm, E. P. Warner, and H. Bateman, and the power-plant terms were referred to the subcommittee on power plants for aircraft. The complete report was adopted by the subcommittee on aerodynamics on March 8, 1920, and recommended to the executive committee for approval and publication.

Report No. 92, entitled "Analysis of Wing Truss Stresses," by E. P. Warner and Roy G. Miller, Langley Memorial Aeronautical Laboratory. Airplane wing trusses are generally designed to contain redundant members (stagger wires and external drag wires) which, according to common practice, are not taken into account in calculations, so as to simplify the stress analysis by rendering the structure statically determinate. A more accurate method, in which the redundancies are included, involves a solution by means of Castigliano's method of least work.

For the purpose of demonstrating the practical application of the method of least work the stresses for several cases of loading were worked out for a structure similar to that of the Curtiss JN-4H.

Case I was taken as the condition of velocity of 100 miles per hour combined with the angle of attack of maximum lift. Case Ia assumed the same loading but neglected the distortion of wooden members in the least-work analysis. So little error was involved in Case Ia (nowhere exceeding 5 per cent of the ultimate strength) that this simplified method was employed for each succeeding case.

Case II assumed a diving speed of 120 miles per hour and an angle of attack of no lift.

Case III was worked out for the conditions imposed by the sand load recommended in N. A. C. A. Technical Note No. 6.

An analysis for each case was also carried through with the stresses corrected for the worst initial tensions which tensiometer readings on service machines indicated were probable.

It was concluded that—

(i) The making of a least-work analysis of a new design for at least one case is thoroughly justified.

(ii) The wooden members may be omitted from consideration in the work equations without causing any serious error.

(iii) The effect of the stagger wires is unimportant when the load is approximately equally distributed between the front and rear trusses. The stagger wires are subjected to their worst stresses while diving.

(iv) Only very rarely are both external drag wires stressed simultaneously.

(v) The initial tensions are almost always excessive, particularly in the stagger wires.

The following recommendations were made:

I. Only one external drag wire should be used on each side of the plane of symmetry and none are required if the front flying wires are strengthened and their attachment to the fuselage carried forward.

II. The long stagger wire is generally the more severely stressed. If a steel tube is used for stagger bracing it should form the short diagonal of the panel.

III. Airplanes should be rigged, whenever possible, by means of a tensiometer and in accordance with a schedule of initial tensions to be provided by the designer.

Report No. 93, entitled "Properties of Aerofoil Sections," by the National Advisory Committee for Aeronautics.—The object of this report is to bring together the investigations of the various aerodynamic laboratories of this country and Europe upon the subject of aerofoils suitable for use as lifting or control surfaces on aircraft. The data have been so arranged as to be of most use to designing engineers and for purposes of general reference. It is the purpose of the committee to publish all existing tests on aerofoil sections, and present this information in a new form.

The absolute system of coefficients has been used, since it is thought by the National Advisory Committee for Aeronautics that this system is the one most suited for international use, and yet is one for which a desired transformation can be easily made. For this puropse a set of transformation constants is included in this report.

Each aerofoil section is given a reference number, and the test data are presented in the form of curves from which the coefficients can be read with sufficient accuracy for design purposes. The dimensions of the profile of each section are given at various stations along the chord in per cent of the chord using as datum the line shown on the curves. The shape of the section is also shown in reasonable accuracy to enable one to more clearly visualize the section under consideration together with its characteristics. The more accurately to obtain the dimensions of the profile of each section, a separate data sheet for each section has been included, which gives an additional decimal place for the greater portion of the ordinates.

The authority for the results here presented is given as the name of the laboratory at which the experiments were conducted with the size of model, wind velocity, and date of test.

Three separate indices are given—a chart index which makes it possible for a designer to select the wing section most suitable for the particular design he is interested in; a group index which is arranged in the same order as the curve sheets; that is, by countries and laboratories at which tests were conducted, each section also being designated by a reference number; and an alphabetical index.

In order that the designer may easily pick out a wing section which is suited to the type of machine on which he is working, four index charts are given which classify the wings according to their aerodynamic and structural properties.

Report No. 94, entitled "The Efficiency of Small Bearings in Instruments of the Type Used in Aircraft," by F. H. Norton, Langley Memorial Aeronautical Laboratory.—This report deals with the construction and properties of bearings and pivots for use in instruments. The static and running friction for both thrust and radial loads was determined for a number of conical pivots and cylindrical and ball bearings. The static rocking friction was also measured for several conical and ball bearings under a heavy load, especially to determine their suitability for use in an N. P. L. type wind tunnel balance. In constructing conical pivots and sockets it was found that the pivots should be hardened and highly polished, preferably with a revolving lap, and that the sockets should be made by punching with a hardened and polished punch. It was found that for a light load the conical pivots give less friction than any other type, and their wearing qualities when hardened are excellent. When the load exceeds about 1,000 grams ball bearings give less friction than pivots and will stand shocks and wear better. Very small ball bearings are unsatisfactory because the proportional accuracy of the balls and races is not high enough to insure smooth running. For rocking pivots under heavy loads it was found that a ball-and-socket bearing, consisting of a hemispherical socket and a sphere of smaller diameter concentric with it with a row of small balls resting between the two, was superior to a pivot resting in a socket. It was found that vibration such as occurs in an airplane will greatly reduce the static friction of a pivot or bearing, in some cases to as little as one-twentieth of its static value.

