THIRTY-SECOND ANNUAL REPORT

OF THE

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

1946

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Letter of Submittal

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
Washington, D. C., January 10, 1947.

DEAR MR. PRESIDENT: In compliance with the provisions of the Act of Congress approved March 3, 1915 (U. S. C. title 49 sec. 243), I have the honor to submit herewith the Thirty-second Annual Report of the National Advisory Committee for Aeronautics, covering the fiscal year 1946.

The circumstances of war prevented detailed reports of the NACA's activities during the war years. It is the aim of this report to present a concise picture of significant activities since 1940. The financial report relating to 1946 is included in this document. Financial reports and summaries relating to the years intervening between the Twenty-eighth Annual Report published in 1942 and the present will follow.

The close of the war marked the end of one whole phase of development of the airplane as conceived by the Wright brothers. The airplane in its present form is no longer a sound basis for future planning for the national defense. The power available in jet propulsion systems brings flight through and above the speed of sound within reach. Yet, the attainment of practical flight at such speeds requires the application of new knowledge which must be obtained by diligent research with new tools and new methods. As with the Wright brothers at the first flight, we stand at a new frontier where research to establish the scientific principles and laws governing high-speed flight will determine our future in the air.

Respectfully submitted.

JEROME C. HUNSAKER,
Chairman.

THE PRESIDENT,
The White House, Washington, D. C.

National Advisory Committee for Aeronautics

Headquarters, 1500 New Hampshire Avenue NW, Washington 25, 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 49, sec. 241). 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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EDWARD R. SHARP, LL. B., Manager, Aircraft Engine Research Laboratory, Cleveland Airport, Cleveland, Ohio

CARLTON KEMPER, B. S., Executive Engineer, Aircraft Engine Research Laboratory, Cleveland Airport, Cleveland, Ohio

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TECHNICAL COMMITTEES

AERODYNAMICS
POWER PLANTS FOR AIRCRAFT
AIRCRAFT CONSTRUCTION
OPERATING PROBLEMS
MATERIALS RESEARCH COORDINATION
SELF-PROPELLED GUIDED MISSILES
SURPLUS AIRCRAFT RESEARCH
INDUSTRY CONSULTING COMMITTEE

Coordination of Research Needs of Military and Civil Aviation

Preparation of Research Programs

Allocation of Problems

Prevention of Duplication

Consideration of Inventions

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AMES AERONAUTICAL LABORATORY, Moffett Field, Calif.

AIRCRAFT ENGINE RESEARCH LABORATORY, Cleveland Airport, Cleveland, Ohio

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

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OFFICE OF AERONAUTICAL INTELLIGENCE, Washington, D. C.

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

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS: Meeting, Washington, D. C., October 24, 1946. Left to right: Dr. E. U. Condon, Director, National Bureau of Standards; Dr. Alexander Wetmore, Secretary, Smithsonian Institution; Maj. Gen. E. M. Powers, Ass't Chief of Air Staff-4, Army Air Forces; Gen. Carl Spaatz, Commanding General, Army Air Forces; Dr. Vannevar Bush, Chairman, Joint Research and Development Board; Dr. Orville Wright; A. E. Raymond, Vice President, Engineering, Douglas Aircraft Co.; R. M. Hazen, Chief Engineer, Allison Division, General Motors Corp.; Dr. J. C. Hunsaker, Chairman, NACA; Dr. G. W. Lewis, Director of Aeronautical Research, NACA; J. W. Crowley, Ass't Director of Aeronautical Research, NACA; J. F. Victory, Executive Secretary, NACA; W. A. M. Burden, Assistant Secretary of Commerce; Rear Admiral L. B. Richardson, Ass't Chief, Bureau of Aeronautics, Navy Department; Dr. T. P. Wright, Civil Aeronautics Administrator, Vice Chairman, NACA; William Littlewood, Vice President, Engineering, American Airlines; Dr. F. W. Reichelderfer, Chief, U. S. Weather Bureau. (Vice Admiral Radford, Deputy Chief, Naval Operations, Air, U. S. Navy, not present.)

THIRTY-SECOND ANNUAL REPORT
OF THE
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Washington, D. C., November 21, 1946.

To the Congress of the United States:

IN accordance with the act of Congress approved March 3, 1915 (U. S. C. title 49, sec. 241), which established the National Advisory Committee for Aeronautics, the Committee submits herewith its Thirty-second annual report for the fiscal year 1946. Because the Committee's reports were suspended during the war years, the present report comprises a summary of important activities since the last published report, for 1942. It will be followed by brief reports for the intervening years.

