TWENTY-SIXTH ANNUAL REPORT

OF THE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

1940

INCLUDING TECHNICAL REPORTS
NOS. 681 TO 703

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1941

TECHNICAL REPORTS

LETTER OF TRANSMITTAL

To the Congress of the United States:

In compliance with the provisions of the act of March 3, 1915, establishing the National Advisory Committee for Aeronautics, I transmit herewith the Twenty-sixth Annual Report of the Committee covering the fiscal year ended June 30, 1940.

Franklin D. Roosevelt.

The White House,
January 13, 1941.

LETTER OF SUBMITTAL

National Advisory Committee for Aeronautics,
Navy Building, Washington, D. C.,
December 27, 1940.

Mr. President:

In compliance with the provisions of the Act of Congress approved March 3, 1915 (U. S. C., title 50, sec. 153), I have the honor to submit herewith the Twenty-Sixth Annual Report of the National Advisory Committee for Aeronautics covering the fiscal year 1940.

As results of the Committee's investigations are in an increasing measure of a secret or confidential character, this annual report, out of consideration for the public interest, does not disclose the full scope of the Committee's work.

One of the essential requisites for retaining leadership in the technical development of aircraft is more and more research. Technical progress is so rapid and the advantages of new improvements so great that research in time of emergency is of even greater relative importance than in time of peace.

The Committee has organized its research activities to answer primarily the research needs of the military services, including special and direct collaboration with aircraft manufacturers on matters looking to improvement in the design and performance of American aircraft.

With increased research facilities at Langley Field and at Moffett Field, California, there is a definite acceleration of progress in improving aircraft performance. Recent authorization of an aircraft engine research laboratory, which will be constructed at Cleveland, Ohio, will further strengthen the Committee in its efforts to keep the United States foremost in the technical development of aircraft.

Respectfully submitted.

Vannevar Bush, *Chairman.*

The President,
The White House, Washington, D. C.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

HEADQUARTERS, NAVY BUILDING, WASHINGTON, D. C.

Created by act of Congress approved March 3, 1915, for the supervision and direction of the scientific study of the problems of flight (U. S. Code, Title 50, Sec. 151). Its membership was increased to 15 by act approved March 2, 1929. The members are appointed by the President, and serve as such without compensation.

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S. PAUL JOHNSTON, *Coordinator of Research*

JOHN F. VICTORY, *Secretary*

HENRY J. E. REID, *Engineer-in-Charge, Langley Memorial Aeronautical Laboratory, Langley Field, Va.*

SMITH J. DEFRANCE, *Engineer-in-Charge, Ames Aeronautical Laboratory, Moffett Field, Calif.*

TECHNICAL COMMITTEES

AERODYNAMICS
POWER PLANTS FOR AIRCRAFT
AIRCRAFT MATERIALS
AIRCRAFT STRUCTURES
AIRCRAFT ACCIDENTS
INVENTIONS AND DESIGNS

Coordination of Research Needs of Military and Civil Aviation

Preparation of Research Programs

Allocation of Problems

Prevention of Duplication

Consideration of Inventions

LANGLEY MEMORIAL AERONAUTICAL LABORATORY

LANGLEY FIELD, VA.

AMES AERONAUTICAL LABORATORY

MOFFETT FIELD, CALIF.

Conduct, under unified control, for all agencies, of scientific research on the fundamental problems of flight.

OFFICE OF AERONAUTICAL INTELLIGENCE

WASHINGTON, D. C.

Collection, classification, compilation, and dissemination of scientific and technical information on aeronautics

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Meeting, April 18, 1940

Left to right, seated: Dr. F. W. Reichelderfer, Chief, United States Weather Bureau; Clinton M. Hester, Administrator, Civil Aeronautics Authority; Robert H. Hinckley, Assistant Secretary of Commerce; Rear Admiral John H. Towers, Chief, Bureau of Aeronautics, Navy Department; Major General Henry H. Arnold, Deputy Chief of Staff, Chief of the Air Corps, War Department; Dr. Orville Wright; Dr. Robert E. Doherty; Dr. Vannevar Bush, Chairman; Dr. George J. Mead, Vice Chairman; Dr. Charles G. Abbot, Secretary, Smithsonian Institution; Dr. Edward Warner; Dr. L. J. Briggs, Director, National Bureau of Standards; Major General George H. Brett, Acting Chief of the Air Corps, War Department; Captain Sydney M. Kraus, Bureau of Aeronautics, Navy Department; Dr. Jerome C. Hunsaker. *Standing:* S. Paul Johnston, Coordinator of Research; Dr. George W. Lewis, Director of Aeronautical Research; John F. Victory, Secretary.

TWENTY-SIXTH ANNUAL REPORT

OF THE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON, D. C., *November 26, 1940.*

TO THE CONGRESS OF THE UNITED STATES:

In accordance with the act of Congress approved March 3, 1915 (U. S. C., title 50, sec. 151), which established the National Advisory Committee for Aeronautics, the Committee submits herewith its Twenty-sixth Annual Report for the fiscal year 1940.

The Committee has found it necessary in the national interests to withhold from public distribution the detailed results of its researches. Therefore, until world conditions change, this and succeeding Annual Reports will deal only in general terms with the results accomplished.

This report describes in general terms many investigations now in progress, each of which may be expected to add something in speed, maneuverability, load capacity, range, safety, or economy, to the merit of American airplanes. Several of these investigations already definitely promise large advances. The Committee has been called upon to investigate problems of immediate importance to the Army and Navy involving the means of obtaining the quickest and greatest possible improvements in the performance of aircraft. The Committee's function therein is limited to questions of aeronautics. Designing adapted to meet military requirements lies in the province of the military services.

The most significant developments of the past year in relation to the Committee's work may be briefly summarized as follows:

1. A rapid trend for the improvement of aircraft performance growing out of the war in Europe and reflected in the demands upon the Committee by the Army and Navy for basic new data essential for the design of aircraft of ever-increasing performance.
2. Great expansion in aircraft production requiring the development of quantity production methods.
3. An extensive Army and Navy experimental program for the production of new types of aircraft to meet constantly increasing performance requirements.
4. The authorization by law of an aircraft engine-research laboratory which will be a third major research station for the Committee.

The trend in aircraft development.—The outstanding trend produced by the present war in Europe is toward the development of aircraft having higher speeds and greatly increased armor and armament.

To meet the requirements of increased air speed, special research studies have been made of airplanes in current production and also of experimental types. These studies have included investigations in the full-scale wind tunnel in the Committee's Langley Field laboratory and also the study of the drag of component parts.

The demand for increased speed has resulted in the need for much greater horsepower. Whereas pursuit airplanes of a year ago were equipped with engines of 1,000 horsepower, they are now being designed with single engines of 2,000 horsepower. The trends toward increased speed and higher ceiling, toward larger and heavier engines, toward increased armor and armament, necessitate larger and much heavier types of airplanes. This condition has established a definite trend toward higher wing loadings.

Because of the higher flying speeds demanded by the Army and Navy, the Committee has given special study to the important subject of compressibility shock encountered at high speeds. With the speeds now attainable, it is essential that care be taken to design all parts of the airplane structure so as to prevent velocities approaching the speed of sound from occurring at any point. The 500-mile-per-hour wind tunnel at the Committee's Langley Field laboratory has proved of great value in the study of this problem.

With increased wing loading, it has become necessary to extend the study of improved high-lift devices and of lateral-control devices other than ailerons so as to permit the development of a full-span flap. The trend toward higher speeds has brought many attendant problems, such as the need for improved methods of cowling and cooling of engines, the design of wing ducts, and of ducts for the cooling of engine auxiliaries. High operating speeds also make it necessary to give special attention to the design of air scoops and ventilators.

Relation of research to aircraft production program.—Of more immediate interest to the Army, the Navy, and the Council of National Defense is: What can the Committee's research organization do to improve the performance of the aircraft that are to be procured under the current aircraft production program? The Committee's Langley Field laboratory is engaged in critical studies of many types of aircraft proposed for production, using either air-cooled or liquid-cooled engines. The Committee is rendering every possible assistance to the Army and Navy to increase to the limit attainable the speeds of airplanes going into production, so that they will be of maximum value for military use.

Relation of research to new types of aircraft.—The national defense demands that improved types of airplanes should be developed as rapidly as possible, since other nations are continually making improvements, and we must not fall behind. Basic research, therefore, cannot be discontinued, no matter how pressing may be the design problems of the moment. It is essential that research laboratories produce a constant flow of new knowledge that will permit the design of airplanes of ever-increasing performance to meet the requirements of the Army and Navy. The Army and Navy have maintained the closest contact with the Committee's laboratories and have taken the fullest advantage of the Committee's facilities in the solution of their pressing problems. The Army Air Corps has appointed at the Committee's laboratory at Langley Field a liaison officer, and the Navy's liaison officer, having headquarters in Washington, visits Langley Field at regular and frequent intervals.

Expansion of research facilities.—The Committee has two major research laboratories, one at Langley Field, Va., known as the Langley Memorial Aeronautical Laboratory, and the other at Moffett Field, Calif., known as the Ames Aeronautical Laboratory. The latter was authorized by act of Congress approved August 9, 1939. The flight research laboratory was the first unit of the Ames Laboratory to get into operation. Other units will be placed in operation as rapidly as their construction is completed.

Both the Langley Memorial Aeronautical Laboratory and the Ames Aeronautical Laboratory are devoted chiefly to aerodynamics, although the Committee has at Langley Field a structures research laboratory, a hydrodynamics research laboratory and a small engine research laboratory. To remedy the deficiency in engine research facilities the Congress by act approved June 26, 1940, authorized the construction of a third major research station for the Committee which is to be an aircraft engine research laboratory. The site finally selected by the Committee under authority of that act is adjoining the municipal airport at Cleveland, Ohio, and the Committee is proceeding with its construction. The details of this action are set forth in Part II of this report.

The Committee highly appreciates the support of the President and the Congress in providing these two additional research stations during the past 2 years. They were indispensable to strengthen research and to accelerate aeronautical progress in the United States. They will prove of great value to the national defense, and it is confidently predicted that their economic value to the Nation will more than offset their cost.

Responsibilities of the Committee.—Under the law it is the duty of the National Advisory Committee for Aeronautics to "supervise and direct the scientific study of the problems of flight, with a view to their practical solution" and also to "direct and conduct research and experiment in aeronautics."

To assist in the discharge of these duties and in the determination of present and future research needs of aeronautics, civil and military, the Committee has established standing technical subcommittees on aerodynamics, power plants for aircraft, aircraft materials, and aircraft structures. The subcommittees are composed of specially qualified representatives of the governmental agencies concerned and of experts from private life. The members of the subcommittees, like the members of the main Committee, serve as such without compensation.

The subcommittees prepare and recommend research programs. Most of the problems recommended for investigation are assigned to the Committee's laboratories. Some problems are assigned to the National Bureau of Standards, when it is to the advantage of the Government to do so in order effectively to utilize existing governmental facilities. Problems are also assigned to universities and technical schools. This policy, the Committee believes, makes effective use of university research facilities, stimulates and coordinates aeronautical research, and also has the advantage of training research personnel.

The Committee regards it as its duty to forecast the trend of aeronautical development, civil and military; to anticipate the research problems that will arise; to design and provide research equipment as needed to solve the problems; to conduct the more fundamental scientific investigations in its own laboratories; and to transmit the results directly to the governmental agencies and to those units of the aircraft industry that are most concerned.

Relation of research to commercial air transportation and to private flying.—The United States has an outstanding place in commercial and private aviation. The current civilian pilot training program of the Civil Aeronautics Administration will, without doubt, serve further to stimulate private flying in the United States and to give it an impetus which will have far-reaching results in the years to come. The progress in civil and commercial aviation in the United States has been due to a combination of causes. The responsible Government agencies have provided indispensable assistance in the encouragement and regulation of civil and commercial aviation. The American aircraft industry has been keenly alert to improve the design and quality of the aircraft used. The air transport lines have shown initiative and efficiency in operation and have been thorough in their efforts to eliminate accidents and the causes of accidents. The results of the Committee's scientific researches, even though now initiated for the most part to meet military needs, are generally applicable to civil aircraft and are in no small measure responsible for their high efficiency and safety.

In the present emergency when the needs of national defense are predominant, ways and means should nevertheless be found to sustain and continue the advance of commercial aeronautics. Air mail and passenger transportation have already become of great value to the Nation and in time of war would be essential to our industrial effectiveness.

PART I

REPORTS OF TECHNICAL COMMITTEES

In order to carry out effectively its functions of supervision, conduct, and coordination of research, the National Advisory Committee for Aeronautics has established a group of technical committees and subcommittees. These committees prepare and recommend to the main Committee programs of research to be conducted in their respective fields. As a result of the nature of their organization, which includes representation from various governmental agencies concerned with aeronautics, together with experts from civil life, the technical committees act as coordinating agencies, providing effectively for the interchange of information and ideas and for the prevention of duplication.

In addition to its standing committees and subcommittees, it is the policy of the National Advisory Committee for Aeronautics to establish from time to time special technical subcommittees for the study of particular problems as they arise.

The Committee has four principal technical committees—the Committee on Aerodynamics, the Committee on Power Plants for Aircraft, the Committee on Aircraft Materials, and the Committee on Aircraft Structures. Under these committees there are nine standing subcommittees and six special technical subcommittees. The membership of these groups is listed in Part II.

The Committees on Aerodynamics and Power Plants for Aircraft recommend the programs for, and keep in touch with research in these two major fields conducted at the Committee's laboratories and the special investigations conducted at educational institutions and at the National Bureau of Standards. Most of the research under the cognizance of the Committee on Aircraft Materials and a large part of the research under the cognizance of the Committee on Aircraft Structures are conducted at the National Bureau of Standards. In addition, a number of structural investigations, including in particular investigations of a theoretical nature, are conducted at the Committee's laboratory at Langley Field and at educational institutions.