Report No. 95, entitled "Diagrams of Airplane Stability," by H. Bateman, California Institute of Technology.—In this report a study is made of the effect on longitudinal and lateral oscillations of an airplane of simultaneous variations in two resistance derivatives while the remainder of the derivatives are constant. The results are represented by diagrams in which the two variable resistance derivatives are used as coordinates, and curves are plotted along which the modulus of decay of a long oscillation has a constant value. The same type of analysis is also carried out for the stability of the parachute. For longitudinal stability it is concluded that a decrease in η is unfavorable to stability, but it may be offset by a variation in the other derivatives. The effect of a spring flap is discussed that will change ζ from its usual value of 0 to either a positive or negative quantity. It is found that a positive value of ζ is unfavorable to stability. It is also found that an increase in the value of ξ is unfavorable to stability, and that, if ξ is made positive, the time of damping is decreased. In lateral stability it is found that the greater the value of ξ the greater is the effect on the damping of a change in w, and that an increase in w decreases the time of damping, but does not greatly alter the period. When $\xi=0$ an increase in η decreases the time of damping and increases the period, but when ξ is positive the effect seems to be reversed. An increase in z widens the gap between the curves $t=a$ constant, and to greatly increase the period when $\xi=1$ and $\xi=2$. The chief effect of a decrease in η seems to be a slight change in curvature of the curve $t=a$ constant. In discussing the stability of a helicopter it is concluded that the gyroscopic effect on stability will be greater than in the case of the airplane.

Report No. 96, entitled "Statical Longitudinal Stability of Airplanes," by E. P. Warner, Langley Memorial Aeronautical Laboratory.—This report, which is a continuation of the "Preliminary Report on Free Flight Testing" (No. 70), presents a detailed theoretical analysis of statical stability with free and locked controls and also the results of many free flight tests on several types of airplanes.

In developing the theory of stability with locked controls an expression for pitching moment is derived in simple terms by considering the total moment as the sum of the moments due to wings and tail surface. This expression, when differentiated with respect to angle of incidence, enables an analysis to be made of the factors contributing to the pitching moment. The effects of slip stream and down wash are also considered and it is concluded that the C. G. location has but slight effect or stability, and that stability is much improved by increasing the efficiency of the tail surfaces, which may be done by using an "inverted" tail plane.

The results of free flight tests with locked controls are discussed at length and it is shown that the agreement between the experimental results and theory is very satisfactory.

The theory of stability with free controls is not amenable to the simple mathematical treatment used in the case of locked controls, but a clear statement of the conditions enables several conclusions to be drawn, one of which is that the fixed tail surfaces should be much larger than the movable surfaces.

The discussion of flight tests with free controls covers the effect of C. G. position, tail setting, and slip stream on the JN-4H and gives an analysis of the curves of forces on control stick for the VE-7, U. S. A. C-11, and Martin transport.

Report No. 97, "General Theory of the Steady Motion of an Airplane," by George de Bothezat, Engineering Division, Air Service of the Army.—The writer points out briefly the history of the method proposed for the study of the steady motion of an airplane, which is different from other methods now used. M. Paul Painlevé has shown how convenient the drag-lift curve was for the study of airplane steady motion. His treatment of this subject can be found in "La Technique Aeronautique," No. 1, January 1, 1910. In the author's book "Etude de la Stabilité l'Aeroplane," Paris, 1911, he has added to the drag-lift curve the curve called the "speed curve" which permits a direct checking of the speed of the airplane under all flying conditions. But the speed curve was plotted in the same quadrant as the drag-lift curve. Later, with the progressive development of aeronautical science, and with the continually increasing knowledge concerning engines and propellers, the author was brought to add the three other quadrants to the original quadrant, and thus was obtained the steady motion chart which is described in detail in this report.

This chart therefore permits one to read directly for a given airplane its horizontal speed at any altitude, its rate of climb at any altitude, its apparent inclination to the horizon at any moment, its ceiling, its propeller thrust, revolutions, efficiency, and power absorbed, that is, the complete set of quantities involved in the subject, and to follow the variations of all these quantities both for variable altitude and for variable throttle. The chart also permits one to follow the variation of all of the above quantities in flight as a function of the lift coefficient and of the speed.

The author also discusses in this report the interaction of the airplane and propeller through the slipstream and the question of the properties of the engine-propeller system and its dependence upon the properties of the engine considered alone and of the propeller considered alone will be found treated here in the general manner demanded by actual aeronautical engineering practice. There is also a discussion of the question of a standard atmosphere.

In Part IV the general theory of the steady motion of an airplane is developed, and after the basic equations have been established and the methods to be used described a general survey of the properties of airplane steady motion is given. A detailed discussion of climbing phenomena will be found and the general formulas established for the rate of climb and time of climb, which quantities under the simplest assumptions appear as hyperbolic functions of the ceiling. It is also shown as a consequence under what conditions one can drive the law of linear variation of the rate of climb with altitude as observed practically.

Report No. 98, entitled "Design of Wind Tunnels and Wind Tunnel Propellers," by E. P. Warner and F. H. Norton, Langley Memorial Aeronautical Laboratory.—This report is a continuation of National Advisory Committee for Aeronautics' Report No. 73. The variations in velocity and direction of the wind stream were studied by means of a recording air speed meter and a recording yawmeter. The work was carried on both in a 1-foot diameter model tunnel and in a 5-foot full-sized tunnel, and wherever possible comparison was made between them. It was found that placing radial vanes directly before the propeller in the exit cone increased the efficiency of the tunnel to a considerable extent and also gave a steadier flow. The placing of a honeycomb at the mouth of the experimental portion was of the greatest aid in straightening the air flow, but at the same time this decreased the efficiency of the tunnel. Several types of diffuser were tried in the return air stream, but only a slight improvement resulted in the steadiness of the flow. Some experiments were tried on the effect of the shape of exit cone and it was found that a straight cone in all cases gave the highest efficiency. The effect of placing a closed room about the model tunnel of the same proportional size as the building on the 5-foot tunnel decreased the speed for the same power 14½ per cent. Several spinners were placed about the propeller in the model tunnel in the hope that they would give increased efficiency and a steadier flow, but in no case was there any improvement.