The National Advisory Committee for Aeronautics is the Government agency charged with responsibility for scientific aeronautical research. It was established by the Congress in 1915 to "supervise and direct the scientific study of the problems of flight with a view to their practical solution," and was authorized to "direct and conduct research and experiment in aeronautics" in such laboratory or laboratories in whole or in part as may be placed under its direction.

To discharge its responsibilities, the NACA must endeavor to forecast the trend of aeronautical development, civil and military; to anticipate the research problems that will arise; to design and provide the special research facilities as needed to solve the problems; to coordinate the fundamental research programs of the Government; to conduct fundamental scientific investigations in its own laboratories, and to encourage and support research in scientific and educational institutions. The results of the Committee's research, in the form of consultations and reports, are made available to the military services and other governmental establishments, to industry, to air transport operators, to scientific and educational institutions and libraries, and to others concerned.

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 operating problems, and aircraft construction. 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 and to the Forest Products Laboratory when it is to the advantage of the Government to do so in order effectively to utilize existing governmental facilities. Problems are also assigned, by research contracts, to scientific and educational institutions. This policy, the Committee believes, makes effective use of non-governmental research facilities, stimulates and coordinates aeronautical research, and also has the advantage of training research personnel.

The Committee also has established an industry consulting committee to guide its fundamental research toward objectives of optimum value in meeting the needs of industry for fundamental information necessary in the design of aircraft of higher performance.

The state of basic aeronautical knowledge must be kept well in advance of application in order that the needs of the Nation may be served.

The results of the research efforts of the Committee have a broad influence on the national security and national economy. The fundamental aeronautical data thus provided are basically important to the forward planning of the development programs of the military services and the aircraft manufacturing and operating industries. This basic information insures not only the procurement of efficient air weapons for national defense, but also safer, faster, and more economical aircraft for the rapidly expanding air transport services, and safer, more efficient, and more useful airplanes for the rapidly expanding private flying activities in the United States.

During the war, the NACA devoted virtually its whole effort to making this country's aeronautical

weapons more effective than the enemy's. This amounted to sacrifice of the future to the present.

In the recent war, the chief offensive weapon was the airplane. America's early strategy dictated its perfection rather than long-range research on new weapons. Therefore the Committee concentrated on improving the performance and military effectiveness of the airplane to a degree of development beyond the best the enemy had to offer. The climax came in the first complete defeat of an enemy without setting foot on its home soil. Now the reserve of knowledge available when we entered the war, and without which victory would have been greatly delayed, has been exhausted.

This forces us to face the urgent necessity for renewed emphasis on fundamental research. Without certain essential design data the development of very high-speed aircraft and guided missiles cannot proceed on a sound basis, nor can tactical or even strategic plans for air warfare be developed with any assurance of practicability.

The importance of applied science to the war effort was not fully realized until late in the war, and there was not an adequate appreciation of the important role of young men in any rapidly advancing technology. Two conflicting principles governed the action of Selective Service. One, that every citizen should sacrifice equally in the common cause, and the other that every citizen should be used where his talents could best contribute. Since these principles were not effectively differentiated, service was not truly selective. As a result, young scientists, engineers, and technicians were drafted from research laboratories and industry, and an unnecessary handicap imposed on the task of keeping the instruments of war in the hands of our fighting men superior to those of the enemy. America also sacrificed its future to its immediate needs by halting the processes of advanced education, thus creating a lack of scientific manpower from which it cannot recover for years.

The close of the war marked the end of one whole phase of development of the airplane as conceived by the Wright brothers. The airplane in its present form is no longer a sound basis for future planning for the national defense. The power available in jet-propulsion systems brings flight through and above the speed of sound within reach. We now see no definite limit to the power that may become available for aircraft propulsion. Nor do we see a definite limit to the speed that may be attainable.

It is the immediate objective of the NACA to solve, as quickly as facilities and personnel permit, the most pressing problems attendant on high-speed flight, and to provide for the future development of knowledge in this seemingly endless new field of research. In general, the NACA must continue to direct its research to the needs of military, commercial, and private aviation, to increase the performance, economy, and safety of aircraft.