The four technical committees recommend to the main Committee the investigations in their respective fields to be undertaken by educational and scientific institutions under contract with the National Advisory Committee for Aeronautics, and keep in touch with the progress of the work and the results obtained. The experimental investigations in aerodynamics, aircraft power plants, aircraft materials, and aircraft structures undertaken by the Army Air Corps, the Bureau of Aeronautics of the Navy, the National Bureau of Standards, and other Government agencies are reported to these four committees.

REPORT OF COMMITTEE ON AERODYNAMICS

LANGLEY MEMORIAL AERONAUTICAL LABORATORY

LANDING SPEED AND SPEED RANGE

Continual increase in the wing loadings of modern high-performance airplanes has necessitated continued research directed toward the development of more efficient high-lift devices. The Committee, as in the past several years, has devoted considerable effort to the investigation of the more promising types of trailing-edge flaps.

The investigation of wings with slotted flaps in the 7- by 10-foot wind tunnel has been continued. The results of the tests of the 30-percent thick airfoil with slotted flaps, mentioned in last year's report, have now been published in Technical Note No. 755.

The NACA 23012 and 23021 airfoils have been tested with two sizes of split flaps of airfoil section that were arranged to move backward as well as downward. These flaps were tested over a large range of positions and deflections, both with and without a gap or a slot between the nose of the flap and the airfoil.

Tests have also been made of a small-chord model with a Gwinn and a plain flap. These results are reported in Technical Note No. 763.

CONTROL AND CONTROLLABILITY

The Committee's flight investigation of the flying qualities of various airplanes, which has been actively continued during the past year, has resulted in the accumulation of a considerable fund of data on the control characteristics of present-day airplanes ranging in size from the smallest training airplane to the largest transports and bombers. It has been possible through analysis of these data to specify satisfactory lateral control in the form of an easily measured criterion. Analysis of the data has also shown the influence of various design features on the observed airplane characteristics and has yielded a method by which aileron effectiveness can be quickly predicted from a knowledge of airplane dimensions.

As a preliminary step in evaluating the requirements of the elevator control, an analysis is being made of the use of elevators in landing, the principal limiting design condition for the elevator control. Recorded data obtained in a great number of actual landings of airplanes of various types are being correlated with data obtained under comparable conditions at altitude.

The investigation in the 7- by 10-foot wind tunnel of lateral-control devices has been continued. The data on spoiler, deflector, and slot devices have been analyzed.

STABILITY

The flight investigation of the flying qualities of numerous airplanes has contributed a considerable fund of information on the stability characteristics of existing modern airplanes. During the past year, analyses of these data, particularly those relating to longitudinal stability, have been made with two objectives in mind. One objective was to determine the degree of correlation that could be obtained between quantitative values measured during flight tests and the pilot's impression of the suitability of the airplane for the performance of the normal functions of the machine. It was found that the measured characteristics could be correlated with the pilot's impression when the control movement and the corresponding control force required to maneuver the airplane were taken as a criterion of the practical stability. On this basis, satisfactory and unsatisfactory airplanes were properly rated in terms of their measured characteristics. Another consideration was the determination of the effect of various design features on the observed stability characteristics. In this connection it is noteworthy that the fuselage and the engine nacelle moments were among the principal destabilizing agents. Predictions of stability that ignore these factors are greatly in error, but it is possible by semiempirical means to take into account the destabilizing effect of these bodies for the prediction of power-off longitudinal stability.

As a result of independent tests of many airplanes in the full-scale wind tunnel, a large amount of data has been accumulated relating to the effects of the propeller slipstream on the longitudinal stability and control of airplanes. These data are being reviewed and correlated to show some of the more important consistent effects of the slipstream.

To determine the influence of the different airplane parts on the over-all characteristics of the airplane, a study has been completed showing the effects of dihedral and fin area on aileron and rudder control. Of particular interest is the relatively large effect of the vertical-fin area on the aileron effectiveness and operating force.

The investigation of the aerodynamic characteristics of tail surfaces is being continued by the measurements of section characteristics in the 4- by 6-foot wind tunnel. The first phase of the work, pressure-distribution tests of an NACA 0009 airfoil with three sizes of unbalanced movable surfaces, each with three sizes of tabs, has been completed. These data are presented in Technical Notes Nos. 734, 759, and 761. From a further analysis of the results, charts of the principal design parameters have been prepared to enable the designer to determine the aerodynamic characteristics of any unbalanced movable surface. The agreement between the experimentally determined and the theoretical values of the parameters is good except for the prediction of hinge-moment coefficients for narrow-chord flaps. The analysis also indicates that the largest stick forces should be expected with flap-airfoil chord ratios from 0.40 to 0.60. The effect of gap between the unbalanced flap and the fixed surface has been investigated. The tests to determine the effects of flap nose shape and aerodynamic balance with and without gaps are being continued.

Research on the influence of the design variables on lateral-stability characteristics has been continued in the 7- by 10-foot wind tunnel. Large changes in tail effectiveness with changes in the vertical position of the wing on the fuselage have been noted. The vertical-tail effectiveness was decreased when the wing was in a high position on the fuselage and was increased when the wing was in a low position. Flap deflection increased the tail effectiveness regardless of wing position.

This lateral-stability investigation is being extended to include the effects of fore-and-aft position of the wing on the fuselage.

During the year, investigation in the 7- by 10-foot wind tunnel of the power-on stability characteristics of models of present-day airplanes was begun. A technique for reproducing in this tunnel the thrust of the full-scale airplane over the entire flight range has been developed, and complete tests of a model of a low-wing pursuit-type airplane have been made.

In stability studies, as in gust research, the growth of lift on the wing following a sudden change of conditions is of extreme importance and has been the subject of some study. The work on this subject is presented in Technical Report No. 681. A further study has been made dealing with the effect of a sudden change of angle of attack on the lift of the horizontal tail, taking into account the variation in the downwash angle at the flow over the wing.

The study of lateral stability, as affected by the automatic pilot, has been completed.

During the past year the new 12-foot free-flight wind tunnel has been used for the investigation of the stability and the control of five airplane designs.

The models are flown both without power and when powered by small electric motors.

SPINNING

The 15-foot free-spinning wind tunnel has been used in the investigation of spinning characteristics of new airplane designs. In all, 23 models were tested. The greatest emphasis was placed on the determination of the general characteristics of the spins of large multiengine airplanes.

The analysis of the data from the spin tests of a low-wing monoplane with various wing and tail arrangements is now practically complete. The test work has been extended to cover the case of a high-wing monoplane. In general, it appears that the high-wing position has a very favorable effect on the recovery characteristics as compared with the low-wing position.

Flight and wind-tunnel spin tests of a low-wing monoplane have been completed and the agreement shown, although good, is not completely satisfactory.

STALLING

A part of the investigation of flying qualities previously mentioned consisted of observations of the stalling characteristics of each airplane tested in flight. These studies of stalling have provided important information on practical design considerations affecting the stall and have, in particular, emphasized the interrelation of the stability of the airplane at low speeds with the apparent character of the actual stall. At the request of the Civil Aeronautics Authority, particular attention during the past year has been devoted to a study of means for improving the stalling characteristics of several very light airplanes. These airplanes are used almost exclusively by private owners or for preliminary flight training. The investigations have been directed toward developing flying characteristics that would prevent the complete stall from developing regardless of the manipulation of the controls or the power condition, and at the same time to retain adequate control by the pilot for any normal aerial or ground maneuver. The possibility of spinning could thus be averted. In a series of tests with one representative light airplane it was found that, by slight modifications mainly to the wing and the tail surfaces, lateral instability due to stalling could be prevented for all conditions of power; at the same time, a normal amount of control for all essential functions could be retained. It should be noted that, if spinning is desired for instruction purposes, it would be possible to arrange the controls so that a quick change in the control linkage would make stalling possible. Further experiments are under way in an effort to extend these characteristics through a greater center-of-gravity range.

The analysis of the effect of taper, twist, change of camber, and Reynolds number on the stalling characteristics of wings without flaps, mentioned in last year's report, was completed during the year. The analysis is now being extended to include the case of flaps of various deflections and span lengths.

MANEUVERABILITY

The characteristics of various airplanes in accelerated maneuvers have been studied in connection with the general investigations of flying qualities. Data obtained have shown the desirable limits for longitudinal stability as well as stick forces. In this connection, a marked variation of the stability required with wing loading was observed.

LANDING

The investigation of the landing characteristics of airplanes to obtain statistical information on the vertical velocities and accelerations in landings has been extended to include tests of several small, light airplanes. The investigation has now covered practically the entire range of landplane types and sizes, including several airplanes with tricycle landing gears.

The results of a theoretical study of the shimmy of castering wheels first mentioned in the 1938 report have been published as Technical Report No. 686. The report on the investigation of the friction required to prevent shimmy for various arrangements of the swiveling wheel has been published as Technical Note No. 760. These results indicate that the theory, as covered in the above-mentioned report, is adequate for calculating the necessary damping. The effects of type of tire and pressure of the tire were found to be insignificant. The solid friction required to prevent shimmy increased with increased moment of inertia of the spindle and with increased caster angle.

In accordance with a request from the Civil Aeronautics Authority, the Committee investigated the landing distance of a typical transport airplane to aid in clarifying the problem of field size required for such machines in civil transport operation.

AERODYNAMIC EFFICIENCY

Tests of military airplanes in the Committee's full-scale tunnel over the past several years have demonstrated the extreme importance of aerodynamic refinement as applied to even the smallest details. The gains due to the refinement of any one detail may not be large, but the over-all effect of applying the results of basic research to each detail in turn may, when taken together, produce surprising results. Such results as have already been accomplished are strikingly brought out by a comparison of modern military airplanes with those employed during the last war.

Airfoils.—Basic investigations of the aerodynamic properties of airfoils have led to marked advances in our fundamental knowledge of aerodynamic flows in general. The wing section affords an ideal medium on which to investigate the general properties of aerodynamic flows.

The significance of wind-tunnel turbulence in bringing about a break-down of the low-drag laminar flow on airfoil surfaces has been appreciated for many years. Therefore, every effort was made to reduce the turbulence in the new airfoil-testing equipment to a condition that may be referred to as "aerodynamically smooth" flow, that is, a turbulence level below which further reductions in turbulence would produce no further effects of practical importance. As mentioned in last year's report, preliminary tests with the new equipment indicated that the turbulence level had been reduced below that of other wind tunnels. The airfoil studies were therefore continued, pending the completion of more careful flight inestigations made specifically for purposes of comparison. One of the improved airfoils arising from the investigation has now been tested in several of the Committee's wind tunnels to gain further knowledge of the practical effects of the turbulence present in the air streams of existing wind tunnels. Through the cooperation of the National Bureau of Standards, it has been possible to examine the absolute turbulence of the same air streams through the use of hot-wire equipment.

In the full-scale tunnel, data had previously been secured for a series of conventional symmetrical airfoils ranging from 9 to 18 percent in thickness (Technical Report No. 647). During the past year, this investigation has been extended to include airfoils of 25 and 35 percent thickness. Otherwise, airfoil testing of the usual type has been almost discontinued.

Aerodynamic interference.—Investigations dealing with nacelle and propeller interference mentioned in earlier reports have continued during the year. Interferences between wings and propellers have been further investigated in both the propeller-research tunnel and the full-scale tunnel.

In the full-scale tunnel, interference investigations have been extended to include various nacelle arrangements for both two- and four-engine airplanes. The relative size of the nacelles was sufficiently varied to simulate the conditions encountered for a range of large airplanes, varying in size from 6½ to 100 tons. With the completion of this work, the remaining problems appear to be more dependent upon detailed arrangements of the power plant installation than on the general interference effects produced.

Propeller research.—Force tests were conducted on three full-scale propellers operating in front of four body-nose shapes, varying from a streamline nose that continued through the propeller plane in the form of a large spinner to a conventional open-nose radial-engine cowling.

An analysis of the propeller losses in the slipstream has been made by the use of the distribution of the thrust and the torque along the radius combined with theoretical equations. The data were obtained in the NACA 20-foot tunnel on a two-blade propeller of 4-foot diameter. A method was derived for estimating the axial and the rotational energy in the wake as a fractional part of the propeller power for any propeller under any operating conditions.

Propeller development.—The development of propeller-blade sections mentioned in last year's report is being continued in the 24-inch high-speed tunnel. The investigation has yielded new propeller-blade sections that may be expected to permit important gains in propeller efficiency, particularly for high-speed military types where the compressibility effect on the propeller is beginning to appear as the most serious obstacle to great gains in high-speed performance. Even in commercial applications, however, some gains may be expected to result from the use of improved blade sections.

Cowling and cooling.—Some of the most important technical problems on which the Committee has been engaged during the past year were concerned with cowling and cooling of aircraft engines. Investigations have dealt not only with the installation and the cooling of both liquid- and air-cooled engines but also with the character and the efficiency of the flow in the various auxiliary internal-flow systems associated with the modern airplane. Extensive work during the year, dealing mainly with military applications and conducted in nearly all of the Committee's wind tunnels, is yielding new information concerning the details of the engine installation and the effects of the cooling and the auxiliary internal-flow systems on the external flow and the over-all characteristics of the airplane.

The program dealing primarily with the flow in the internal ducts is being carried out in the propeller-research tunnel. This investigation deals with such problems as blowers, ducts, diffusers, and vanes, with the object of studying the possible improvements in the efficiency of the internal systems. The question of securing adequate ground cooling has also received further attention.

COMPRESSIBILITY EFFECTS

The method of successive approximations, attributed to Janzen and Rayleigh, has been used to calculate the flow of a compressible fluid past a sphere to the third order of approximation. The results of this investigation have been presented in Technical Note No. 762.

Further investigation has been continued on the effect of compressibility on the moment of an arbitrary body. This study has been instituted mainly for the purpose of obtaining some insight into the underlying assumptions and the range of applicability of the Prandtl-Glauert approximation.