Report No. 99, entitled "Accelerations in Flight," by F. H. Norton and E. T. Allen, Langley Memorial Aeronautical Laboratory.—This report deals with the accelerations obtained in flight on various airplanes at Langley Field. The instrument used in these tests was a recording accelerometer of a new type designed by the technical staff of the National Advisory Committee for Aeronautics. The instrument consists of a flat steel spring supported rigidly at one end so that the free end may be deflected by its own weight from its neutral position by any acceleration acting at right angles to the plane of the spring. This deflection is measured by a very light tilting mirror caused to rotate by the deflection of the spring, which reflected the beam of light onto a moving film. The motion of the spring is damped by a thin aluminum vane which rotates with the spring between the poles of an electric magnet. Records were taken on landings and take-offs, in loops, spins, spirals, and rolls. It was found that the loading in a fairly heavy landing reached a maximum of 5 g., in a loop it reached a maximum of about 3.7 g., in a spin a maximum of about 3 g., while in a roll it attained the value of 4.2 g., showing that this maneuver puts a greater strain on the airplane than any other. A JN-4H was pulled as suddenly as possible out of a dive at 50, 60, 70, and 80 miles an hour. The records show that the time elapsed between pulling the stick back and reaching the maximum acceleration was independent of the air speed and amounted to about 0.9 seconds. These accelerations are slightly lower than the theoretical accelerations that would be obtained if the airplane were suddenly turned to the angle of maximum lift. It was also found that an airplane had a certain definite period of vibration which could be excited by the engine, but which was not at all dependent upon it, as the vibrations were nearly as evident when the airplane was gliding with a dead stick. This period of vibration appeared to be inversely proportional to the weight of the airplane. It is concluded from these tests that in no reasonable stunting would the load in flying ever exceed a factor of four and one-half times the normal stress.

Report No. 100, entitled "Accelerometer Design," by E. P. Warner and F. H. Norton, Langley Memorial Aeronautical Laboratory.—In connection with the development of an accelerometer for measuring the loads on airplanes in free flight a study of the theory of such instruments has been made, and the results of this study are summarized in this report. Portion of the analysis deals particularly with the sources of error and with the limitations placed on the location of the instrument in the airplane. The discussion of the dynamics of the accelerometer includes a study of its theoretical motions and of the way in which they are affected by the natural period of vibration and by the damping, together with a report of some experiments on the effect of forced vibrations on the record.

Report No. 101, entitled "The Calculated Performance of Airplanes Equipped with Supercharging Engines," by E. C. Kemble, Harvard University.—In Part I of this report are presented the theoretical performance curves of an airplane engine equipped with a supercharging compressor. In predicting the gross power of a supercharging engine, the writer uses temperature and pressure correction factors based on experiments made at the Bureau of Standards (cf. Reports No. 45 and 46 of this committee). Means for estimating the temperature rise in the compressor are outlined. Since the compressor will be designed for a definite normal pressure ratio, the gross power output under normal conditions is easily computed when the intake temperature is known. In the case of a gear-driven compressor, the net power is obtained by subtracting the power absorbed by the compressor from the gross power. For use in determining the size and power absorption of the compressor needed in a given case, a formula for the variation of the volumetric efficiency of the motor with intake temperature and exhaust pressure is derived.

In calculating the power output of an engine fitted with a turbine-driven compressor, it is assumed that the back pressure created by the turbine is equal to the increase in the carbureter pressure produced by the blower.

A graphical method is outlined whereby performance curves for either type of engine-compressor unit at all speeds and altitudes may be laid out with the aid of assumed compressor characteristics. Comparative performance curves for a Liberty engine operating with a turbine-driven compressor, a gear-driven compressor, and without supercharging, are derived in an illustrative calculation. A discussion of the relative fuel consumption of supercharging and nonsupercharging engines when the carbureter is adjusted for maximum power is appended.

Part 2 of this report presents an estimation of the performance curves of an airplane fitter with a supercharging engine. If the heat leak from gas turbine and exhaust pipes to the water jackets is prevented, and the cooling system is kept under constant pressure, no additional radiator equipment should be required when a supercharging compressor is fitted to an airplane engine.

A method of estimating airplane performance at altitudes with the aid of curves for the "reduced" thrust horsepower available and required, is developed. This method simplifies the graphs of the thrust horsepower required at altitudes, and is particularly useful in comparing the performance of airplanes of different sizes, wing loadings, and propelling plant characteristics, which have the same lift and drift coefficients. Two methods for drawing curves of the thrust horsepower available with a variable pitch propeller are indicated.

In an illustrative example horizontal flight speed and maximum climbing speed curves are worked out for the Lepere two-seater fighter when equipped with supercharging and nonsupercharging engines, and with both fixed and variable pitch propellers. These are supplemented by altitude-time curves at maximum climbing rate and curves showing the relative fuel economy (i. e., relative distance traversed per pound of fuel) in horizontal flight with the engine wide open at all altitudes.

A supercharging installation suitable for commercial use is described, and it is shown that with the aid of the compressor a great saving in fuel and a considerable increase in carrying capacity can be effected simultaneously.

In an appendix the writer derives a theoretical formula for the correction of the thrust coefficient of an airscrew to offset the added resistance of the airplane due to the slip-stream effect.

Report No. 102, entitled "Performance of Liberty-12 Engine," by S. W. Sparrow and H. S. White, Bureau of Standards.—In cooperation with the Engineering Division of the Air Service of the United States Army, a Liberty-12 engine has been tested at the Bureau of Standards. The program of tests was planned to yield that information considered most important in determining the value of the engine for aviation. Full power runs were made at the ground, at 25,000 feet, and at several intermediate altitudes. To determine the mechanical efficiency of the engine, friction horsepower was measured at the ground and at 15,000 feet. As a basis for predicting engine performance with a propeller, a series of tests was made in which the dynamometer load and engine throttle were adjusted at each speed to simulate the engine load which would be imposed at that speed by a propeller operating under normal full load at 1,700 r. p. m.