In long range planning for the country's aeronautical future, there is greater need than ever before for Nationwide teamwork, because of the great cost and manpower requirements of modern aeronautical research and development facilities. Important installations and their uses must not be unnecessarily duplicated. Only on the foundation of aeronautical science can the potentialities of national defense, of air transportation, of commerce, and of communication with other peoples be realized.

fleet." One important research finding has been that a very long afterbody greatly reduces the normal accelerations and "ballooning" during landings in waves.

Prior to the war, adequate information on seaplane landing loads was non-existent. Impact basin equipment had been constructed at Langley so that accurate data could be obtained under controlled conditions. Steps had been taken toward the improvement of existing theories. During the war, the impact basin was placed in operation, and much progress was made in experimental and theoretical research on seaplane landing loads. Several fundamental relationships were firmly established. The impact basin was also used in specific tests to obtain design data for naval seaplanes.

PROPULSION RESEARCH

PROPULSION SYSTEMS

Intensive research activity in the past few years has resulted in the more rapid advancement of propulsion systems than at any previous period in aeronautical history. A transition from researches for peak development of the reciprocating engine to fundamental researches on new high speed propulsion methods has been in progress. The period has been marked by the development of reciprocating engines of high power and efficiency and by the birth and development of gas turbines, ramjets, and rocket engines. Many of these achievements can be directly traced to the expansion of research effort in this country in the field of propulsion.

At the beginning of fiscal year 1940, research on aircraft propulsion systems was conducted for the Committee by the Power Plants Division at the Langley laboratory, at the National Bureau of Standards, and by various educational institutions on contract. In August 1939 the Special Survey Committee on Aeronautical Facilities recommended that the Committee construct a new engine research laboratory at the earliest possible date. A special committee on Engine Research Facilities submitted plans for a new aircraft propulsion laboratory. The new laboratory was approved by the Committee and the President and was authorized by Congress on June 26, 1940. Work on construction of the Aircraft Engine Research Laboratory at Cleveland, Ohio, was started immediately. The first research project at the new laboratory was initiated on May 8, 1942.

From 1940 through 1942 the research personnel and equipment of the Power Plants Division at Langley Field were increased to a maximum commensurate with the facilities available. The Power Plants Division, prior to 1940, was primarily concerned with fundamental problems of increasing the power, the efficiency, and reducing the fuel consumption of reciprocating aircraft engines. At the outbreak of the war, the engine research of the Power Plants Division was shifted to specific problems of increasing the power, the efficiency, and the reliability of military aircraft engines in the development and production stage. These aircraft power plants were all reciprocating engines.

During 1943 the program of research on the reciprocating engine for military use was greatly expanded as the research facilities at Cleveland were completed. The program on fuels and combustion studies started at Langley Field was continued at Cleveland on a more extensive scale. The need for fuel research was particularly acute because of the tremendous increase in the quantities of fuel required by the military forces. Investigations were started on lubricants and on the fundamentals of lubrication. As rapidly as the engine research building facilities became available in 1943 and early 1944, research projects concerned with complete engines, components of the engine, and auxiliaries were started. By 1944 investigations were being carried out on all the major components and auxiliaries of reciprocating aircraft engines for military use. In addition, investigations were under way on over-all engine performance, materials, and stresses and vibration in the laboratory and in flight.

In 1943, interest in the gas-turbine jet-propulsion engine for military use resulted in the building of two test cells for ground level investigations. Experiments were conducted in these facilities on the first type of gas turbine engine built in this country. When the altitude wind tunnel was completed early in 1944, the first investigation was a study of the altitude performance of the gas-turbine engine installation in a pursuit airplane. The design of this tunnel was such that gas turbine engines could be investigated over a wide range of altitude conditions. The shift in emphasis from research on reciprocating engines to gas-turbine engines was made in accordance with the research requirements of the development program for jet-propelled military aircraft. The jet-propelled airplane, however, did not reach service use by this country until the end of the war.

THERMODYNAMIC RESEARCH

Thermodynamic Properties of Gases

The design of efficient aircraft engines that involve the use of a gas turbine as the principal source of power or as an auxiliary, and the analysis of the performance of such engines and their components depend on a knowledge of the thermodynamic properties of the working fluids. Accordingly, tables and charts have been prepared for calculations of the thermodynamic quantities associated with the steady-state flow processes of gas-turbine engines and composite engines. The prepared

charts permit, within the temperature limits used, the convenient and accurate calculation of the ideal and actual change of condition of the working fluid and the mass flow per unit area for each phase of the working process of a gas-turbine engine and for the auxiliary turbines and compressors of a composite engine.