Much basic work on compressibility effects has been done following the fundamental investigations of the compressibility problem in the small high-speed tunnels. Further investigations have been made, however, of the conditions under which the compressibility burble occurs. The phenomenon was first observed in the 11-inch high-speed tunnel as it occurred on a circular cylinder. Subsequently a series of cylinders was tested in this tunnel. The drags, when plotted against Reynolds number, showed substantial agreement with the earlier classic investigations in the low-speed range well below four-tenths the speed of sound. A small and progressive increase in drag coefficient was observed for each of the cylinders when approaching this speed; and each of the cylinders showed a much more abrupt increase beyond this speed, where the compressibility burble was observed to occur. Owing to the small size of the tunnel, it was not possible to carry these investigations through the range of critical Reynolds number for the cylinders. It has been possible through the use of the 8-foot high-speed tunnel to extend the investigation to include cylinders of several inches in diameter and extending through the critical range of Reynolds numbers. The results are now being analyzed to study the flow phenomenon associated with the combined critical effects of both Reynolds number and compressibility.

The new 19-foot pressure tunnel, which has been put into operation during the past year has provided an excellent means of separating certain effects of Reynolds number and compressibility, although it was not designed for high speeds and the investigation of compressibility effects. By a variation of the pressure in the tunnel, it is possible with the same model to reach the same Reynolds number at various speeds or Mach numbers, depending on the pressure or the density of the air in the tunnel.

WIND-TUNNEL CORRECTIONS

Corrections for tunnel-wall interference have required further study during the year, owing to the use of relatively large models for extending the test range of Reynolds number. Such studies have resulted in more accurate determinations of tunnel-restriction effects associated with the use of large models. The tunnel-restriction effects are more serious in the high-speed range, owing to the stream distortions associated with compressibility.

ICE FORMATION

Aerodynamic theory has been applied to some of the problems associated with the icing of airplane wings. One phase of the subject investigated dealt with the relative space cleared of water droplets by the passage of the wing. This subject is of importance under conditions corresponding to those of the most severe icing.

The results of the investigation of ice prevention on windshields mentioned last year have been published as Technical Note No. 754. The double-pane windshield with hot air circulating between the two glass panes, which appeared to be the most promising method investigated, was found to increase the reflection of stray light, and in one case this increase was reported to be an obstacle to its use in night landings. Possible means of overcoming this difficulty are under investigation.

The investigation of the use of exhaust heat for ice prevention on airplane wings has been continued. Various methods of distributing the heat available in the engine exhaust have been studied by tests of a wing model mounted on an airplane in flight. The results of this investigation have provided useful data on the most effective means for distributing the available heat.

ROTATING-WING AIRCRAFT

The investigations of the stalling of inboard elements of the retreating rotor blade on the YG-1B autogiro have been reported in Technical Note No. 741. Similar investigations of the same machine equipped with rotor blades of improved design have been completed during the past year. The results indicate that the size and the importance of that portion of an autogiro rotor disk where blade elements operate beyond their stalling angle are appreciably influenced by the static stalling angle of the airfoil section chosen for the rotor blade. They also show that the elimination of control-stick vibration in direct-control rotating-wing aircraft requires the use of rotor blades that do not twist periodically during rotation. Much work has been done on the extension of existing rotor theory.

NATIONAL BUREAU OF STANDARDS

WIND-TUNNEL INVESTIGATIONS

The aerodynamic activities of the National Bureau of Standards have been conducted in cooperation with the National Advisory Committee for Aeronautics.

Wind-tunnel turbulence.—With the development by the Committee of new airfoils of extremely low drag the question of wind-tunnel turbulence assumes even greater importance than before. Accordingly, much attention has been given to practicable methods of reducing the turbulence in existing wind tunnels.

In cooperation with the Langley Field staff, measurements were made of the longitudinal and transverse components of turbulence in a number of wind tunnels and in flight by means of portable hot-wire equipment. The flight results, in agreement with previous measurements by other methods at the Committee's laboratory, indicated that the small-scale turbulence of the atmosphere is substantially zero and hence that wind tunnels should have as low a turbulence as possible.

Boundary-layer investigations.—The study of transition at low turbulence levels on a thin, flat plate parallel to the wind direction has been continued. The effects of small pressure gradients near zero pressure gradient have been determined. The change in position of the transition region with turbulence has been measured over the range from 0.04 to 0.27 percent turbulence (mean of the three components).

Greater attention has been given, however, to the detailed study of the transition region under conditions of the lowest turbulence in the effort to obtain a more fundamental understanding of the process. Measurements and photographic records have been obtained of the longitudinal and transverse components of the turbulent fluctuations parallel to the plate.

A few records have been made of the simultaneous fluctuations at two points. Similar measurements and records have been taken in the laminar layer to study the "pulsations" discovered in earlier work.

Hot-wire equipment.—There has been a steady development of improved equipment for use in turbulence measurement. Amplifiers of greater sensitivity and stability and of less weight, hot-wire holders and supports of greater ruggedness and adapted to special purposes have led to quicker and more accurate measurements. A thorough study was made of the effects of variation of the heating current produced by the changing resistance of the wire during turbulent speed fluctuations. The two-wire head for measurement of transverse components, and its convenient control circuits, are now standard equipment.

The principal developments have been in connection with suitable mountings for making measurements within boundary layers that are free from spurious results due to vibration.

AERONAUTIC-INSTRUMENT INVESTIGATIONS

The work on aeronautic instruments has been conducted in cooperation with the National Advisory Committee for Aeronautics and the Bureau of Aeronautics of the Navy Department.

The report on the first phase of the investigation of corrugated diaphragms was published as Technical Note No. 738. Experimental work continued actively during the year on determining the useful deflection limits of the beryllium copper and phosphor bronze diaphragms in which the drift, elastic hysteresis, and after-effect are used as criteria. A method of suddenly applying and removing pressure on the diaphragms was developed in connection with the drift measurements.

At the suggestion of the Langley Memorial Aeronautical Laboratory additional data at higher piston speeds were obtained for inclusion in the report on dashpots. This work extended the data into the turbulent region where the damping resistance increases considerably above that predicted by the theory based on viscous flow.

A standard barometer of the U-tube type has been constructed for standardizing mercurial barometers used to test altimeters. It is equipped with means for controlling and measuring the vacuum above the mercury column and is temperature-controlled. The precision of reading attained at present is 0.02 millimeter of mercury.

SUBCOMMITTEE ON METEOROLOGICAL PROBLEMS

The Subcommittee on Meteorological Problems keeps in contact with the progress of investigations being conducted by the various agencies on problems relating to atmospheric conditions which are of particular importance in connection with aircraft design and operation. The Special Subcommittee on Lightning Hazards to Aircraft is organized under the Subcommittee on Meteorological Problems.

Atmospheric disturbances and their effect on airplane operation.—The total flight time with V–G recorders installed in transport airplanes has been increased to more than 103,000 hours. Of this total, approximately 60,000 flight hours have been on land transports flying the airlines in the United States; the rest of the flight hours have been on the flying boats of Pan American Airways, Inc., flying between the United States and Europe, South America, and the Orient. During the past year all gust data that had been collected were transferred to punch cards to permit more efficient analysis.

Gust structure.—The investigation of the gust structure has been extended to determine the variations both with altitude and with direction. A reworking of the data obtained from flights below 17,000 feet has indicated that vertical and horizontal gusts are of about equal intensity in the atmosphere. More vertical than horizontal gusts appear to be present under thermally unstable atmospheric conditions, and under wind turbulence the conditions appear to be reversed.

Because the great mass of existing gust data has been obtained at relatively low altitudes, and because the newer aircraft reach their top speeds at higher altitudes, it has been necessary to obtain data on the variation of gusts with altitude. For this purpose an instrument called the G–Altitude (G–A) recorder has been developed to complement the well-known V–G recorder in service.

A further investigation in gust structure has been started by the procurement of an Army stratosphere airplane, and the necessary radiosonde equipment for making high-altitude soundings.

Lightning hazards to aircraft.—Data are being accumulated from air transport operators by means of a questionnaire on incidents of lightning strikes to airplanes. The data obtained from these questionnaires are being analyzed with a view to obtaining more information as to the extent to which electrical phenomena constitute a serious hazard to aircraft in flight especially with regard to their effect on flight personnel and the aircraft structure and equipment. Laboratory studies are also being conducted concerning the physical effects of high-voltage discharges on thin metal sheets through the cooperation of the General Electric Co. and the Westinghouse Electric & Manufacturing Co.

A study is being continued at the University of New Mexico, under the cognizance of the Special Subcommittee on Lightning Hazards to Aircraft, to determine the nature of electrical discharges in the atmosphere. In this work detailed information will be obtained on a large number of lightning strokes occurring during different parts of the year. Eight synchronized instruments capable of recording rapid changes in the electrical potential gradient at the surface of the earth distributed over a circular area approximately 5 miles in diameter will be used. It has been found that many electrical discharges are complicated by the fact that a large number of simple discharges between different charge centers may take place in succession, separated by time intervals of 1/100 second or more.

SUBCOMMITTEE ON SEAPLANES

During the past year the facilities of the NACA tank have been almost continuously in use for the study of specific problems and the testing of specific models submitted either by the military services or by manufacturers. In the latter category were two models of commercial transport seaplanes in which the Navy was interested, and two for use in connection with designs being prepared for the military services. The work was so urgent that NACA projects were carried on only to fill in between these tests; consequently, the only other model tested was one forming a part of the NACA program of research devoted to the development of improved forms of hulls for flying boats.

Plant and equipment.—The dynamically similar models used in investigations of the dynamic stability of seaplanes while taking-off and landing must accurately reproduce not only the form of the hull but also the aerodynamic structure (wings and tail surfaces). In these tests, the air in the tank should be perfectly still, corresponding as nearly as possible to the condition of take-off with no wind. Unfortunately, the towing carriage generates large turbulence and this turbulence in turn causes disturbance of the air well ahead of the carriage. A new auxiliary carriage made of steel tubing was constructed and put into service during the past year. This carriage was designed to give better air conditions and to improve the facility with which tests could be made. Although completely still air has not been obtained, there has been a considerable improvement.

The methods of constructing the very special dynamic models have been continuously improved, and the information gained from the test of each new model has been used to check the operation of the various features incorporated in it and to indicate the desirability of further changes. There have been almost no fundamental changes but many changes in detail.

Effect of angle of dead rise on resistance and drag.—The effect of the angle of dead rise of the bottom on the hydrodynamic resistance and the aerodynamic drag has been investigated on a series of three models of seaplane floats. The angles of dead rise investigated were 20°, 25°, and 30°.

Effects of chine flare on water resistance and spray.—The cross section of the bottom of most flying-boat hulls now shows a recurved portion, or flare, at the chine. Its primary purpose is to cause the wave coming from under the hull to be deflected and thus be kept from rising until it strikes the propellers or the wings, as it sometimes will if no such flare is provided.

Models of 22 flying-boat hulls were tested in the NACA tank for the purpose of determining the effect on water resistance and spray of 13 variations in the transverse section of the bottom of the forebody and 3 variations in the form of the bottom of the afterbody. The chine flare was found to reduce the height of the part of the spray that originated where the chine was above water level but did not reduce the height of the part of the spray that originated where the chine was below water level. The first type of spray comes from a sheet of water that travels across the bottom at high speed and may be termed a "velocity" spray. The second type is produced by water that escapes under the chine from the high pressure generated at the chine and may be termed a "pressure" spray. The chine flare causes an increase in the pressure on the bottom at the chine, and the addition of certain types of chine flares actually increases the height of this latter type of spray.

Study of the flow of water along the bottom of a model of a flying-boat hull.—Knowledge of the manner in which the water encountered by the bottom of a flying-boat hull moves over that bottom is of great value in understanding the effects of the various changes in form that are investigated. Observation of the flow, as it issues from beneath the bottom at the chines and the steps, indicated that changes in the direction of flow have marked effects on spray and resistance but, as long as it was possible to observe only the end effects, it was impossible to do much in the way of determining where the changes originated or what were the fundamental causes. Obviously direct observation of the flow throughout the entire length of the bottom would give much valuable information. In order to verify this observation, a model with a transparent bottom was constructed.

SUBCOMMITTEE ON VIBRATION AND FLUTTER

A number of requests have been received in the past year for comprehensive flutter studies of certain specific types of aircraft. Considerable computational information has been gained on the ternary cases or those with 3 degrees of freedom. This information throws light, in particular, on the important effects of structural friction and the need for obtaining dependable values for the damping parameters. The labor of the calculation methods for 3 or more degrees of freedom has been appreciably reduced, making it feasible to handle certain more complicated cases that may arise in tail-fuselage flutter. Further studies are now in progress on the influence of special effects associated with compressibility, finite span, floats, tabs, and higher-order modes.

The essential correctness and adequacy of the flutter theory for the prediction of critical speeds of wing flutter have already been demonstrated by numerous tests at the Committee's laboratory and elsewhere. The main problems are now in the technique of determining correct flutter parameters, and in the application of the theory to more unusual or complicated cases.

Tests on the ground.—Equipment for determining natural frequencies of airplanes on the ground has been improved and applied to a number of airplanes.

Tests of flutter models.—A large number of flutter tests have been made on models in the 8-foot high-speed tunnel. These investigations included tests showing the effect of compressibility upon flutter speed up to 500 miles per hour.

Wing frequencies.—Theoretical studies have been made of torsional and bending vibration of wings with particular reference to the effect of taper and of mass coupling upon the frequencies.

Damping.—The value of the structural damping parameter in an actual wing is being determined by tests on an outer wing panel mounted in the vacuum sphere. With the air pressure reduced to 1/20 of an atmosphere and the damping effect of the mounting and the instruments reduced to a minimum, the residual value of damping is attributed to the internal structural friction in the wing.

Propeller vibration.—Tests and theoretical studies are being made of the effects of shaft flexibility and rotation upon propeller-vibration frequencies and stresses. The effects of angle setting and chordwise flexibility upon the frequencies of a freely suspended propeller have been studied by means of models and theoretical analysis.