Among the quantities calculated from the test measurements are: Brake horsepower; brake mean effective pressure; fuel consumption; mixture ratio; mechanical, thermal, and volumetric efficiency; and the percentage of the heat in the fuel appearing in the jacket water and in the exhaust. Jacket water temperature, oil temperature, manifold pressure, etc., are recorded to show the conditions under which the test was made.

The provision on the carburetor for adjusting the mixture ratio is shown to be inadequate at altitudes above 15,000 feet. Improving the mechanical efficiency of the engine and making such changes as will prevent the present decrease of volumetric efficiency with increase of altitude are suggested as two possibilities of improving the altitude performance of the engine.

Report No. 103, entitled "Performance of Hispano-Suiza 300-horsepower Engine," by S. W. Sparrow and H. S. White, Bureau of Standards.—A 300-horsepower Hispano-Suiza engine has been tested at the Bureau of Standards. The program of tests was planned in cooperation with the Engineering Division of the Air Service of the United States Army and was intended primarily to determine the characteristic performance of the engine at various altitudes. The engine was operated at the ground, at 25,000 feet, and at intermediate altitudes, both at full load and at loads similar to those that would be imposed upon the engine at various speeds by a propeller whose normal full-load speed was 1,800 r. p. m. Friction horsepower also was determined in order that the mechanical efficiency of the engine might be calculated.

From the test data there were computed the brake horsepower; brake mean effective pressure; specific fuel consumption; mixture ratio; jacket loss; exhaust loss; and thermal, mechanical, and volumetric efficiencies. A record of jacket water temperatures, oil temperatures, manifold pressures, etc., shows the conditions under which the test was made.

A brake horsepower of 352 was obtained at 2,200 r. p. m. and a maximum brake mean effective pressure of 128 pounds per square inch at about 1,600 r. p. m. The mechanical efficiency varied from 88 per cent to 83 per cent from speeds of 1,400 r. p. m. to 2,200 r. p. m., while the brake thermal efficiency, based on the lower calorific value of the fuel, was about 26 per cent over this speed range. At 1,800 r. p. m. and at an air density of 0.040 pounds per cubic foot the brake horsepower was about 42 per cent and the indicated horsepower about 47 per cent of that at the ground.

Report No. 104, entitled "Torsion of Wing Trusses at Diving Speeds," by Roy G. Miller, Langley Memorial Aeronautical Laboratory.—It is the purpose of this report to indicate what effect the distortion of a typical loaded wing truss will have upon the load distribution. The case of high angle of incidence may be dismissed immediately from consideration as the loads on the front and rear trusses are nearly balanced, and consequently there will be little angular distortion. A given angular distortion will have the maximum effect upon load distribution in the region of the angle of no-lift, because the slope of the lift curve is highest here, and it is here that the greatest angular distortion will occur, because the load on the front truss acts downward while the load on the rear truss acts upward.

The RAF-15 aerofoil was chosen as most typical of present-day wing sections and serves for an illustrative example. This was combined with the JN-4 wing truss, a biplane with overhanging upper wings. Starting with the assumption of a loading for a rigid structure, the wing truss and the deflections were calculated. The assumption of loading for the second trial was based upon the deflections as determined by the first trial. After several approximations it was possible to compute accurately the angular distortion at each panel point.

It was found that no great angular distortion occurred at panel points where there was adequate stagger bracing but that it was considerable at the tip of the overhanging portion of the upper wing. In conclusion, it may be said that it is not worth the added complication to correct the load distribution on the conventional biplane for wing truss distortion but that it would be highly advisable in the case of a monoplane, where the wires of the lift truss make an acute angle with the spars and where there can be nothing to take the place of stagger bracing. It would also be advisable in the case of the internally braced wing where the relative deflection is likely to be high.

Report No. 105, entitled "Angles of Attack and Air Speeds During Maneuvers," by E. P. Warner and F. H. Norton, Langley Memorial Aeronautical Laboratory.—In seeking further information as to the nature of maneuvers and as to the maneuverability characteristics of airplanes, continuous measurements of the angles of attack and air speeds at several points along the wings have been made during spins and loops. Very striking results have been obtained with reference to the rolling velocity and the distribution of load in spins and the variation of the angle of attack in loops, a surprisingly large range of angle being experienced during slow loops. This work is fully described in Technical Report No. 105.

Report No. 106, entitled "Turbulence in the Air Tubes of Radiators for Aircraft Engines," by S. R. Parsons, Bureau of Standards.—The existence of turbulent flow in the air passages of aircraft radiators and of variations in character or degree of turbulence with different types of construction is shown by the following experimental evidence:

(1) Pressure gradients along the air tubes are roughly proportional to the 1.7 power of the speed, which is characteristic of turbulent flow in long circular tubes of the same diameters.

(2) The surface cooling coefficients of radiators vary widely (0.002 to 0.007) when expressed as heat dissipated per unit time, per unit cooling surface, per unit temperature difference between air and water, and at a given average linear speed through the tubes.

(3) A fine wire electrically heated shows different cooling coefficients in the air tubes of different radiators.

(4) Temperature gradients in the air tubes are of the form characteristic of turbulent flow and fail to show sudden breaks such as might indicate a dividing line between regions of viscous and of turbulent flow.

The use of special devices for increasing turbulence may increase the heat transfer per unit surface for a given flow of air through the radiator but such practice decreases that flow for a given speed of flight and increases head resistance. At very low flying speeds, or in cases where the radiator is mounted in the nose of the fuselage, turbulence devices may sometimes be used to advantage, but every type known to the writer is detrimental to the general performance of the radiator at high speeds.