Cycle Analyses

Analytical investigations of the turbojet and turbine-propeller engine cycles have been conducted to provide information to determine the most effective lines of research to be followed for improvement of these engines.

Turbojet engine. An analysis of the turbojet cycle was made and charts were developed that permit the rapid and accurate evaluation of the performance of the system for any given set of operating conditions and system parameters. The charts take into account turbine, compressor, and combustion efficiencies; discharge nozzle coefficient; losses in pressure in the inlet duct and combustion chamber; ambient atmospheric conditions; flight velocity; compressor pressure ratio; and combustion-chamber outlet temperature. It was shown that maximum thrust per unit mass rate of air flow occurs at a lower compressor pressure ratio than that of minimum specific fuel consumption; the thrust per unit mass rate of air flow increases as the combustion-chamber discharge temperature increases. For minimum specific fuel consumption, however, an optimum combustion-chamber discharge temperature exists, which in some cases may be less than the limiting temperature imposed by the strength-temperature characteristics of present materials.

Turbine-propeller engine. The analysis of the turbine-propeller system is an extension of the analysis of the turbojet and parallels it very closely, the design curves being very similar to those obtained for the turbojet. In this system the turbine power is in excess of the compressor power and, for any given pressure ratio, there exists an optimum division of available power between the turbine and the jet. An expression derived for the jet velocity gives this optimum power division.

A simplified analysis has also been made of the effects of intercooling, reheat, regeneration, and combinations of these factors on the performance of the turbine propeller engines. Results show that intercooling gives a moderate increase in power with little effect on specific fuel consumption, reheat causes an appreciable gain in power with a corresponding rise in specific fuel consumption, and with regeneration only little power is lost whereas large gains in efficiency are possible. Of the combination cycles, the addition of reheat and regeneration to the basic turbine-propeller system appeared the most promising because appreciable gains in both power and efficiency are obtainable.

Waste Energy Recovery, Reciprocating Engines

Exhaust jet stacks. A simple method of recovering some of the energy in the engine exhaust is to fit the engine with individual exhaust stacks directed to the rear to utilize for jet propulsion the kinetic energy of the exhaust gas produced in the exhaust ports by the residual high pressure in the engine cylinders at the time of exhaust valve opening.

An investigation was made on a single-cylinder engine to determine the optimum nozzle size for various engine operating conditions with short straight stacks and with stacks of representative shapes and lengths. It was found that data leading to a specification of the optimum exhaust nozzle area could be correlated for each stack shape.

Flight tests were made on a pursuit airplane with a radial engine fitted with jet stacks. The jet stack installation increased the flight speed 18 miles per hour (from 314 to 332 m. p. h.) at 20,000 feet as compared with the collector installation. Additional investigations were made on other engines and airplanes. The use of jet stacks, which was pioneered by the NACA, has found widespread acceptance in British and American aircraft.

Composite engine. One of the most efficient methods of recovering exhaust energy is by means of the exhaust-gas turbine (for example, by a turbo-supercharger). Additional gains in power and economy can be had by passing all the engine exhaust gas through the turbine and using any excess turbine power, over that required for supercharging, for propulsion of the aircraft. The optimum division of power between the engine and turbine is a function of the sensitivity of engine power to changes in exhaust pressure, operating altitude, power level, component efficiencies, and other variables.

Investigations on several single and multicylinder engines were made to determine the effect of exhaust pressure and other engine variables on the engine component performance. The single-cylinder engine included liquid and air cooled, two- and four-stroke cycle, spark- and compression ignition engines. The multicylinder engines included an 18-cylinder air cooled engine and a 12-cylinder liquid-cooled engine. Tests were also made with a 12-cylinder liquid-cooled and a 9-cylinder air-cooled engine each equipped with a blowdown turbine, which utilizes the kinetic energy of the engine exhaust gases in the individual cylinder exhaust stacks.

From the results of these investigations and from supercharger and steady-flow turbine characteristics, the performance of various composite engine systems was computed.

The results of the analyses of composite engines show that substantial reduction in specific fuel consumption is attained for the various types of composite engine

investigated regardless of the nature of the basic engine. The best specific fuel consumptions were attained at about 30,000 feet by the use of both a steady-flow turbine and a blowdown turbine. Consideration of the weight of the engine as well as the weight of fuel shows that, for short flights at low altitudes, the engine with jet stacks is superior; at altitudes in excess of about 10,000 feet the engine with both geared blowdown turbine and geared steady-flow turbine is superior to all other types of combinations of piston engines with jet stacks or auxiliary turbines.