REPORT OF COMMITTEE ON POWER PLANTS FOR AIRCRAFT

LANGLEY MEMORIAL AERONAUTICAL LABORATORY

INCREASE IN ENGINE POWER

High octane number fuels.—The study of the relationship between maximum permissible engine performance and the knocking characteristics of aircraft-engine fuels has been continued under cognizance of the Subcommittee on Aircraft Fuels and Lubricants and is described in the report of that subcommittee.

Valve overlap.—An appreciable gain in engine power and a reduction in combustion-chamber temperatures can be obtained by operating with a large valve overlap. The effect of valve overlap on engine performance, when the inlet and the exhaust manifold pressures simulate those encountered when operating at altitude with mechanical and exhaust turbine-driven superchargers, has been investigated on a single-cylinder air-cooled engine. Performance tests were made over a range of inlet and exhaust pressures varying from 15 to 45 inches of mercury absolute.

The investigation of the performance of a multicylinder air-cooled engine, equipped with a special cam ring giving 130° of valve overlap, has been completed.

Piston rings.—One of the factors limiting the power output of aircraft engines is the failure of the piston rings to give satisfactory sealing and low wear. An investigation to determine the effect of various factors in piston-ring design on the operation of rings in high-output engines has been started. The factors investigated were: face, width, finish, and chemical treatment; side finish; and ring material.

Flow through poppet valves.—An investigation has been started to improve the flow coefficients of poppet valves. By an increase in the ratio of the outside to the inside diameter of the valve seats, the reconversion of kinetic energy to static pressure will be increased, and the pressure drop through the valves will be decreased. Tests have been made with steady flow through poppet-valve models having different seat widths, and the pressure drop has been determined. The effect of flaring the outer part of the passage between the valve and the cylinder head has also been determined.

Power recovery by jet propulsion.—An analysis has been made of the power recovered by discharging the exhaust gas rearward, from nozzles on the collector-ring exits, from separate exhaust stacks, and into the cooling duct behind the engine or radiator.

Two-stroke-cycle spark-ignition engine.—Research on the two-stroke-cycle, fuel-injection, spark-ignition engine has, during this year, been principally concerned with increasing maximum power. The liquid-cooled engine used in this investigation is a uniflow type having scavenging and charging air admitted to the cylinder through piston-controlled inlet ports with exhaust through four poppet valves in the head.

COMBUSTION RESEARCH

Knock.—The NACA high-speed motion-picture camera has been used to take an extensive series of photographs, at the rate of 40,000 frames per second, of normal combustion, preignition, and knock in the NACA combustion apparatus.

The N. A. C. A. combustion apparatus has also been used for a study of the knocking characteristics of several fuels that were available only in small quantities. The pressure and the temperature of the intake air were increased until a single charge of fuel injected into the cylinder resulted in knocking combustion. A complete range of fuel-air ratios was investigated, using inlet-air temperatures up to 300° F.

Preignition characteristics of fuels.—An investigation of the preignition characteristics of aircraft-engine fuels, made on the NACA combustion apparatus, has been concluded.

Air flow in engine cylinders.—The glass-cylinder engine has been modified to operate on a two-stroke cycle, with intake through ports in the cylinder wall and exhaust through four poppet valves in the head. Replaceable port bands, containing round ports of various sizes and having their axes inclined at various angles both horizontally and vertically, have been built.

Spark-plug temperatures.—A thermocouple installation has been designed for measuring the central electrode temperature of standard spark plugs and is now being used in the investigation of the knocking characteristics of aircraft-engine fuels.

FUEL CONSUMPTION

Safety fuel.—The performance of five new safety fuels having the same heating value as gasoline and relatively good antidetonating qualities has been investigated.

The antidetonating qualities of these fuels were investigated by comparing them with calibrated fuels in the same engine used for the performance tests. The tests showed that, by the addition of lead, the antidetonating qualities of these fuels could be increased to a point where the fuels could be used in most of the modern aircraft engines.

The effect of fuel-injection timing and injection-valve opening pressure on engine performance with safety fuels was investigated, and the performances of safety fuels with two types of injection-valve nozzles were compared.

HEAT TRANSFER ON LIQUID-COOLED ENGINES

An investigation is being made of the heat-transfer processes in a liquid-cooled engine using a number of coolants. From the results of tests in which ethylene glycol and water were the coolants, semiempirical equations have been derived relating cylinder-head temperatures to indicated horsepower, rate of coolant flow, and various physical properties of the coolant.

Heat-transfer coefficients.—A preliminary investigation of the heat-transfer properties of several liquids has been carried out with a laboratory apparatus built to approximate engine conditions. Experimental work has been completed that shows the effect of the ratio of length to diameter of an air passage on the value of the heat-transfer coefficient prevailing in the passage. Considerable increase in heat-transfer coefficient can be obtained by using smaller values of the length-diameter ratio in the air passages.

Heat-transfer process.—Tests to determine the heat-transfer process in a Wright Cyclone cylinder have been completed. The theory of engine-cylinder cooling developed in a previous report was further substantiated by the data obtained on the Cyclone cylinder. Equations for the average head and barrel temperatures of this cylinder, as functions of the engine and cooling conditions, were utilized to calculate the variation in cylinder temperature with altitude for level flight and climb. A method was presented for correlating average head and barrel temperatures and the temperatures at individual points on the head and the barrel obtained on the test stand and in flight. The method has been applied to the correlation and the comparison of data obtained on a number of service engines. Data were also obtained that showed the variation of cylinder temperature with time when the power and the cooling-pressure drop are suddenly changed.

Heat-transfer coefficients in flight.—Tests have been made to determine the heat-transfer coefficients of an electrically heated finned cylinder in flight. The object of the tests was to determine the heat transfer in flight and compare it with that obtained in the laboratory tests to determine best fin dimensions. The baffle arrangement around the cylinder in flight was similar to that used on modern radial engines. The results of the tests showed that the laboratory coefficients were about the same as the flight coefficients.

Engines in wings.—The necessity of reducing engine-nacelle drag has become increasingly acute owing to the gradual elimination of other sources of parasitic resistance. An obvious refinement for multiengine airplanes is the removal of the nacelles from the wings and enclosure of the complete power plant within the wing. An investigation has been started to determine the cooling requirements of aircraft engines completely enclosed in a wing and having the cooling air supplied by a blower.

Piston temperature.—As a part of the program for the study of piston cooling, tests were conducted on a single-cylinder, air-cooled carburetor engine, and the effect of engine-operating conditions on the piston temperatures was determined.

Radiators.—The study of radiator design has been continued to determine the effect on design of placing limitations, such as fixing the frontal area, mass flow or pressure drop of cooling air, or length of tube in the air-flow direction. Formulas are being developed to make it possible to design the best radiator for conditions where any one of the quantities listed is fixed, also to give the maximum possible cooling efficiency obtainable under certain design limitations.

Experimental work is in progress to determine in detail the nature of flow through tube banks. The better understanding of flow across tubes being obtained as a result of this work may make possible some improvement in radiator design.

Oil coolers.—An analysis has been made of experimental oil-cooler data from commercial sources. Experimental work is in progress to determine heat-transfer data for use in oil-cooler design.

Intercoolers.—A mathematical analysis of conventional fin-type intercooler design has been made with a view to showing how to calculate the intercooler design that will use least power for specified cooling requirements.

The theoretical and the experimental investigations of a light-weight type of intercooler have been continued. Tests have been completed on a laboratory test unit, and the results show good agreement with theory.

VARIATION OF ENGINE POWER WITH ATMOSPHERIC CONDITIONS

Two formulas have been derived for predicting the power at altitude from sea-level tests; one for the case where the exhaust pressure equals the intake manifold pressure and the other for the case where the exhaust pressure is greater or less than the intake manifold pressure.

NATIONAL BUREAU OF STANDARDS

Phenomena of combustion.—The results of studies of the normal burning of mixtures of benzene, normal heptane, iso-octane, and carbon monoxide with oxygen and nitrogen were published by the Committee as Technical Report No. 682. The conclusions drawn in this report are applicable also to studies made subsequently with triptane as the fuel. The spherical bomb and auxiliary apparatus employed in this work are being modified for use at higher initial pressures.

The study of detonation and methods of detecting detonation has been continued. Several experimental indicators of detonation, using the principle of the spring-loaded ball, have been built. The most successful of these has been tested on the cylinders of several engines, showing considerable promise in each case. Further development is in the direction of making the device smaller and applicable to a wider variety of engines.

Flow characteristics of fuel lines.—Under the auspices of the Cooperative Fuel Research Committee, the Bureau has nearly completed an experimental study of the pressure drop across component parts of aircraft fuel systems as a function of size, design, and rate of gasoline flow.

Magnetos, testing and development.—Type tests were conducted on several types of magnetos.

A new altitude chamber was constructed for making electrical tests on aviation engine magnetos and other accessories.

SUBCOMMITTEE ON AIRCRAFT FUELS AND LUBRICANTS

LANGLEY MEMORIAL AERONAUTICAL LABORATORY

Investigation of antiknock characteristics of fuels.—The investigation of the knocking characteristics of fuels in a liquid-cooled engine having a hemispherical combustion chamber has been continued. The data obtained with this cylinder, like results for other cylinders tested, show that the data on fuel knock can be correlated by plotting an end-gas density factor against an end-gas temperature factor. This investigation is to be continued using one of the latest types of air-cooled engine cylinders.

A study of the heat losses and the temperature rise of the surfaces of the combustion-chamber wall of an aircraft-engine cylinder has been made to determine the changes that occur when engine operation passes from normal nonknocking operation into knocking operation. Importance is attached to the behavior of the temperatures of the combustion-chamber surface when knocking occurs because of the danger of preignition and consequent engine failure. Contrary to expectations the data obtained show that, when moderate audible knock is encountered, the temperatures of the combustion-chamber surfaces do not rise abnormally fast. Such a result was also found for hot spots in the cylinder, such as spark-plug electrodes. The temperatures of the combustion-chamber surfaces that become new sources of ignition were found, however, to increase markedly and rapidly after surface ignition commenced. The tests with this cylinder show that the allowable knock rating is little affected by the average cylinder-wall temperatures. Likewise, hot-spot temperatures are little affected by average wall temperatures.

NATIONAL BUREAU OF STANDARDS

Investigation to develop nonleaded aircraft fuel of over 100 octane number.—This investigation, carried on for the past three years in cooperation with the National Advisory Committee for Aeronautics, the Army Air

Corps, and the Bureau of Aeronautics of the Navy Department, will be extended to include the examination of certain branched-chain paraffin hydrocarbons in the volatility range of aviation safety fuel.

Stability of aviation oils.—The study of the stability of aviation oils at the National Bureau of Standards during the last several years resulted in the development of a laboratory test for stability by means of which it is believed possible to predict both the changes which will occur in oils during operation in aircraft engines and the extent of deposits which are formed in these engines. A large number of engine inspections have been made during the year and information on the condition of these engines, as regards engine deposits, has been compared with laboratory data on the oils on which the engines were operated.

Ring sticking with aviation oils.—During the engine inspections made in connection with the study of oil stability, information was obtained concerning the extent of ring sticking.

Bearing corrosion.—In connection with the investigation of the corrosion of master-rod bearings, the study of the tendency of aviation oils to form corrosive acids has been continued.

Wear characteristics of aviation oils.—Considerable progress has been made at the National Bureau of Standards in the investigation of the wear characteristics of aviation lubricating oils. A satisfactory test procedure has been developed for the operation of the laboratory wear apparatus and data have been obtained on a number of reference oils. The effectiveness of a large number of compounding agents in reducing the amount of wear has also been determined.

Lubrication of master-rod bearings.—Considerable progress has been made on the investigation of master-rod bearing lubrication with the small bearing machine. The information obtained includes the frictional characteristics and heat-dissipation characteristics of bearings of one type of material. The operation covers a wide range of speeds and loads when using a number of oils of different viscosity grade at various oil-inlet temperatures and oil-feed pressures.

SPECIAL SUBCOMMITTE ON SUPERCHARGER COMPRESSORS

The ever-increasing demand for engines that can operate at a high power output over a large range of altitudes has greatly increased the importance of the problems connected with superchargers. With an increase in supercharging it is important that the supercharger operates efficiently in order that it will require a minimum amount of the engine power to compress the air to the desired pressure and that the heat of compression or the discharge air temperature will not be unduly increased. A high supercharger discharge air temperature is very objectionable for many reasons; it increases the load on the intercooler and the detonating propensity of the fuel and impairs the engine power because of the reduced weight of charge that can be inducted. An efficient supercharger also would be more reliable because the heat stresses would become a less important consideration for impellers operating at high tip speeds.

The Special Subcommittee on Supercharger Compressors was appointed to study means for improving the efficiency of centrifugal superchargers and is actively engaged on this problem.

SPECIAL SUBCOMMITTEE ON EXHAUST-GAS TURBINES AND INTERCOOLERS

The exhaust-gas turbine is an important device for recovering part of the energy available in the exhaust gases of internal-combustion engines. It has been found to be a useful means for driving the superchargers of aircraft engines and, with the increasing importance of superchargers, it has become equally important to increase the efficiency of the driving means.

With an increase in the output of supercharger compressors, it is necessary to prevent any increase in the temperature of the charge entering the engine cylinder in order to avoid detonation. The intercooler is a means for reducing the temperature of the charge after or during the compression process and becomes increasingly important as the heat of compression of the air in passing through the supercharger increases with the greater amount of work performed on each unit mass of air.

The Special Subcommittee on Exhaust-Gas Turbines and Intercoolers was appointed to study the means for improving the efficiency of exhaust-gas turbines and intercoolers, and is actively engaged on this problem.

REPORT OF COMMITTEE ON AIRCRAFT MATERIALS

SUBCOMMITTEE ON METALS USED IN AIRCRAFT

Permanence of aircraft metals under continuous weathering.—Exposure tests of aircraft metals in sheet form were continued throughout the year. The tests covered commercial aluminum and magnesium alloys and various chromium-nickel ("stainless") steels under conditions of continuous exposure in a marine atmosphere and in atmospheric exposure with intermittent wetting with sea water at high tide. A report was issued by the National Advisory Committee for Aeronautics during the year summarizing the results of the first year's work and a similar one on the second year's results will appear soon. In addition, a general report summarizing results of tests covering a period of 10 years was published by the National Bureau of Standards as a research paper.