Report No. 107, entitled "A High-Speed Engine Pressure Indicator of the Balanced Diaphragm Type," by H. C. Dickinson and F. B. Newell, Bureau of Standards.—This report describes a pressure-measuring device especially adapted for use in mapping indicator diagrams of high-speed internal-combustion engines. The cards are obtained by a point-to-point method giving the average of a large number of engine cycles. The principle involved is the balancing of the engine cylinder pressure against a measured pressure on the opposite side of a metal diaphragm of negligible stiffness. In its application as an engine indicator the phase of the engine cycle to which a pressure measurement corresponds is selected by a timing device. The report discusses briefly the errors which must be avoided in the development of an indicator for light high-speed engines, where vibration is serious, and outlines the principles underlying the design of this instrument in order to be free of such errors. A detailed description of the instrument and accessories follows, together with operating directions. Specimen indicator diagrams are appended. The indicator has been used successfully at speeds up to 2,600 r. p. m., the highest speed engine available for trial. Its sensitivity is approximately that of a standard 6-inch dial gauge of the Bourbon tube type.

Report No. 108, entitled "Some Factors of Airplane Engine Performance," by Victor R. Gage, Bureau of Standards.—This report was prepared for the National Advisory Committee for Aeronautics and is based upon an analysis of a large number of airplane-engine tests made at the Bureau of Standards. This report contains the results of a search for fundamental relations between many variables of engine operation.

The data used came from over 100 groups of tests made upon several engines, primarily for military information. The types of engines were the Liberty 12 and three models of the Hispano-Suiza. The tests were made in the altitude chamber, where conditions simulated altitudes up to about 30,000 feet, with engine speeds ranging from 1,200 to 2,200 r. p. m. The compression ratios of the different engines ranged from under 5 to over 8 to 1. The data taken on the tests were exceptionally complete, including variations of pressure and temperature, besides the brake and friction torques, rates of fuel and air consumption, the jacket and exhaust heat losses.

With the Liberty engine operating at from 500 to 2,000 r. p. m. and with the Hispano-Suiza 300 horsepower operating from 1,400 to 2,200 r. p. m. it is found that the friction torque increases approximately as a linear function of engine speed at a given air density, and approximately as a linear function of density at a constant speed. This means that the friction horsepower increases approximately as the square of the speed. Actually the relation of torque and speed is such that the friction horsepower increases with speed raised to a power between the first and second, this power increasing with speed, approaching the square. The relation depends upon the engine design, the speed, and density of the air. Any statements as to the distribution of the friction losses are based upon incomplete evidence; the indications are, however, that the pumping losses are about half of the total friction.

There is no doubt that for a given process of combustion and at a constant speed the engine power is directly proportional to the weight of charge supplied; in other words, proportional to the charge density at the beginning of compression. As a consequence, if operating conditions are sensibly constant except for altitude, the engine power will be closely proportional to the air density. The volumetric efficiency increases with increase of air temperature at constant pressure, so that power does not decrease as fast as the air density when the temperature is raised, due to changes in vaporization and heat transfer.

Report No. 109, entitled "Experimental Research on Air Propellers, IV," by W. F. Durand and E. P. Lesley, Leland Stanford University.—This report is a continuation of a report on the same subject published in the fifth annual report. The research was conducted in the aerodynamical laboratory of Leland Stanford Junior University, and the report prepared under the direction of Dr. W. F. Durand and Prof. E. P. Lesley. The report states the results of investigations made upon numerous propeller models at the request of the subcommittee on aerodynamics, and contains valuable data to those interested in the design of air propellers. The discussion accompanying the report is necessarily somewhat brief, as the report is to be a part of the general report which will include a review of all the propeller investigations that have been conducted at Leland Stanford Junior University. This general report will be ready for publication with the seventh annual report of the committee.

Report No. 110, entitled "The Altitude Effect on Air Speed Indicators," by M. D. Hersey, Franklin L. Hunt, and Herbert N. Eaton, of the Bureau of Standards.—The object of this paper is to present the results of a theoretical and experimental study of the effect, on the performance of air speed indicators, of the different atmospheric conditions experienced at various altitudes. This matter has ordinarily been handled in a very simple way by following the PV^2 law and therefore correcting the observed reading of the air speed indicator by assuming the differential pressure developed to be directly proportional to the density and independent of any other physical property of the air.

The failure of certain types of air speed indicator to follow the simple PV^2 law at very low or very high speeds is already well recognized. For example, in the case of the Pitot tube, more accurate results can be deduced at high speeds by considering, in addition to the density of the air, its adiabatic compression. Again, in the case of the Venturi, a departure from the law of proportionality to the square of the speed has been recognized also at low speeds; consequently, as shown in this paper, a corresponding departure must be expected at a sufficiently high altitude, even without going to the lower speeds.

Thermodynamic formulas are available indicating the probable performance of Pitot tubes at high speeds where compressibility has to be considered, but all efforts which have thus far been made to arrive at a sufficiently complete formula for the Venturi tube by purely deductive reasoning have proven impracticable, on account of the difficulty of treating viscosity and turbulence. An adequate method of analysis for such problems has, however, been found in dimensional reasoning, for by this means the minimum number of experimental data needed for providing an absolutely complete inductive rather than deductive solution can be determined. In this way in the present paper the general form of the relation expressing the pressure generated in terms of the size of the instrument, its velocity through the air, and the density, viscosity, and elasticity of the medium has been derived. It is shown how all of the last five physical quantities can be reduced to only two independent variables, one involving the viscosity and the other the elasticity or compressibility of the air. Thus the equation becomes simply that of an ordinary surface in three coordinates. By such a surface or family of curves the experimental observations can be represented graphically.

The experiments reported all relate to Venturi tubes. They include water channel experiments to determine the degree of dynamical similarity attainable between air and water and to discover whether compressibility has to be taken into account; observations in a wind stream at reduced pressure, i. e., a vacuum wind tunnel, to determine the effect of density and viscosity; airplane observations as a practical check on the laboratory results; also ordinary wind tunnel tests.