Heat Transfer

Intercoolers. A theoretical study was made of the cross-flow tubular type of intercooler as based on current heat transfer and pressure loss information concerning the flow of air through and across tubes. The results are presented in the form of working charts from which intercooler designs can be quickly made. The heat transfer and pressure loss basis for the analysis is supported by data obtained from a laboratory intercooler test unit. The principal conclusion indicated by the study is that, in order to achieve minimum intercooler size, the heat transferring surface elements should be closely spaced. In addition, it is indicated that an infinite number of intercoolers differing in size and shape can be designed to meet any specified set of operating conditions. Mathematical analyses of both the cross-flow tubular and plate intercoolers were accordingly made, and the results were presented to give the variation of the intercooler volume, surface, frontal area, and linear dimensions with variation in core dimensions for constant intercooler operating conditions.

A method was evolved for plotting intercooler performance data to permit convenient application of the data in the design or selection of intercoolers for a specific application. An analysis was made of the intercooler power losses in flight to determine the intercooler cooling air conditions that give minimum total power loss for any given intercooler cooling effectiveness.

Exhaust gas heat exchanger. The Committee has pioneered the use of thermal anti-icing methods wherein the large quantities of heat contained in the engine exhaust gas are transferred to air circulated through the wing and control surfaces. The exhaust gas heat exchanger is a critical component of such systems. Investigations have been conducted to provide the fundamental information required for the development of improved units. From analysis of heat transfer data, a unit was designed and constructed, and its performance was investigated in the laboratory under simulated conditions. The results indicated that the heat exchanger was an efficient and reliable unit, and that existing heat transfer data were suitable for designing such heat exchangers.

FUELS AND COMBUSTION RESEARCH

Reciprocating Engines

Effect of chemical structure of fuels on knock-limited power. The tendency of a fuel to knock places a limit on the power that can be obtained from a given fuel in a given engine. In connection with the effort of the military services to increase the power output of aircraft engines, a systematic study was made of the effect of chemical structure of fuels on their knock tendency in order to discover fuels of superior performance characteristics. A series of 102 hydrocarbons has been prepared and evaluated in small scale single-cylinder test engines and in a full-scale single-cylinder test engine. A series of paraffinic hydrocarbons, prepared at the National Bureau of Standards, and 30 compounds purchased from commercial sources were also examined as blending agents. A number of the materials investigated showed substantial improvements in permissible power over aviation gasoline of 100/130 performance number.

Fuel-blending relation. In order to avoid the need for engine tests of every possible combination of high performance blending agents, the Committee has conducted extensive studies of the relations between blend composition and knock-limited performance. As a result of these studies, equations were derived that showed the approximate knock-limited performance to be expected when various fuel components were blended.

Special fuel additive. During a critical period of the war it was imperative that aviation gasoline supplies be extended by any available means. It was suggested that the addition of a commercially available additive (xylidines) to certain gasoline stocks would produce a satisfactory fuel for use in aircraft engines.

In preliminary studies it was found that the addition of xylidines to current fuels raised the knock-limited performance to such an extent that 15 percent of lower-grade fuels could be blended into the additive fuel without exceeding the knock limit. Following these preliminary studies more extensive tests were made in various types of engine cylinders then being used in military aircraft.

Special blending agent. A comprehensive program to evaluate triptane (2,2,3-trimethylbutane) and certain other high antiknock components for use in aviation gasoline was undertaken. The program consisted of extensive studies in small-scale engines, in full-scale single-cylinder engines, and finally in a multicylinder engine mounted on a torque stand and in a similar multicylinder engine in flight. The results indicated that triptane could best be utilized in engines specifically designed to operate on high-performance fuels but that definite gains could be realized by its use as a component of fuel blends for current aviation engines.

Pre-ignition. A study was conducted on the influence of fuels on pre-ignition in small-scale single-cylinder engines. In these particular studies it was found that increases in compression ratio, spark advance, coolant temperature, or inlet-air temperature decreased the pre-ignition-limited performance.