That portion of the test covering welded and riveted joints in the light alloys has yielded very definite and useful information as to the combination of metals which must be avoided in assembly work, both in the regular assembly joints and in the attachment of auxiliary parts to the main structure. In some unfavorable cases, heads of rivets may be completely disintegrated by the end of the first year, whereas, if the proper combination of metals is chosen, the rivets and adjoining metal are in excellent condition after exposure in a similar environment.

The tests on insulating materials for use between faying surfaces are in a relatively early stage. The results, however, have clearly shown the need for a more detailed study along this line, particularly when conditions permit the retention of a film of water in a crevice.

Some of the insulating materials used, or proposed for commercial use, were very inefficient.

In the exposure tests of sheet stainless steel, visual inspection of the specimens is usually sufficient to permit a rough rating of the materials. A more exact rating was obtained by flexural fatigue tests of specimens of the material in its initial state, and of companion specimens taken from the exposed sheet material. By this means it has been possible to evaluate quite accurately the relative corrosion damage on different stainless-steel compositions and also to differentiate between the corrosive effects in different environments.

Although discoloration of the spot welds by superficial rusting was evident on all materials after exposure, in no cases was the attack on the welds detrimental from the structural standpoint.

Elastic properties of high-strength constructional aircraft metals.—The second report in this investigation, summarizing the data on the effect on the tensile elastic properties of plastic deformation (cold working) and of heat treatment, is now in press. The beneficial effect of heat treatment of stainless steel, especially with respect to its elastic properties, is especially noteworthy. With the completion during the year of the study of elastic properties of the metals at low temperatures, the phase of the investigation on tensile elastic properties was completed. The assembling of the report on this part of the investigation has been practically completed. The dearth of information on torsional elastic properties of the metals used in tubular form in aircraft construction prompted the extension of the investigation in this direction. The materials necessary for this study have been assembled and the work is scheduled to start in the near future.

Protective treatment of magnesium.—It is well recognized that corrosion is a controlling factor which determines the length of useful life of magnesium as a structural material, especially in a marine environment. Initial surface treatment is therefore very important for this class of metals. As yet no thoroughly satisfactory method of treatment has been developed for magnesium alloys, as has been done for the aluminum alloys.

Aircraft metals at subzero temperatures.—The results of the extensive recent series of tests in this field have been assembled and coordinated and are available to designers and manufacturers. They will be published ultimately as a research paper of the National Bureau of Standards.

SUBCOMMITTEE ON MISCELLANEOUS MATERIALS AND ACCESSORIES

Development of plastic material for aircraft structures.—The experimental work on the development of reinforced plastics suitable for aircraft construction is now proceeding along three main lines.

The first phase involves the synthesis of phenolic resins from various raw materials, such as phenol, cresols and xylenols on the one hand and formaldehyde, acetaldehyde, and furfural on the other, and determining the relationship which exists between the composition and the properties of these resins. It has been observed in work with the birch veneers that maximum-strength values are obtained when the modulus of elasticity of the resin binder is similar to that of the wood. This should also be true of other types of laminated products. Hence, this work on the properties of pure synthetic resins should make possible the selection of resins suitable for use with whatever type of reinforcing agent is found to be desirable in molding aircraft structures.

The second phase of the experimental program involves further investigation of a number of reinforcing materials. Various types of paper, cloth, wood veneers, fibers, and thin metal wires and sheets have been made into laminated panels and their properties determined. Optimum arrangement of these various elements in a composite structure, and determination of the minimum temperature and pressure necessary to obtain proper bonding of the reinforcing agents, are the ultimate objectives of this work. Commercial resins and resins synthesized in the laboratory at the Bureau of Standards are being used in this work.

The third phase of this investigation involves the determination of the pertinent physical properties of those reinforced plastics which indicate possibilities for use for aircraft construction. Materials submitted from commercial sources, as well as those prepared in the laboratory at the National Bureau of Standards, have been examined, and such properties as tensile strength, compressive strength, flexural strength moduli of elasticity in tension, compression and flexure, shear strength, impact strength, bearing strength, water absorption, and specific gravity have been measured, and these data are being incorporated into a report. Particular attention is being directed at the present time to determining the moduli of elasticity and the coefficients of thermal expansion of the resins and reinforcing agents, in order that these materials may be matched up as closely as possible with respect to these properties.

Evaluation of transparent plastics as windshields for aircraft.—In previous reports of work on transparent plastics, it was noted that accelerated aging tests made with apparatus employing an enclosed carbon arc as the source of ultraviolet light failed to correlate well with the results of outdoor exposure. A detailed investigation of accelerated weathering of transparent plastics was therefore undertaken to obtain a reliable test for rapid evaluation of weathering properties.

The effects of different laboratory accelerated-weathering conditions upon various types of transparent plastics were evaluated by measurements of light transmission and haze, and by visual examination of the specimens for crazing, fusing, blooming, discoloration, and warping. These results were compared with data obtained for specimens of the same plastics exposed to the weather in Washington, D. C. On the basis of these tests, a method of accelerated weathering of transparent plastics has been developed which gives results correlating well with the actual behavior of the materials in outdoor exposure tests.

REPORT OF COMMITTEE ON AIRCRAFT STRUCTURES

LANGLEY MEMORIAL AERONAUTICAL LABORATORY

STRUCTURAL RESEARCH

The structural research conducted under the supervision of the Committee on Aircraft Structures is concerned with both the theoretical and the experimental approach. Wherever possible each problem is attacked by both methods in order to obtain sound and proved formulas for use in stress analysis and design. Some of the structural problems on which progress has been made during the past year are discussed in the following paragraphs.

Rib design.—One of the structural problems that has been quite generally overlooked in the past by engineers is the design of intermediate frames and ribs in stressed-skin structures. The work on this subject, reported last year, has been greatly extended both theoretically and experimentally.

Diagonal-tension beams.—In practical design where diagonal-tension beams are encountered, it is usually found that the beam lies in a region somewhere between a shear-resistant web and a completely developed diagonal-tension field. In order to supply information on the transition region between these two extreme conditions, a special investigation of the incompletely developed diagonal-tension field beam was undertaken.

Stress distribution in monocoque structures.—The shear deformation of monocoque structures is such as to cause the stress distribution to differ considerably, in many cases, from that given by the ordinary theory of bending. Consequently, for a proper analysis of stressed-skin structures, the effect of this shear deformation must be considered. Technical Note No. 739 presents a convenient method of solving this problem by the method of dividing the beam into a number of bays that can be assumed to have constant cross section and loading. The solution is particularly well adapted to beams of variable cross section and loading. The recurrence formula given in the paper is analogous in form to the well-known three-moment equation of beams.

Photoelastic analysis of three-dimensional stress systems.—During the past year a photoelastic analysis of three-dimensional stress systems was made by utilizing the polarization phenomena associated with the scattering of light. By this method, the maximum shear and the directions of the three principal stresses at any point within a model can be determined, and the two principal stresses at a free-bounding surface can be separately evaluated. Polarized light is projected into the model through a slit so that it illuminates a plane section. The light is continuously analyzed along its path by scattering and the state of stress in the illuminated section is obtained. By means of a series of such sections, the entire stress field may be explored. The method was used to analyze the stress system of a simple beam in bending. The results were found to be in good agreement with those expected from elementary theory. This work is presented in Technical Note No. 737.

Local instability of compression members.—During the past year one paper (Technical Note No. 743) has been prepared wherein charts are presented for the coefficient in the formula for critical compressive stress at which cross-sectional distortion begins in columns with I-sections, Z-sections, channel sections, and rectangular-tube sections.

Torsional instability of columns.—Until recent years little progress had been made in developing the theory of torsional failure of columns.

Before proceeding with further theoretical analyses on torsional instability of columns, the Committee considered it desirable to make a careful experimental investigation of the subject. Arrangements were made to have the tests conducted by Professor Niles at Stanford University. These tests were completed during the past year and the results are presented in Technical Note No. 733. The results of the tests that were made on channel section columns tend to validate the theoretical formulas developed by the Committee.

As a consequence of this experimental investigation the Committee is now proceeding to work out theoretical formulas on torsional instability of columns in a practical form for designers. Where these formulas give a lower critical stress than the ordinary column formulas, failure can be expected to occur by torsional instability.

Compressive strength of sheet-stiffener panels.—An extensive investigation of the compressive strength of sheet-stiffener panels was made under contract by the California Institute of Technology and the results are reported in Technical Note No. 752.

STRUCTURAL LOADS ON AIRPLANES

The Committee, in cooperation with the Civil Aeronautics Authority, instituted a program during the past year of installing V–G recorders in all large airplanes and in the smaller types of airplane as they were produced and put into service. In line with this program a few flight records were obtained on the Boeing S–307 Stratoliner during the early flight tests and more recently in regular scheduled operation on the air transport lines.

Gust tunnel.—Some time has been spent during the past year in improving the accuracy of the gust tunnel and in developing a method of recording the wing deflections of the airplane models as they traverse the gust tunnel.

The results of tests of a gust-alleviating flap which have been previously mentioned, have been analyzed and published in Technical Note No. 745. The analysis indicated that the reduction in acceleration due to the flap could be calculated with a fair degree of accuracy.

Tests in the gust tunnel on a model of a canard airplane, which were reported last year, have since been published in Technical Note No. 758.

An investigation of the effect of the stability of an airplane on the gust-load factor is now in progress. In this investigation the gust shape and the various stability parameters are being varied to determine their effect on the load factor. A series of calculations on the effect of stability is being made concurrently to complete the investigation.

Dynamic overstress.—During the past year calculations of the reactions of an airplane with a flexible wing have been made for a large number of cases. Calculations were made on the basis of the previously verified assumption that the actual damping under rapidly changing conditions is equivalent to a constant proportion of the ideal damping for steady-flow conditions. The calculations indicate that, except for the sharpest gusts, the stress in the wing is equal to or less than that for static conditions. The results also show that the accelerations at the wing tip will be two to three times the acceleration in the fuselage for sharp gusts and will decrease to unity for the larger gust-gradient distances.

In order to investigate the accuracy of the calculations, a series of tests on an airplane model with a flexible wing is in progress in the gust tunnel.

Load distribution.—The analytical study of the variation of the net wing loads under conditions of combined normal and angular accelerations has been published in Technical Note No. 757. This study included the shear and the moment variation due not only to one-wheel landings but also to aileron deflections in flight.

Measurements of the pressure distribution over a single rib of an airplane diving at speeds in excess of 550 miles per hour have been made.

Tail loads.—The study of tail loads has been continued along the lines indicated in the last annual report of the Committee. The analytical report giving the results of the study of factors affecting the tail loads has been completed. The supplementary flight tail-load program, in which the tail of a small airplane was mounted on calibrated springs and in which conditions of elevator movement were rigidly controlled, has been completed. The evaluation of the data is now nearly completed.

Loads on seaplane hulls.—The evaluation of the large amount of pressure, stress, and acceleration data taken in the flight tests of the two large flying boats mentioned in the last annual report has been completed. The results from these investigations are, in general, in reasonable agreement, although individual impacts show wide variation in the loads. It appears that the relative severity of rough-water and smooth-water impacts is principally due to differences in the distribution of water load over the bottom.

The survey of the available literature on the theory of landing impacts, which is a part of the research program for understanding the processes involved in the landing impact, has been completed. The impact theory is applied to numerous cases in which actual impact data are available. The checks obtained are such that, if isolated, they would seem to corroborate the theory. The need for an impact basin is indicated.

NATIONAL BUREAU OF STANDARDS

The work on aircraft structures has been conducted in cooperation with the National Advisory Committee for Aeronautics and the Bureau of Aeronautics of the Navy Department.

Tensile and compressive stress-strain graphs of thin sheet metal.—With the development of the pack test, a large amount of data on compressive, as well as tensile, properties of thin sheet metal for aircraft has been accumulated at the National Bureau of Standards.

Strength of flush-riveted joints.—The program on static tests of flush-riveted joints has been extended to include single-rivet and multiple-rivet joints fabricated by the principal aircraft manufacturers, each manufacturer using his own type of joint and riveting technique.

Aging of aluminum rivet alloys.—Data on the increase in strength with aging of riveted joints and rivet wire were acquired as a byproduct of the investigation of riveted joints. Curves were obtained on four commonly used aluminum rivet alloys for the increase, with aging time up to 2½ years, of tensile and shearing strength of rivet wire, shearing strength of riveted joints, and driving stress required to form a standard cone-point head.

Aircraft tubing.—The second portion of the program on high-strength chromium molybdenum steel tubing of the type used in landing gears was completed by tests of 15 tubes with D/t ratios from 12 to 34 under combined axial and bending loads. The results indicate the errors involved in computing the strength of these tubes under combined load by various methods of interpolation between the strength under pure axial load and pure bending load.

Flat plates under normal pressure.—The program of normal pressure tests of flat plates has been completed with a report on rectangular plates. It was found that all results for rectangular plates with clamped edges could be plotted on a dimensionless basis to give an empirical relation between the washboarding pressure, i. e., the pressure at which yielding begins, the dimensions of the plate, and the tensile properties of the material.

Sheet-stringer panels.—End compression tests have been carried out on six spot-welded aluminum-alloy sheet-stringer panels which were identical except for a variation in spot-weld spacing from ½ to 4 inches between centers. Three of the panels failed by separation of spot welds at a stress appreciably below that for failure by stringer instability. The remaining three panels failed by stringer instability at a stress in agreement with an empirical chart prepared on the basis of tests on riveted panels.

Monocoque box under transverse load.—The second and third portions of the program of tests on monocoque boxes were completed with a stress survey of a monocoque box specimen under pure bending loads and cantilever bending loads. At low loads the strain distribution in the center portion of the box was found to agree closely with that calculated from the simple beam theory. Buckling of the sheet between stringers occurred at a stress in agreement with that observed in the end compression test described in Technical Note No. 721.