The results by these various experimental methods are all in qualitative agreement and have been reduced to a common basis for quantitative comparison by the graphical method outlined above. At the conclusion of the paper a chart is given containing the most probable results available to date for the relative performance characteristics of five well-known types of air-speed nozzle both American and foreign, involving Venturi tube combinations. This chart provides the necessary experimental basis for computing altitude corrections.

This investigation is primarily of importance in connection with low speed or high altitude flight, for the altitude correction under the conditions of high-speed flight near sea level is sufficiently well given for most instruments by the simple PV^2 law.

LIST OF TECHNICAL NOTES ISSUED BY NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS DURING THE PAST YEAR.

No. 1. Notes on Longitudinal Stability and Balance. By Edward P. Warner.
2. Airplane Performance as Influenced by the Use of a Supercharged Engine. By George de Bothezat.
3. Notes on the Theory of the Accelerometer. By Edward P. Warner.
4. The Problem of the Helicopter. By Edward P. Warner.
5. Relation of Rib Spacing to Stress in Wing Planes. By A. F. Zahm.
6. Static Testing and Proposed Standard Specifications. By Edward P. Warner.
7. Notes on the Design of Supercharged and Overdimensioned Aircraft Motors. Translated from Technische Berichte, Vol. III, sec. 5. By Schwager.
8. Duralumin. By E. Unger and E. Schmidt. Translated from Technische Berichte, Vol. III, sec. 6.
9. Abstract of Theory of Lifting Surfaces, Part I. By L. Prandtl, 1918. Prepared by Paris office.
10. Abstract of Theory of Lifting Surfaces, Part II. By L. Prandtl, 1919. Prepared by Paris office.
11. The Problem of the Turbo-Compressor. By René Devillers.
12. Recent Efforts and Experiments in the Construction of Aviation Engines. Translated from Technische Berichte, Vol. III, sec. 5. By Schwager.
13. Soaring Flight in Guinea. By P. Idrac.
14. Increase in Maximum Pressures Produced by Preignition in Internal Combustion Engines. By S. W. Sparrow.
15. Tests of the Daimler D IVa Engine at a High Altitude Test Bench. By W. G. Noack. Translated from Technische Berichte, Vol. III, sec. 1.
16. Experience with Geared Propeller Drives for Aviation Engines. By Kutzbach.
17. Italian and French Experiments on Wind Tunnels. By W. K. Knight.
18. The Dynamometer Hub. By W. Stieber. Translated from Technische Berichte, Vol. III, sec. 6.
19. The Steadiness Factor in Engine Sets. By W. Margoulis.
20. Notes on Specifications for French Airplane Competitions. By W. Margoulis.
21. Drag or Negative Traction of Geared-Down Supporting Propellers in the Downward Vertical Glide of a Helicopter. By A. Toussaint.

RESEARCH PROGRAM AND ESTIMATES.

For the year 1922 the National Advisory Committee for Aeronautics has planned a comprehensive program of aeronautical research, which in the opinion of the committee covers the most important features that have to do with the further development of power plants for aircraft, aerodynamical improvements in aircraft, and new materials for aircraft.

Aerodynamical research.—The program of aerodynamical research is to be carried out with a view to the successful development of an airplane incorporating an internally braced wing structure, in order to eliminate practically all of the structural resistance, a factor which greatly handicaps the performance of the present type of airplane. The program includes research on the aerodynamical characteristics of airplane structures, including wings and fuselage, that are applicable to all-metal and internally braced types of construction. The research is to be carried on both in the wind tunnel and in free flight, so that by an examination of the performance of full-scale airplanes using the new type of construction as compared with the performance indicated by experiments on models in the wind tunnel further knowledge of the scale factor between model and full-scale performance may be obtained. The aerodynamical research program also contains provision for the determination of the variation of loading along the span for the thick wing sections which are likely to be used in all-metal, internally braced designs. This research will supply data very much needed in the design of these new types of machines, which, because of their structural permanency, their high load carrying capacity, and their high maximum speed, will undoubtedly be the airplanes of the future.

In free flight testing the program provides for the complete performance tests of airplanes to determine accurately the aerodynamical characteristics of the airplane, especially with reference to their stability, so that information may be obtained that will aid the designing engineer to predict accurately the performance of a new airplane. The outstanding feature of the airplane over other means of transportation is the high speed at which it is possible to fly, and it is appreciated that if the airplane is to become an important factor in transportation the efficient operating speed of the airplane must be materially increased. The program contemplates a research with the aim of obtaining those characteristics of an airplane that make for high operating speeds and a large speed range. The research program also includes the development of new instruments to aid in air navigation and new instruments to be used in the accurate performance tests of airplanes. Experimental research for the determination of the pressure distribution over the surface of an airplane and its controls is provided for, and likewise the distribution over the surface of an airship and its controlling members. The data obtained will enable the engineer to design the structure more accurately, as he will know definitely the forces acting on the structure under all operating conditions.

The committee asks for the sum of $215,000 to carry out research work in connection with aerodynamics.

Materials research.—The subcommittee on materials for aircraft has brought to the attention of the main committee the fact that since the armistice all-metal construction of airplanes has received the careful attention of airplane manufacturers in Europe, with the result that apparently successful models have been constructed. The war was fought with machines constructed of wood, which from many standpoints is most unsatisfactory, especially from a constructional point of view. Wood has a nonhomogeneous structure, is uncertain in strength and weight, warps and cracks, and weakens rapidly when exposed to moisture. The advantages of using metal construction for airplanes are apparent, as the metal does not splinter, is more homogeneous, and the properties of the material are much better known and can be relied upon. Metal also can be produced in large quantities, and it is felt that in the future all large airplanes must necessarily be constructed of metal. The program for the year 1922 provides for experimental research in the development of light alloys of aluminum and magnesium base for use in aircraft. Aluminum alloys are now being produced that have the same physical properties as mild steel, with one-third the weight, and the program further provides for the development of light alloys, especially in connection with their heat treatment and method of fabrication. The physical properties of light alloys are not accurately known, especially with reference to the fatigue resistance properties of the material, and the program provides for experimental research covering this phase of the problem.