Fuel-vapor loss. Laboratory investigations indicated that the fuel vapor loss from an aircraft fuel tank amounted to about 15 percent of the original fuel load during a climb to an altitude of 40,000 feet with an initial fuel temperature of 110° F. Flight investigations were conducted to check the simulated altitude laboratory results. The fuel vapor loss is affected by type of fuel, fuel temperature, altitude of climb, flight time, and fuel system. Preventive and recovery methods were studied in simulated flights.

Jet Propulsion Engines

The research program based on the combustion problems of jet propulsion engines has two broad over-all objectives: (1) to obtain generalized results and conclusions about combustion applicable to design, performance, and related practical problems currently encountered in jet propulsion engines, and (2) to obtain information leading to the eventual understanding of the physico-chemical processes in combustion. These two objectives are not mutually exclusive, and an investigation aimed at one generally contributes something to the other.

Effect of combustor operating conditions on combustion efficiency. An investigation in the altitude wind tunnel on a turbojet engine revealed that for each rotative speed of a turbojet engine an altitude existed above which the engine would not operate; that is, the engine had an altitude operation limit. An investigation was then made of the combustor alone in the combustion laboratory, where engine combustor conditions could be simulated, and it was found that the altitude operational limit of the engine could be explained in terms of the effect of the combustor inlet conditions on combustion efficiency. It was found that independently increasing the air velocity or decreasing the air temperature or pressure at the combustor inlet decreased the combustion efficiency. Under some adverse inlet conditions a peak combustor temperature rise was obtained that was considerably less than the theoretical temperature rise available and further increase in combustor temperature rise could not be achieved regardless of increase in fuel flow. The altitude operational limit of the engine coincided with the conditions in the combustor tests where the peak combustor temperature rise was less than that required for engine operation. The trends of combustion efficiency with combustor inlet temperature, pressure, velocity, and fuel-air ratio determined in these tests were verified in investigations of additional combustors of both the annular and individual tubular types.

Effect of combustor-air distribution on combustor efficiency. At the request of the Bureau of Aeronautics of the Navy Department the Committee investigated the effect of distribution of air flow in the combustor on combustion efficiency in order to increase the operational altitude of two turbojet engines. Changes in combustor design were investigated that provided a larger and more sheltered zone for the primary air. As a result of these design changes, the operational ceiling of the two turbojet engines investigated was more than doubled.

Ramjet combustion. With ramjet combustion chambers, investigations were made to determine the criteria of good flame holders. The influence on combustion of such geometric variables as amount of area restriction, size of individual shielded zones, distance of lateral flame travel between adjacent shielded zones, and presence of pilot flames is being studied. The effect of different types of fuel injection is also being studied; an intermediate degree of fuel atomization and dispersion with fuel-rich zones coinciding with the shielded zones behind the flame holders was found to be the better arrangement in many cases.

High energy fuels for turbojet engines. In addition to synthesis of compounds for studies in reciprocating engines, pure compounds of the types desired in turbojet engines are being prepared for investigation in a turbojet combustion chamber. Special emphasis is being placed on fuels of high energy content per unit volume.

Effects of fuel characteristics on performance of turbojet combustors. Different hydrocarbon types showed no appreciable differences in performance except in the case of aromatic hydrocarbons, which gave combustion efficiencies about 20 percent lower, under some conditions, than other types. Some of the differences between the performance of different fuels were decreased by better atomization of the low-volatility fuels. Other fuel studies showed that the rate of carbon deposition in turbojet combustors increased with increasing aromatic content and with decreasing volatility.

COMPRESSOR AND TURBINE RESEARCH

Centrifugal Compressors

Investigations were conducted on various impellers to determine the merits and the effect of changing each of several design variables. As part of a program to determine design criteria for impellers, a series of constant angular-acceleration inducers were investigated both as separate components and in combination with an impeller. The application of the inducer type developed in this program to a commercial centrifugal impeller

resulted in a gain of eight points in compressor performance.

Combining the results of inducer research and of the preliminary impeller research, an investigation was started to determine the most effective blade and passage shapes for impellers. Six impellers having a wide range of blade loading conditions have been investigated; efficiencies of 85 percent, pressure ratios above 5, flow capacities double those of conventional impellers, and equivalent tip speeds of 2,000 feet per second have been reached.

Research on centrifugal-compressor types designed on the basis of flow theory (including a two-dimensional radial-inlet impeller and an axial-discharge impeller especially adaptable to gas-turbine power plants) was undertaken to develop a sound mathematical basis of impeller design. Initial investigations on the radial-inlet impeller have indicated the sources of losses and have established a method of analyzing the flow in impeller channels.