Fatigue tests of aluminum-alloy wing beams.—Axial fatigue tests of wing beams by the resonance method were continued with tests on additional specimens. These tests were run at relatively low stress amplitudes in order to obtain points on the stress versus cycles-to-failure curve which would indicate the fatigue limit of the assembled structure.

PART II

ORGANIZATION AND GENERAL ACTIVITIES

The National Advisory Committee for Aeronautics was established by act of Congress approved March 3, 1915, and the membership increased from 12 to 15 by act approved March 2, 1929 (U. S. C., title 50, sec. 151). Its membership is appointed by the President and consists of two representatives each of the War and Navy Departments from the offices in charge of military and naval aeronautics, two representatives of the Civil Aeronautics Administration (Civil Aeronautics Act of 1938), one representative each of the Smithsonian Institution, the United States Weather Bureau and the National Bureau of Standards, together with six additional persons who are "acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences." These latter six serve for terms of 5 years. All the members serve as such without compensation. During the past year the following changes occurred in the membership of the main Committee:

The term of office of Col. Charles A. Lindbergh expired December 1, 1939, and, pursuant to his own request, he was not reappointed.

To succeed Colonel Lindbergh, the President appointed Brig. Gen. Walter G. Kilner, United States Army, retired, formerly Assistant Chief of the Army Air Corps, for the 5-year term expiring December 1, 1944. General Kilner resigned on March 12, 1940, because of the fact that he had accepted a position with one of the aircraft manufacturers.

To fill the vacancy caused by General Kilner's resignation, the President, on March 26, 1940, appointed Dr. Robert E. Doherty, president of the Carnegie Institute of Technology, Pittsburgh, Pa., to serve the remainder of the term expiring December 1, 1944.

Hon. Clinton M. Hester, Administrator of Civil Aeronautics, on August 2, 1940, submitted his resignation as a member of the Committee as a representative of the Civil Aeronautics Authority, because of his retirement from his post as Administrator of Civil Aeronautics.

On September 5, 1940, the President appointed Col. Donald H. Connolly, Administrator of Civil Aeronautics, a member of the Committee to succeed Mr. Hester to serve as one of the two representatives of the Civil Aeronautics Administration provided by law.

Under the rules and regulations governing the work of the Committee, as approved by the President, the Chairman and Vice Chairman are elected annually, as are also the Chairman and Vice Chairman of the Executive Committee. On October 19th, 1939, Dr. Vannevar Bush was reelected Chairman and Dr. George J. Mead was reelected Vice Chairman of the main Committee. Dr. Bush was also reelected Chairman of the Executive Committee and Dr. Charles G. Abbot was reelected Vice Chairman of the Executive Committee.

The executive offices of the Committee, including the office of aeronautical intelligence and the office of aeronautical inventions, are located in the Navy Building, Washington, D. C., in close proximity to the air organizations of the Army and Navy.

The office of aeronautical intelligence was established in the early part of 1918 as an integral branch of the Committee's activities. It serves as the depository and distributing agency for the scientific and technical data on aeronautics comprising the results of fundamental Committee researches and also the scientific and technical information collected by the Committee from governmental and private agencies in this country and abroad. The data collected are classified, catalogued, and disseminated by this office.

On June 3, 1940, the headquarters of the Committee's technical assistant in Europe, Mr. John J. Ide, were transferred temporarily from the American Embassy in Paris to the American Legation at Berne, Switzerland. On June 14, 1940, the activities of the office of the technical assistant in Europe were suspended by the Committee, and Mr. Ide returned to the United States by air from Lisbon in July 1940.

RESEARCH FACILITIES

Langley Field, Va.—With the consistent support of the President and of the Congress, the Committee has developed at Langley Field, Va., a large and well-equipped aeronautical research laboratory, known as the Langley Memorial Aeronautical Laboratory.

At the present time, the Langley Field laboratory comprises the following units: The 8-foot, 500-mile-per-hour wind tunnel; the full-scale wind tunnel with a throat 60 by 30 feet; a 19-foot pressure wind tunnel; the 20-foot propeller-research tunnel; the 5-foot variable-density wind tunnel; a 7- by 10-foot wind tunnel; a 4- by 6-foot vertical wind tunnel; a 15-foot free-spinning wind tunnel; a 12-foot free-flight wind tunnel;

a refrigerated wind tunnel with a throat 7½ by 3 feet; two high-velocity jet-type wind tunnels of 11- and 24-inch throat diameters, respectively; the 2,900-foot NACA tank; an engine research laboratory; a flight research laboratory; an instrument laboratory; and administration, shop, and service buildings. The research facilities at Langley Field also include the following recent additions: A structures-research laboratory and a two-dimensional flow wind tunnel.

The Committee is proceeding to construct at Langley Field a stability wind tunnel, a 16-foot high-speed wind tunnel, a 20-foot free-spinning wind tunnel, a second seaplane-towing tank, an electric power generating plant, and extensions to the NACA hangar and administration building.

Moffett Field, Calif.—The Committee has in process of construction at Moffett Field, Calif., a second major research station, authorized by act approved August 9, 1939, at a total cost of not to exceed $10,000,000. Of this amount $6,090,980 has been appropriated by the Congress.

The laboratory was named on April 18, 1940, with the approval of the President, the Ames Aeronautical Laboratory in honor of Dr. Joseph S. Ames, past Chairman of the Committee and President Emeritus of the Johns Hopkins University at Baltimore, Md. Dr. Ames was one of the original members of the National Advisory Committee for Aeronautics appointed by President Wilson in 1915 and had served continuously for over 24 years as a member, including 20 years during which he was either Chairman of the main Committee or Chairman of its Executive Committee.

At the present time the Ames Aeronautical Laboratory comprises the following units: A flight-research laboratory and a shop building. The Committee is proceeding to construct a 16-foot wind tunnel, two 7- by 10-foot wind tunnels, a stock and utilities building, a science laboratory, an administration building. and other wind tunnels.

The Committee will conduct its research activities at this laboratory under a status similar to that under which it functions at Langley Field.

THIRD RESEARCH STATION

Reference was made in the previous annual report to the recommendation of the Special Survey Committee on Aeronautical Research Facilities, which, on October 19, 1939, recommended, "that an engine research laboratory be constructed at the earliest possible date." That committee was composed of Col. Charles A. Lindbergh, chairman; Maj. Gen. Henry H. Arnold, Chief of the Army Air Corps; Rear Admiral John H. Towers, Chief of the Bureau of Aeronautics, Navy Department; and Hon. Robert H. Hinckley, Chairman of the Civil Aeronautics Authority. The main committee immediately appointed a Special Committee on Engine Research Facilities to advise with the Director of Aeronautical Research and submit recommendations with regard to the scope of the proposed new engine research laboratory. This Special Committee on Engine Research Facilities was composed of the following:

Dr. George J. Mead, Chairman.
Commander Rico Botta, United States Navy.
Mr. Frank W. Caldwell, Hamilton Standard Propellers.
Mr. R. M. Hazen, Allison Engineering Company, Division of General Motors Corporation.
Mr. S. D. Heron, Ethyl Gasoline Corporation.
Mr. L. S. Hobbs, Pratt & Whitney Aircraft Corporation.
Mr. Carlton Kemper, Langley Memorial Aeronautical Laboratory.
Mr. Gaylord W. Newton, Civil Aeronautics Authority.
Mr. Arthur Nutt, Wright Aeronautical Corporation.
Maj. E. R. Page, Air Corps, United States Army.

The report of the Special Committee on Engine Research Facilities, dated January 23, 1940, presented a complete detailed plan for the equipment of the proposed engine research laboratory. This report was approved by the main Committee on February 7, 1940, and a supplemental estimate of appropriation was submitted to the Bureau of the Budget on March 7, 1940. After careful study in the Bureau of the Budget, the project was approved by the President and submitted to the Congress on May 20, 1940 (House Doc. No. 777, 76th Cong., 3d sess.).

After hearings before the House Appropriations Committee, the aircraft engine research laboratory was authorized by the Congress in the "First Supplemental National Defense Appropriation Act, 1941," approved June 26, 1940. That act appropriated $2,000,000 and carried contract authorization to a total of $8,400,000 for the construction and equipment of the proposed laboratory, including acquisition of a site to be selected by the committee. Seventy-two sites for the proposed laboratory were brought to the attention of the committee and were referred to a Special Committee on Site, consisting of Dr. Vannevar Bush, chairman, Dr. Lyman J. Briggs, Maj. Gen. George H. Brett, Army Air Corps, Capt. Sidney M. Kraus, United States Navy.

The Special Committee on Site determined the considerations to be evaluated and approved a schedule of weights. The characteristics of each of the seventy-two sites, as described in the proposals and as supplemented by interviews and inquiries, were subjected to careful analysis. The elements that were evaluated included the size, status and amount of air traffic on the flying field; the area available; the character of the soil; the acceptability of the site; water and sewage connections; vulnerability to air attack; adequacy and cost of electric power; proximity to a suitable industrial center; accessibility to the aircraft engine industry; accessibility to centers of scientific and technical activity; composition, cost, and quantity of water; climate and weather; and living and working conditions for employees.

A careful analysis of the sites offered impressed the committee with the fact that the proposed laboratory could be effectively operated in any one of a number of cities. A Special Subcommittee on Site Inspection was therefore appointed consisting of:

John F. Victory, chairman.

Capt. Donald J. Keirn, Air Corps, United States Army, Wright Field, Dayton, Ohio.

Lt. Comdr. John M. Rutherfurd, United States Navy, Bureau of Aeronautics.

Mr. Russell G. Robinson, of the Committee's engineering staff.

A total of 37 cities or localities was visited and inspections made of from 1 to 4 sites in each place. The reports on inspections were made without recommendations and were carefully considered by the Special Committee on Site. As additional information was received by mail and by interview it was incorporated in the record of each site. The Special Committee on Site, after five meetings and most careful consideration of all factors, made a unanimous recommendation to the main Committee, and the latter, after carefully reviewing the methods used and the evidence, and after prolonged discussion and questions, unanimously approved the report and recommendation of the Special Committee on Site to the effect that the site at the municipal airport at Cleveland, Ohio, was in its combination of advantages the site for the aircraft engine research laboratory that would best serve the nation's interests.

This decision was announced on November 25, 1940, and immediately the Committee started advertising for bids on construction.

The site selected consists of approximately 200 acres fronting on a first-class municipal airport and backed by a metropolitan park. The cost of the land is $500. The Committee will proceed with construction of the laboratory as rapidly as possible.

COOPERATION WITH THE AVIATION INDUSTRY

In the formulation of its research programs, the Committee includes provision for the problems of aeronautical research which are of particular importance to the aviation industry, in connection with both the design and operation of aircraft. The representatives of the industry refer their problems of this nature to the Committee as they arise, either by correspondence or through personal contact. The Committee avails itself of every opportunity to obtain suggestions and recommendations from representatives of the aircraft manufacturers and operators as to investigations which are deemed of special importance.

Because of the great increase in the number and importance of urgent research problems under investigation by the Committee and the greatly increased pressure of work resulting from the effort required in the design and construction of new research facilities, the Committee this year found it necessary to postpone its annual conference with representatives of the aircraft industry usually held at its laboratory at Langley Field, Va. In order to insure that this posponement would not result in depriving the industry of the Committee's assistance in the solution of urgent and important problems, the Committee arranged for the various aircraft manufacturers separately to send their representatives to the Langley Field laboratory for conferences with members of the Committee's staff to discuss important problems.

Realizing that frequently the value of information is greatly enhanced by its prompt availability, the Committee makes every effort to place the results of its researches at the earliest possible date in the hands of those units of the industry which have been designated by the Army or Navy to receive restricted or confidential information. It sometimes appears, in the course of an extensive investigation being conducted by the Committee, that the results so far obtained will be of special interest and value to the aircraft industry if made available immediately. In such cases the Committee issues the information in advance confidential form.

CONSIDERATION OF AERONAUTICAL INVENTIONS

By act of Congress approved July 2, 1926, an Aeronautical Patents and Design Board was established consisting of Assistant Secretaries of the Departments of War, Navy, and Commerce. In accordance with that act as amended by the act approved March 3, 1927, the National Advisory Committee for Aeronautics passes upon the merits of aeronautical inventions and designs submitted to any aeronautical division of the Government, and submits reports thereon to the Aeronautical Patents and Design Board. That board is authorized, upon the favorable recommendation of the Committee, to "determine whether the use of the design by the Government is desirable or necessary and evaluate the design and fix its worth to the United States in an amount not to exceed $75,000."

During the past year the inventions section received correspondence relating to about 2,650 inventions and designs pertaining to the aeronautical art. All of these proposals were given careful consideration and evaluated. The necessary correspondence was conducted to advise the submitters of the evaluations and interviews were granted inventors to discuss new proposals and their merits.

COORDINATION OF AERONAUTICAL RESEARCH

As recommended by a special committee appointed in 1939 to study the problem of coordination of all aeronautical research activities in the United States, a

Coordinator of Research, Mr. S. Paul Johnston, was appointed January 9, 1940. A coordination office was set up in the Committee's headquarters in Washington, and provisions made for a resident coordination representative on the West Coast. In order to maintain close contact with manufacturers and in order to keep in touch with all organizations, governmental and private, that operate research facilities, the coordination staff has during the year made approximately the following number of visits:

75 visits to schools and universities.
130 visits to aircraft manufacturers.
30 visits to aircraft engine manufacturers.
65 visits to miscellaneous accessories and materials manufacturers.
10 visits to governmental laboratories (other than NACA).

This work has not been restricted to any particular area in the United States but has included every locality where anything of significance in aeronautical progress is known to be under way. Reports submitted to the laboratory by the coordination staff in the field have been extremely valuable in providing closer contacts between the research personnel of the NACA and the aircraft and engine industries.