This research will be carried on under the direction of the subcommittee on materials for aircraft and will be conducted by private corporations, and also by the Navy and the Army Air Service interested in the production of the material.

Aeronautic Power Plant Research.—The future progress of civil and military aviation is so fundamentally dependent upon the development of highly reliable and economical power plants that the problems connected with increasing these features of aircraft power-plant operation are considered to be among the most important at present demanding the attention of aeronautical research laboratories. The capital investment, maintenance charges, and fuel cost are all very high in the case of the present aircraft engine and must be materially lowered before the cost of power can be reduced to figures which will make possible the extensive development of commercial and pleasure aviation. The shortage and high cost of aviation gasoline, as well as the complication and relative unreliability of the carburetion and ignition systems, emphatically indicate the necessity for the development of an engine which will operate by direct hydraulic injection of low-grade fuel, with compression sufficiently high to ensure automatic ignition. The committee feel that the early development of an engine of this type is one of the most important technical problems involved in the growth of commercial aviation in this country, and the research program for the coming year provides for extensive work in this field.

Perhaps the next most important power-plant problem is the elimination of the water-cooling system, it being at present agreed that the added complication, weight, and head resistance of the indirect cooling system are to be considered as fundamentally unecessary handicaps to power-plant performance and reliability, and that these must ultimately be overcome. Although considerable research has been conducted upon the direct cooling of engine cylinders, the results must be considered as merely indicative, and much yet remains to be done before the successful and economical direct cooling of aircraft engines will become possible, especially with cylinders of large dimensions and high specific power output. The program covers the requirements in this problem in a comprehensive manner.

The perfecting of superchargers, or other means for securing the maximum power output of aviation engines at all altitudes, is considered to be one of the vital problems, and the program provides for a continuation of the research examination of the many possibilities offered in this field. All of those applications of commercial, military, and pleasure aviation which depend upon high speed for their successful fulfillment can only reach their complete development through flying at high altitudes with power plants capable of maintaining a high percentage of their maximum power output and equipped with variable pitch or variable characteristic propellers.

The program also contains provision for continuing the performance tests of new types and improved forms of aircraft engines in the altitude chamber; the performance tests of all engine accessories such as carburetors, ignition appliances, lubrication appliances, and cooling appliances, including radiators in the form of complete units and also sample cores; and the study of other interesting developments of important engine details, such as pistons, valves, etc.

The estimate of the committee to cover the necessary power-plant research for the fiscal year of 1922 is $131,600.

In connection with the research on powerplant and aerodynamic problems at Langley Field the committee maintains shop facilities at the Langley Memorial Aeronautical Laboratory, the estimated expenses of which for the year 1922 are $58,666.

Summary.—The committee's estimates for the prosecution of the programs of aerodynamical research, materials research, and aeronautic power plant research, as outlined above, total $405,266. To this should be added, under the committee on publications and intelligence, the work of the Office of Aeronautical Intelligence in the collection, classification, and dissemination of scientific and technical reports and data on aeronautics, requiring the sum of \$59,800, and for the general administration of the Washington office with its present personnel, the sum of \$24,540, making the total estimates for the fiscal year 1922, \$489,906. The appropriation for the fiscal year 1920 was \$175,000, and for the present fiscal year the appropriation was increased to \$200,000. The continuous prosecution of a well organized plan of scientific research is an essential factor in the development of the science of aeronautics, and the increased estimates of the committee for the fiscal year 1922 are made necessary by the increasing relative importance of scientific research in the general scheme of a national aviation policy, as outlined in the closing section of this report.

FINANCIAL REPORT.

The appropriation for the National Advisory Committee for Aeronautics for the fiscal year 1920, as carried in the sundry civil appropriation act approved July 19, 1919, was \$175,000, under which the committee reports expenditures and obligations during the year amounting to \$174,296.75, itemized as follows:

Salaries (including engineering staff)	\$65, 299. 58
Wages	23, 559. 51
Equipment	12, 539. 57
Supplies	19, 493. 22
Transportation and communication	1, 281. 42
Travel	6, 066. 58
Special investigations and reports	40, 716. 39
Construction of buildings	5, 840. 50
Total	174, 296. 75

CONCLUSION.

A NATIONAL AVIATION POLICY.

Aviation activities during the war were concentrated on the development and production of military aircraft. The selection of the landing fields that were established was necessarily guided by military considerations. The close of the war found us with an aeronautic industry at the stage of quantity production, a large amount of aircraft material on hand, a large number of trained flyers, and a few scattered landing fields. In brief, all this constituted the national inheritance from the investment of hundreds of millions of dollars for the hurried development of military aviation during the war. In the two years that have elapsed since the armistice a good proportion of the aircraft material has become obsolete. A majority of the technical personnel and trained flyers have returned to civil life and to pursuits not connected with aviation. The great aircraft industry has almost disappeared, and some of the landing fields have been surrendered. Those that have been retained really represent one of the most valuable physical assets salvaged from our aircraft expenditures.

As a nation we must seek to realize clearly the lessons of the war and to profit by them, Our efforts in the development of a military air force and the organization of an aircraft industry during the war were remarkable accomplishments in themselves, but the handicap of a negligible industry at the outbreak of the war and the general lack of technical knowledge were too great to be satisfactorily overcome in a short time, regardless of the money available. It is now our clear duty to take to heart the lessons and mistakes of the war period and to shape a national aviation policy that will be productive of the greatest possible structural development consistent with prudent economy.