Methods of performance testing were investigated to establish a means of accurately rating compressors and to determine performance of existing service types and available experimental types of supercharger impellers. Tentative standards for testing and rating centrifugal compressors were prepared.

Matching. A convenient method developed for presenting the performance of a compressor system in relation to that of a power section consists in plotting on the same graph the performance of the compressor system and the power section in terms of variables common to both. Intersection of the performance curves determines the points of operation for the complete unit.

Application of this method of analysis to supercharged engines has shown that pressure losses through the compressor system, especially through the inlet elbows, considerably reduce over-all output of the power plant. The fundamentals of flow through elbows were investigated and an elbow was designed in which the total pressure losses through the elbow were 10 percent of the velocity pressure at the compressor inlet. An improvement in the velocity distribution at the compressor inlet was simultaneously obtained.

Surging. Analytical and experimental investigations were made of surging, a phenomenon that establishes the minimum flow at which a compressor can operate. The results show that surging is possible only when the pressure ratio of the compressor decreases with a decrease in volume flow. The maximum rate of change of pressure ratio with volume flow that can be tolerated without surging is dependent on the magnitude of the individual capacities and resistances of the entire compressor system. The results of these researches indicated several methods of extending the surge-free operation of a compressor. Experiments with one of these methods demonstrated that not only could the surge-free range of a centrifugal compressor be extended but that hitherto unattainable regions of high pressure ratio and efficiency could be realized.

Superchargers. Preliminary studies of a liquid-cooled type of aircraft engine having two stages of supercharging indicated that the supercharging and induction systems of the engine were critical. The individual performance characteristics of the superchargers were obtained for both sea level and simulated altitude conditions and the information thus obtained was used to determine the optimum supercharger operating conditions in the engine.

Axial Flow Compressors

Blade design and single-stage theory. The investigation of the individual stages of a multistage axial-flow compressor resolves itself naturally into two parts; study of the performance of the blade elements, and consideration of the effect of different velocity distributions along the radius. Factors affecting the blade-element performance are camber, solidity, and blade profile. Theoretical and experimental investigations have resulted in useful correlations between these two parts. Detailed theoretical studies made of the effect of the distribution of velocity in the radial direction have been used as a basis for the design of a number of single-stage research compressors.

Multistage compressors. The eight-stage axial-flow compressor designed and constructed in 1938 by the Committee on the basis of high-speed airfoil theory has been the subject of extensive investigations. An investigation of the performance of this compressor demonstrated that a maximum over-all adiabatic efficiency of 0.87 and a maximum pressure ratio of 5.4 were attainable. The effect of Reynolds number was investigated and it was found that when the simulated altitude at the compressor inlet increased from 27,000 to 50,000 feet, the efficiency decreased 4 points. The useful operating range of the compressor was extended as a result of an investigation on the use of adjustable stator-blade angles. Theoretical research on multistage axial-flow compressor design has led to criteria for estimating the effects of basic design variables on the performance of the compressor.

Compressor and turbine matching. An investigation was made to determine the interaction of compressors and turbines as components of a jet engine. The engine used for this investigation consisted of the NACA eight-stage axial-flow compressor and a specially designed turbine. The data from this investigation were studied to develop a theory for determining the performance of a jet engine from a knowledge of the performance of its components and for estimating how each of these

components affects the performance of the other. The results of this work indicate that, in general, investigations of complete jet engines without knowledge of the performance of the components cannot be expected to indicate how well the components match, because only a small range of the possible field of operation of the turbine component is covered. The application of the developed method of analysis does permit, however, the evaluation of the effect of modifications of jet engine components on over-all performance without actually retesting the engine.

Tentative standard procedures for rating and testing. The NACA Subcommittee on Compressors, realizing the importance of standard procedures for rating and testing multistage axial-flow compressors, appointed a special panel to establish such procedures. Experimental techniques and calculation procedures were established that would give the highest accuracy and reproducibility of results.

Single stage-compressors. In order to improve the performance of axial-flow compressors, it is necessary that the effect of a large number of variables be determined. These variables include velocity diagram, blade section, blade camber, solidity, aspect ratio, tip clearance, blade-root radius, and blade finish. Because of the desirability of investigating these fundamental effects on simple compressors, where all the variables can be easily controlled, three 14-inch-diameter, single stage, variable-component compressors were designed; these three compressors simulated the intermediate, inlet, and outlet stages respectively, of a multistage compressor. The first two of these compressors are in operation under investigation.