A number of special problems are being handled through the Coordination Office. Among them are: (*a*) A spot-welding research program on aluminum alloys in cooperation with the Army, the Navy, the National Bureau of Standards, and the Welding Research Committee; (*b*) an analysis of engine power ratings and engine accidents in cooperation with the C. A. A., and the National Defense Advisory Commission; (*c*) an investigation of current design practice with respect to ducting for cooling engines and power plant accessories, (*d*) a survey of current opinion and practice in the industry regarding standardized and interchangeable power plant assemblies; (*e*) a continuation of the investigation of the use of plastic materials and plastic bonded plywoods for the Army and Navy, in cooperation with the National Bureau of Standards, the Forest Products Laboratory, and other Government agencies. Where it seemed desirable, conferences have been arranged at various places, including the Langley Field laboratory, and arrangements have been made frequently for laboratory personnel to visit industry units on special problems of urgent interest to national defense.

AERONAUTICAL RESEARCH IN EDUCATIONAL INSTITUTIONS

One of the main duties with which the Coordinator of Research is charged is the utilization to the maximum advantage to the United States of available research facilities in educational and scientific institutions. Early in 1940 an extensive survey was made by a questionnaire of educational institutions in the United States that were known to have facilities that had any bearing on aeronautical research. There is now on file in the Washington office full information on the equipment and personnel of some 75 schools. Many of these schools have been visited personally by the Coordinator or his staff as a check on the material submitted in response to the questionnaire.

During the course of the year, suggestions have been solicited from Government agencies and from the aircraft and engine industries for research problems suitable for university laboratory allocation. Although many proposals for research are still being initiated by universities, it is the policy of the coordination division to suggest to such private laboratories problems that fit into the requirements of the Government.

With funds available under the 1941 appropriations, some 30 research projects have been set up in various university laboratories, subdivided as follows:

	Projects
Aerodynamics	6
Structures	10
Materials	5
Power plants	9

A number of proposals are now under consideration by the various subcommittees, which, by January 1941, will absorb the entire balance of funds available for the current fiscal year. In view of the large number of research projects that have bearing on the defense programs, increased appropriations for the support of research in scientific and educational institutions have been requested for the fiscal year 1942.

SUBCOMMITTEES

The National Advisory Committee for Aeronautics has organized standing technical committees, with subcommittees, for the purpose of coordinating the research needs of aviation and preparing research programs in their respective fields. The four main technical Committees on Aerodynamics, Power Plants for Aircraft, Aircraft Materials, and Aircraft Structures, with their subcommittees, recommend the programs for aeronautical research conducted by the Committee's laboratories and those conducted by other agencies. Under the Committee on Aerodynamics two additional standing subcommittees have recently been organized to provide for studies in particular fields of aerodynamic research, namely, the Subcommittee on Propellers for Aircraft and the Subcommittee on Rotating-Wing Aircraft.

As previously stated, it is the policy of the Committee to establish from time to time special technical subcommittees for the study of particular problems as they arise. To meet the increasing needs of the military services and the industry, three new special subcommittees have been appointed during the past year under the Committee on Power Plants for Aircraft. These are the Subcommittees on Supercharger Compressors, Exhaust-Gas Turbines and Intercoolers, and Induction-System De-Icing.

The work of the standing and special technical committees and subcommittees has been described in part I. The organization of all the Committee's subcommittees is as follows:

COMMITTEE ON AERODYNAMICS

Dr. Edward Warner, Chairman.
Mr. Edmund T. Allen, Boeing Aircraft Co.
Maj. Howard Z. Bogert, Air Corps, United States Army, Matériel Division, Wright Field.
Lt. Col. Franklin O. Carroll, Air Corps, United States Army, Matériel Division, Wright Field.
Mr. Charles H. Chatfield, United Aircraft Corporation.
Commander Walter S. Diehl, United States Navy.
Dr. Hugh L. Dryden, National Bureau of Standards.
Mr. John Easton, Civil Aeronautics Administration.
Mr. J. T. Gray, Civil Aeronautics Administration.
Mr. Eastman N. Jacobs, National Advisory Committee for Aeronautics.
Mr. S. Paul Johnston, National Advisory Committee for Aeronautics (ex-officio member).
Prof. Otto Koppen, Massachusetts Institute of Technology.
Dr. George W. Lewis, National Advisory Committee for Aeronautics (ex-officio member).
Dr. Clark B. Millikan, California Institute of Technology.
Mr. Robert R. Osborn, Vultee Aircraft, Inc.
Commander F. W. Pennoyer, Jr., United States Navy.
Mr. H. J. E. Reid, National Advisory Committee for Aeronautics.
Mr. Fred E. Weick, Engineering and Research Corporation.
Mr. John B. Wheatley, The Glenn L. Martin Co.
Mr. Theodore P. Wright, Curtiss-Wright Corporation.

SUBCOMMITTEE ON AIRSHIPS

Dr. J. C. Hunsaker, Chairman.
Starr Truscott, National Advisory Committee for Aeronautics, Vice Chairman.
John Easton, Civil Aeronautics Administration.
Capt. Garland Fulton, United States Navy.
Lt. Col. C. F. Greene, Air Corps, United States Army, Matériel Division, liaison officer at NACA Laboratory.
S. Paul Johnston, National Advisory Committee for Aeronautics (ex-officio member).
Dr. George W. Lewis, National Advisory Committee for Aeronautics (ex-officio member).

SUBCOMMITTEE ON METEOROLOGICAL PROBLEMS

Dr. F. W. Reichelderfer, Chairman.
Col. E. S. Gorrell, Air Transport Association of America.
Dr. W. J. Humphreys, United States Weather Bureau.
Dr. J. C. Hunsaker, Massachusetts Institute of Technology.
S. Paul Johnston, National Advisory Committee for Aeronautics (ex-officio member).
R. W. Knight, Civil Aeronautics Adminstration.
Dr. George W. Lewis, National Advisory Committee for Aeronautics (ex-officio member).
Delbert M. Little, United States Weather Bureau.
Dr. Charles F. Marvin, Washington, D. C.

Capt. Arthur F. Merewether, Air Corps, United States Army.
Lt. Comdr. Howard T. Orville, United States Navy.
Mr. Richard V. Rhode, National Advisory Committee for Aeronautics.
Dr. C. G. Rossby, United States Weather Bureau.

SPECIAL SUBCOMMITTEE ON LIGHTNING HAZARDS TO AIRCRAFT

Delbert M. Little, United States Weather Bureau, Chairman.
Dr. O. H. Gish, Carnegie Institution of Washington.
Lt. Comdr. Robert S. Hatcher, United States Navy.
Charles H. Helms, National Advisory Committee for Aeronautics.
S. Paul Johnston, National Advisory Committee for Aeronautics (ex-officio member).
Dr. George W. Lewis, National Advisory Committee for Aeronautics (ex-officio member).
K. B. McEachron, General Electric Co.
Irving R. Metcalf, Civil Aeronautics Administration.
E. J. Minser, Transcontinental & Western Air, Inc.
Captain C. K. Moore, Air Corps, United States Army, Matériel Division, Wright Field.
Dr. F. B. Silsbee, National Bureau of Standards.

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Lt. Albert B. Scoles, United States Navy.
R. L. Templin, Aluminum Co. of America.
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Grove Webster, Civil Aeronautics Administration.

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Dr. Jerome C. Hunsaker.
Capt. Sydney M. Kraus, United States Navy.
John F. Victory, Secretary.

COMMITTEE ON PERSONNEL, BUILDINGS, AND EQUIPMENT

Dr. Vannevar Bush, Chairman.
Dr. Charles G. Abbot.
Dr. George J. Mead.
John F. Victory, Secretary.

SPECIAL COMMITTEE ON SITE FOR AIRCRAFT ENGINE-RESEARCH LABORATORY

During the past year, a Special Committee on Site, with the following membership, was appointed to determine the location best suited to the needs of the proposed new aircraft engine-research laboratory:

Dr. Vannevar Bush, Chairman.
Maj. Gen. George H. Brett, Air Corps, United States Army.
Dr. Lyman J. Briggs.
Capt. Sydney M. Kraus, United States Navy.

TECHNICAL PUBLICATIONS OF THE COMMITTEE

The Committee has four series of publications, namely, technical reports, technical notes, technical memorandums, and aircraft circulars.

The technical reports present the results of fundamental research in aeronautics. The technical notes are mimeographed and present the results of short research investigations and the results of studies of specific detailed problems which form parts of long investigations. The technical memorandums are mimeographed and contain translations and reproductions of important foreign aeronautical articles. The aircraft circulars are mimeographed and contain descriptions of new types of foreign aircraft. No aircraft circulars were issued during the past year.

Because of the present national emergency, and at the request of the Army and the Navy, the technical reports and technical notes of the Committee were on June 1, 1940, placed in a restricted status, and as such are not available for general distribution.

The following are lists of the publications released during the past year:

TECHNICAL REPORTS

No.
681. The Unsteady Lift of a Wing of Finite Aspect Ratio. By Robert T. Jones.
682. Flame Speeds and Energy Considerations for Explosions in a Spherical Bomb. By Ernest F. Fiock, Charles F. Marvin, Jr., Frank R. Caldwell, and Carl H. Roeder.
686. Stability of Castering Wheels for Aircraft Landing Gears. By Arthur Kantrowitz.

TECHNICAL NOTES

731. Tests in the Gust Tunnel of a Model of the XBM–1 Airplane. By Philip Donely and C. C. Shufflebarger.
732. A Simple Method of Obtaining Span Load Distributions. By Albert Sherman.
733. Experimental Study of Torsional Column Failure. By Alfred S. Niles.
734. Pressure-Distribution Investigation of an N. A. C. A. 0009 Airfoil with a 50-Percent-Chord Plain Flap and Three Tabs. By William G. Street and Milton B. Ames, Jr.
735. Pressure-Distribution Measurements on a Tapered Wing with a Partial-Span Split Flap in Curved Flight. By Th. Troller and F. Rokus.
736. Tidewater and Weather-Exposure Tests on Metals Used in Aircraft. By Willard Mutchler and W. G. Galvin.
737. Photoelastic Analysis of Three-Dimensional Stress Systems Using Scattered Light. By R. Weller and J. K. Bussey.
738. Corrugated Metal Diaphragms for Aircraft Pressure-Measuring Instruments. By W. A. Wildhack and V. H. Goerke.
739. A Recurrence Formula for Shear-Lag Problems. By Paul Kuhn.
740. Stress Concentration Around an Open Circular Hole in a Plate Subjected to Bending Normal to the Plane of the Plate. By C. Dumont.
741. Observations in Flight of the Region of Stalled Flow over the Blades of an Autogiro Rotor. By F. J. Bailey, Jr., and F. B. Gustafson.
742. Pressure-Distribution Measurements on a Rectangular Wing with a Partial-Span Split Flap in Curved Flight. By Frank G. Rokus.
743. Local Instability of Columns with I-, Z-, Channel, and Rectangular-Tube Sections. By Elbridge Z. Stowell and Eugene E. Lundquist.
744. The Development of Electrical Strain Gages. By A. V. de Forest and H. Leaderman.
745. Tests of a Gust-Alleviating Flap in the Gust Tunnel. By Philip Donely and C. C. Shufflebarger.
746. The Frequencies of Cantilever Wings in Beam and Torsional Vibrations. By C. P. Burgess.
747. Propeller Rotation Noise Due to Torque and Thrust. By Arthur F. Deming.
748. Principles, Practice, and Progress of Noise Reduction in Airplanes. By Albert London.
749. A New Method of Studying the Flow of the Water Along the Bottom of a Model of a Flying-Boat Hull. By Kenneth E. Ward.
750. A Generalized Vortex Theory of the Screw Propeller and Its Application. By Hans Reissner.
751. Damping Formulas and Experimental Values of Damping in Flutter Models. By Robert P. Coleman.
752. An Investigation of Sheet-Stiffener Panels Subjected to Compression Loads with Particular Reference to Torsionally Weak Stiffeners. By Louis G. Dunn.
753. Measurement of the Forces Acting on Gliders in Towed Flight. By W. B. Klemperer.
754. An Investigation of the Prevention of Ice on the Airplane Windshield. By Lewis A. Rodert.
755. Wind-Tunnel Investigation of an N. A. C. A. 23030 Airfoil with Various Arrangements of Slotted Flaps. By I. G. Recant.
756. The Effect of Piston-Head Shape, Cylinder-Head Shape, and Exhaust Restriction, on the Performance of a Piston-Ported Two-Stroke Cylinder. By A. R. Rogowski, C. L. Bouchard, and C. Fayette Taylor.
757. A Study of Unsymmetrical-Loading Conditions. By Henry A. Pearson.
758. Measurements and Analysis of the Motion of a Canard Airplane Model in Gusts. By Philip Donely, Harold B. Pierce, and Philip W. Pepoon.
759. Pressure-Distribution Investigation of a N. A. C. A. 0009 Airfoil with a 30-Percent-Chord Plain Flap and Three Tabs. By Milton B. Ames, Jr., and Richard I. Sears.

760. A Full-Scale Investigation of the Effect of Several Factors on the Shimmy of Castering Wheels. By Walter B. Howard, Jr.

761. Pressure-Distribution Investigation of an N. A. C. A. 0009 Airfoil with an 80-Percent-Chord Plain Flap and Three Tabs. By Milton B. Ames, Jr., and Richard I. Sears.

762. The Flow of a Compressible Fluid Past a Sphere. By Carl Kaplan.

763. Wind-Tunnel Investigation of Two Airfoils with 25-Percent-Chord Gwinn and Plain Flaps. By Milton B. Ames, Jr.

TECHNICAL MEMORANDUMS

912. Increase of the Specific Load Under Tension, Compression, and Buckling of Welded Steel Tubes in Airplane Construction by Suitable Treatment of Structural Steel and by Proper Design. By J. Müller. From Luftfahrtforschung, Vol. 16, No. 1, January 10, 1939.

913. Measurement of the True Dynamic and Static Pressures in Flight. By Georg Kiel. From Luftfahrtforschung, Vol. 15, No. 12, December 10, 1938.