The Government agencies actively concerned with the use of aviation at the present time are the Army Air Service, the Naval Air Service, and the Postal Air Service. Other agencies such as the Geological Survey, the Coast and Geodetic Survey, the Forest Service, etc., have more or less need for the use of aircraft in their work. The National Advisory Committee for Aeronautics is concerned not so much with the promotion of the uses of aviation as with the scientific study of the problems involved and the technical development of the art for the benefit of governmental agencies and of the public generally, but the committee believes that the use of aircraft by the various governmental agencies should be encouraged where its efficient use is practicable; also that the general development of aviation for all purposes should be encouraged by the National Government. The faithful performance of our national duties in these respects becomes compelling from considerations of wise military preparedness.

In time of war aviation will probably be the first arm of offense and defense to come into action. For this there must be an established industry and a trained and active air service. Aerial supremacy at the outset of hostilities would be a tremendous military advantage. Ultimate victory would unquestionably incline to the side that could establish and maintain supremacy in the air. Huge expenditures of money in time of danger and frantic efforts to train personnel and to develop hastily an aircraft industry from almost nothing will not do. There must be wise preparedness; there must be in healthy existence at least a nucleus of an industry capable of adequate expansion; there must exist civil and commercial aeronautical activities in all parts of the country which would be the main support of the industry in time of peace. In pure self-defense the Government must encourage the development of commercial aviation. The alternative proposition is the creation and maintenance of a powerful standing military air service relatively self-reliant in time of war. We can not, however, afford the expense which such a policy would entail, and there would be no advantage in time of peace from such expenditures comparable in any way to the advantages to be gained from the support of civil aviation. We should maintain an active air service in time of peace, which should possess inherent strength and be something more than a mere nucleus for expansion in time of war. In the final analysis, however, we must depend upon civil aviation to furnish a military reserve force. The remarkable accomplishments of our Motor Transport Service during the war were only made possible by the healthy condition of our automobile industry. The problem is to place our aircraft industry in a healthy condition, and to do this we must enter without delay upon a sane, sound policy for the development of civil aviation. The relative cost of fostering an organized plan to develop commercial aviation would be much less than the waste that would inevitably result from unprepared entry into war. Aside from military considerations, the fostering of commercial aviation would in time yield adequate returns in itself in the form of promoting and strengthening our means of transportation, advancing the progress of civilization, and increasing the national wealth.

Aviation is a distinct advance in civilization given to the world by America. The importance of the development of aviation from a military standpoint was not fully appreciated before the war, with the consequent lack of encouragement of the development of the art. The handicap of years of comparative inactivity has not yet been overcome. We can not afford to repeat the mistakes of the past. We can not go backward, but must go forward with the intelligent development of aviation in all its branches.

Aviation is still in its infancy; its possibilities, while unknown, appeal to the imagination. The forced development during the war and some of the experimental development since have not been based upon scientific research and sound scientific principles that make for substantial progress. Technical training is necessary, including education in advanced aeronautical engineering, so is the actual training of a large body of men in the technique of the care and operation of aircraft. Broadly speaking, scientific research, technical training, and commercial aviation constitute, or should constitute, the backbone of a national policy.

Reducing to definite form the steps which in the opinion of the National Advisory Committee for Aeronautics are wise and timely, the committee, after careful consideration of all the facts within its knowledge, submits the following specific recommendations:

First. That legislation be enacted providing for Federal regulation of commercial air navigation, licensing of pilots, aircraft, landing fields, etc. At the present time there is no authority of law for any executive agency of the Government to perform such duties. The committee believes that for the executive administration of these new duties of government there should be established in the Department of Commerce a bureau of aeronautics in charge of a commissioner of air navigation, who should also become a member of the National Advisory Committee for Aeronautics. Acting in cooperation with the War, Navy, and Post Office Departments, the committee has prepared a draft of legislation which appears in full in a preceding section of this report under the heading "Organization of Governmental Activities in Aeronautics," and which it strongly recommends for the immediate consideration of Congress. In this connection the committee recommends also the adoption of a policy of Federal aid to the States in the establishment of landing fields for general use in every State in the Union.

Second. That the Congress authorize an American airplane competition in order to stimulate private endeavor in the development of new and improved designs of aircraft, the competition to be under the direction of the National Advisory Committee for Aeronautics, the entries of the successful competitors to be purchased by the Government at a predetermined and announced figure and made available for the use of the Postal Air Service.

Third. That adequate appropriations be made for the military and naval air services in order to permit the continuous development of these exceedingly important arms of the two services, and to enable them to place orders in such a way as to maintain a nucleus of an aircraft industry capable of sufficient expansion to meet military needs in time of emergency. The committee considers this absolutely essential.

Fourth. That the control of naval activities in aeronautics be centralized under a naval bureau of aeronautics in charge of a director of naval aviation. At the present time responsibility for the development of naval aviation is divided between the Office of Operations and the numerous bureaus of the Navy Department. This basis of organization does not permit full cooperation with the Army Air Service or with other governmental and civil agencies, nor does it, in the opinion of the committee, promote the efficient development of aviation within the Navy.

Fifth. That the Air Mail Service of the Post Office Department be further extended and developed. This service has given the best demonstration of the practicability of the use of aircraft for civil purposes. It has been seriously handicapped by inability to secure suitable airplanes adapted to its work. The question is one of design, which should be handled by the industry. The remedy lies in the development of the industry, which can only be brought about at an early date by the indorsement and prosecution by the Government of a constructive, comprehensive policy.

Sixth. That the Congress approve the program of scientific research in aeronautics formulated by the committee and provide for the enlarged facilities necessary for its prosecution. Continuous scientific research is necessary for the real advancement of the science of aeronautics. The number and importance of problems requiring solution have increased greatly with the general development of aircraft, and the development of airplanes of all-metal construction will require a large increase in the aerodynamic research and engineering experimentation conducted by the committee at the Langley Memorial Aeronautical Laboratory at Langley Field, Va.

Respectfully submitted,

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
CHARLES D. WALCOTT, *Chairman.*