914. Engine Knock and Combustion Chamber Form. By Karl Zinner. From Automobiltechnische Zeitschrift, Vol. 42, No. 9, May 15, 1939.

915. Experimental and Analytical Investigation of a Monocoque Wing Model Loaded in Bending. By E. Schapitz, H. Feller, and H. Köller. From Luftfahrtforschung, Vol. 15, No. 12, December 10, 1938.

916. Activation of Hydrocarbons and the Octane Number. By Marcel Peschard. From Publications Scientifiques et Techniques du Ministere de l'Air, No. 132, 1938.

917. The Effect of Compressibility on the Pressure Reading of a Prandtl Pitot Tube at Subsonic Flow Velocity. By O. Walchner. From Deutche Luftfahrtforschung Jahrbuch, 1938.

918. The Enlarged N. A. C. A. Tank, and Some of Its Work. By Starr Truscott. From supplementary volume to Jahrbuch 1938 der deutschen Luftfahrtforschung. (Containing papers presented at Lilienthal Gesellschaft für Luftfahrtforschung, Oct. 1938.)

919. Report on Ice Formation on Aircraft. By the French Committee for the Study of Ice Formation, May 19, 1938. From Bulletin des Services Techniques No. 85, Publications Scientifiques et Techniques du Ministere de l'Air.

920. The Effect of the Slipstream on an Airplane Wing. By A. Franke and F. Weinig. From Luftfahrtforschung, Vol. 15, No. 6, June 6, 1938.

921. Contribution to the Aerodynamics of Rotating-Wing Aircraft. By G. Sissingh. From Luftfahrtforschung, Vol. 15, No. 6, June 6, 1938.

922. The Breda Wind Tunnel. By Mario Pittoni. From Auto Moto Avio, No. 5, March 1939.

923. Measurement of the Air-Flow Velocity in the Cylinder of an Airplane Engine. By Hermann Wenger. From Luftfahrtforschung, Vol. 16, No. 2, February 20, 1939.

924. Modern Methods of Fuel Testing. By F. Seeber. From Luftfahrtforschung, Vol. 16, No. 8, August 20, 1939.

925. Effect of Wing Loading, Aspect Ratio, and Span Loading on Flight Performances. By B. Göthert. From Luftfahrtforschung, Vol. 16, No. 5, May 20, 1939.

926. DFS Dive-Control Brakes for Gliders and Airplanes. By Hans Jacobs and Adolf Wanner; and Analytical Study of the Drag of the DFS Dive-Control Brake. By Adolf Wanner. From Jahrbuch 1938 der deutschen Luftfahrtforschung; Luftwissen, Vol. 4, No. 7, July 1937; and Luftwissen, Vol. 6, No. 5, May 1939.

927. Constant-Pressure Blowers. By E. Sörensen. From Zeitschrift des Vereines deutscher Ingenieure, Vol. 83, No. 32, August 12, 1939.

928. Knocking in an Internal-Combustion Engine. By A. Sokolik and A. Voinov. From Technical Physics of the U. S. S. R., Vol. 3, No. 9, 1936.

929. Aerodynamics of Rotating-Wing Aircraft with Blade-Pitch Control. By A. Pflüger. From Luftfahrtforschung, Vol. 16, No. 7, July 20, 1939.

930. Experimental Contribution to the Study of Combustion in Compression-Ignition Engines. By R. Duchene. From Publications Scientifiques et Techniques du Ministere de l'Air, No. 149, 1939.

931. Testing of High-Octane Fuels in the Single-Cylinder Airplane Engine. By Fritz Seeber. From Luftfahrtforschung, Vol. 16, No. 1, January 10, 1939.

932. Theoretical and Experimental Investigations of the Drag of Installed Aircraft Radiators. By W. Barth. From Proceedings of the Fifth International Congress for Applied Mechanics, Cambridge, Mass., September 12–16, 1938.

933. The Strength of Shell and Tubular Spar Wings. By H. Ebner. From Luftfahrtforschung, Vol. 14, Nos. 4 and 5, April 20, 1937.

934. Application of the Methods of Gas Dynamics to Water Flows with Free Surface. Part I. Flows with No Energy Dissipation. By Ernst Preiswerk. From Institut für Aerodynamik, Eidgenössiche Technische Hochschule, Zurich, No. 7, 1938.

935. Application of the Methods of Gas Dynamics to Water Flows with Free Surface. Part II. Flows with Momentum Discontinuities (Hydraulic Jumps). By Ernst Preiswerk. From Institut für Aerodynamik, Eidgenössiche Technische Hochschule, Zurich, No. 7, 1938.

936. Measurement of Knock Characteristics in Spark-Ignition Engines. By R. Schütz. From Automobiltechnische Zeitschrift, Vol. 42, No. 13, July 10, 1939.

937. Stresses in Single-Spar Wing Constructions with Incompletely Built-Up Ribs. By F. Reinitzhuber. From Luftfahrtforschung, Vol. 16, No. 7, July 20, 1939.

938. The Shock-Absorbing System of the Airplane Landing Gear. By Pietro Callerio. From L'Aerotecnica, Vol. 19, No. 6, June 1939.

939. The Torsion of Box Beams with One Side Lacking. By E. Cambilargiu. From Luftfahrtforschung, Vol. 16, No. 8, August 20, 1939.

940. The Lead Susceptibility of Fuels and Its Dependence on the Chemical Composition. By O. Widmaier. From Automobiltechnische Zeitschrift, Vol. 43, No. 3, February 10, 1940.

941. Some Data on the Static Longitudinal Stability and Control of Airplanes (Design of Control Surfaces). By A. Martinov and E. Kolosov. From Central Aero-Hydrodynamical Institute, Moscow, 1936. Report No. 278.

942. On the Theory of Unsteady Planing and the Motion of a Wing with Vortex Separation. By L. Sedov. From Central Aero-Hydrodynamical Institute, Moscow, 1936. Report No. 252.

943. Tests of Lead-Bronze Bearings in the DVL Bearing-Testing Machine. By G. Fischer. From Luftfahrtforschung, Vol. 16, No 7, July 20, 1939.

944. Italian High-Speed Airplane Engines. By C. F. Bona. (Paper presented at Volta meeting in Italy, Sept. 30, to Oct. 6, 1935.)

945. Experiments on Ball and Roller Bearings under Conditions of High Speed and Small Oil Supply. By Günter Getzlaff. From Jahrbuch 1938 der deutschen Luftfahrtforschung.

946. Experimental Results with Airfoils Tested in the High-Speed Tunnel at Guidonia. By Antonio Ferri. From Atti di Guidonia, No. 17, September 20, 1939.
947. New Equipment for Testing the Fatique Strength of Riveted and Welded Joints. By W. Müller. From special reprint of Schweizer Archiv, No. 10, 1937.
948. A Simple Approximation Method for Obtaining the Spanwise Lift Distribution. By O. Schrenk. From Luftwissen, Vol. 7, No. 4, April 1940.
949. The Maximum Delivery Pressure of Single-Stage Radial Superchargers for Aircraft Engines. By W. von der Null. From Luftwissen, Vol. 7, No. 5, May 1940.
950. Buckling Tests with a Spar-Rib Grill. By Josef Weinhold. From Luftfahrtforschung, Vol. 17, No. 3, March 20, 1940.
951. Variation in Velocity Profile with Change in Surface Roughness of Boundary. By W. Jacobs. From Zeitschrift für angewandte Mathematik und Mechanik, Vol. 19, No. 2, April 1939.
952. Standards for Discharge Measurement with Standardized Nozzles and Orifices. German Industrial Standard 1952. Fourth edition. From VDI–Verlag G. m. b. H., Berlin, 1937.
953. Pressure and Temperature Measurement in Supercharger Investigations. By A. Franz. From Jahrbuch 1938 der deutschen Luftfahrtforschung.
954. Limits of Single-Stage Compression in Centrifugal Superchargers for Aircraft. By K. Kollmann. From Luftwissen, Vol. 7, No. 3, March 1940.

FINANCIAL REPORT

APPROPRIATIONS FOR FISCAL YEAR 1940

The general appropriation for the National Advisory Committee for Aeronautics for the fiscal year 1940, as contained in the Independent Offices Appropriation Act approved March 16, 1939, was $1,717,000. A supplemental appropriation of $223,980 was made available in the Second Deficiency Appropriation Act, fiscal year 1939, approved May 2, 1939, for the same purposes specified in the Committee's regular appropriation act for 1939, to continue available until June 30, 1940. The amount expended during fiscal year 1939 from this fund was $29,434, leaving a balance of $194,546 available for expenditure during fiscal year 1940. An additional amount of $109,020 was made available in the Third Deficiency Appropriation Act, fiscal year 1939, approved August 9, 1939, for the same purposes specified in the Committee's regular appropriation act for 1940. The total amount available for general purposes during the fiscal year 1940, therefore, was $2,020,566. The amount expended during 1940 was $2,020,557, itemized as follows:

Personal services	$1, 388, 881
Supplies and materials	134, 184
Communication service	4, 999
Travel expenses	19, 925
Transportation of things	3, 463
Furnishing of electricity	54, 001
Repairs and alterations	22, 730
Special and miscellaneous investigations	70, 000
Contracts for research	25, 000
Equipment	$297, 374
Expended and obligated	2, 020, 557
Unexpended balance	9
Total, general appropriation	2, 020, 566

The appropriation for printing and binding for 1940 was $23,000, of which $22,991 was expended.

The Independent Offices Appropriation Act approved March 16, 1939, also provided $340,000 for the completion at Langley Field of the two-dimensional wind tunnel for which an initial appropriation of $200,000 was provided in the 1939 act, and $100,000 for modernization of the free-spinning tunnel. The total amount, $440,000, was obligated during the fiscal year 1940 for the purposes specified.

The Second Deficiency Appropriation Act approved May 2, 1939, also provided $2,140,000 for the construction and equipment of additional facilities at Langley Field, Va., including connections to public utilities, and rights-of-way for, and installation of power lines, this amount to remain available until expended. No obligations were placed under this fund during the fiscal year 1939. During the fiscal year 1940, the amount of $1,776,053 was obligated under this fund.

The Third Deficiency Appropriation Act approved August 9, 1939, also provided $1,890,980 for beginning construction of an additional research laboratory and authorized the Committee to enter into contracts for construction and equipment, including the purchase of land, not to exceed a total of $10,000,000. Moffett Field, Calif., was selected as the site of this additional laboratory, which is known as the Ames Aeronautical Laboratory, and the amount of $2,601,156 was obligated during 1940 for construction and equipment.

The amount of $37,089 was received during the fiscal year 1940 and credited to eleven special deposit accounts to cover the cost of scientific investigations for aircraft manufacturers. Nine investigations were completed during 1940, resulting in the deposit in the Treasury of $23,466 to the credit of miscellaneous receipts, as proceeds, and the return of unexpended balances totaling $3,724 to depositors.

An allotment of $250 was received from the State Department for payments during the fiscal year 1940 to employees stationed abroad, on account of exchange losses due to appreciation of foreign currencies. Of this amount $145 was paid during the fiscal year 1940 to employees of the Committee stationed in the Paris office, leaving a balance of $105 which was turned back into the Treasury.

APPROPRIATIONS FOR FISCAL YEAR 1941

The general appropriation for the fiscal year 1941, as contained in the Independent Offices Appropriation

Act approved April 18, 1940, was $2,775,000, and the amount provided for printing and binding was $25,000. This act also provided $1,000,000 for construction and equipment of additional facilities at Langley Field, Va., and $4,200,000 for continuing construction and equipment of the new Ames Aeronautical Laboratory at Moffett Field, Calif. The total amount provided for the Committee in this act therefore was $8,000,000.

The First Supplemental National Defense Appropriation Act, 1941, approved June 26, 1940, provided $2,000,000 for construction and equipment of an airplane engine-research laboratory, including acquisition of land at a site to be selected by the Committee, rights-of-way, and connections to public utilities, installation of power lines, etc., and authorized entering into contracts not to exceed a total cost of $8,400,000. This act also provided $1,200,000 for construction and equipment of a generating power plant at Langley Field, Va. No obligations were placed under these funds during the fiscal year 1940.

CONCLUSION

Scientific research is the most fundamental activity of the Government in connection with the development of America's potential strength in the air. No matter how greatly production facilities may be increased, no matter how many pilots may be trained, unless the aircraft that are built for action are at least equal in performance to those of any possible enemy, the whole effort will be largely wasted.

It is the responsibility of the National Advisory Committee for Aeronautics to anticipate the research needs of aviation, and the progress that can be made, and to provide the Army, the Navy, and the industry in the United States with a constant flow of the new knowledge that is essential to American leadership in aircraft performance.

With the continued farsighted support of the President and of the Congress, the Committee's research facilities, as yet concentrated chiefly at Langley Field, Va., are being greatly strengthened by the construction of the Ames Aeronautical Laboratory for aerodynamic research at Moffett Field, Calif., and of an aircraft engine-research laboratory at Cleveland, Ohio. The former is still largely in the construction stage, and the building of the latter has hardly begun. As these additional facilities are urgently needed, construction is being pushed with all possible vigor. When these facilities come into full operation, the country will have much better assurance that America will be able to keep in advance of the technical developments in aeronautics in other countries.

In the scientific study of the problems of flight, the talent of America has been marshalled through the technical subcommittees and through the stimulation and coordination of research in scientific and educational institutions. Progress in military and naval aviation will find reflection in improved performance, efficiency, and safety of civil and commercial aviation. The Committee believes that commercial aviation will prove of ever-increasing importance to the United States in promoting international trade and good will, especially in the Western Hemisphere. When the present wars have ended, aviation will have an opportunity to prove its real value to civilization in shortening the distances between nations and in facilitating international trade and commerce. When that day comes, the extension of world trade routes of the air will bring some compensation for the awful destruction wrought and to be wrought by military aviation before peace again prevails.

Respectfully submitted.

National Advisory Committee
for Aeronautics,
Vannevar Bush, *Chairman.*