Specific compressors. In cooperation with the military services, the research facilities of the Cleveland laboratory have been utilized to determine the performance of four axial-flow compressors designed for specific jet propulsion engines. Over-all and individual compressor stage performance data were obtained over the entire compressor speed ranges for both sea level and simulated altitude inlet conditions. In one instance, the interstage survey data were used as the basis for blading modifications that changed the air handling capacity of the compressor to the value for which the jet engine was designed, and increased the efficiency by approximately three points, with a corresponding increase in pressure ratio. The finding of each of these investigations were supplied to the military services and manufacturers as a guide in the design of future compressors.

Turbines

Design and performance. In order to design turbines with optimum efficiency, gas flow and power capacity, it is necessary to evaluate the effect of the internal gas-flow phenomena on turbine performance and to evolve a method of shaping the internal turbine members to obtain the optimum flow characteristics. The order of magnitude of the gains to be expected from this study is being evaluated. For this purpose a number of turbine blade-shape parameters have been varied in several sets of blades and a study is being made of the effect of such variations on single-stage turbines using these blades. A theoretical method has been developed that permits the determination of a blade-section shape under the simplifying assumption of two-dimensional flow of a perfect, incompressible fluid. Generalization to the case of the compressible perfect fluid with two-dimensional flow is now being studied. The effect of viscosity on the flow pattern has been experimentally investigated in a stationary set of turbine nozzles and some basic flow phenomena have been determined, which should prove helpful in the analytical treatment of this effect.

The program of turbine-blade investigations that accompanies the program of turbine blade design has two main purposes: (1) to provide experimental data to expand the theoretical studies, and (2) to indicate the changes in turbine performance that cannot at present be predicted by theoretical methods.

A Reynolds number correlation was obtained by studying the performance of a single-stage turbine over a wide range of intake pressures and intake temperatures. This investigation indicated that, if the intake temperature is altered, no change in turbine performance results as long as the ratio of inlet pressures to the 1.1 power of the inlet temperature is unchanged.

The turbine component from a representative jet-propulsion engine was selected for a basic investigation designed to establish a sound method of predicting gas-turbine performance at design operating conditions by means of performance data obtained at greately reduced pressures and temperatures and to examine, in detail, the flow through the various components of the turbine. Investigations have also been made on the air-cooled, mixed-flow turbine to determine the performance of this type of turbine at elevated temperatures.

A two-stage turbine was constructed for the ultimate purpose of studying the combined characteristics of a compressor and a turbine as components of a turbojet engine. An investigation of the turbine alone showed that the turbine had a maximum efficiency of 0.875, which indicated that the stream-filament theory used in designing the blades can produce turbine blades having reasonably high efficiencies.

Cooling. In order to determine the potentialities of various methods of turbine disk and blade cooling, analytical investigations were first undertaken. Four methods of cooling were considered; cooling by conduction to the rim of the turbine disk, admitting cool air

rich or at excessively lean mixtures. Several factors were found to contribute to slow burning; among these factors were poor fuel vaporization and the resulting poor mixture distribution, faulty ignition, water injection, and lack of turbulence. Among these factors, faulty ignition was found to be the most significant element contributing to backfiring. Induction-system design was found to have a marked effect on the backfiring phenomena.

GAS TURBINE ENGINES

Buckingham, in NACA Report No. 159 published in 1923, presented an analysis of the jet-propulsion system for use in propelling aircraft. His results indicated that for the flight speeds then in prospect the efficiency would be too low and the necessary equipment too heavy to make the system feasible.

In February 1939 the air-flow research staff at the Langley laboratory began a general study to investigate the possibilities of jet propulsion for aircraft. The purpose of the investigation was to reevaluate Buckingham's work, considering especially the application of jet-propulsion at speeds higher than he had considered practicable but which, at the later date, appeared attainable.

One problem that arose during this phase of the investigation was control of the combustion in the high-speed air stream in the burner. A series of combustion studies was undertaken with small-scale and full-scale apparatus to obtain combustion data for use in subsequent investigations.

The Special Committee on Jet Propulsion was established in March 1941 to guide jet-propulsion research. Under the guidance of this committee a full-scale test set-up was devised using the information obtained from the preliminary investigations and analyses, and a study was made of blower and duct characteristics as well as the action of burning. The experimental results indicated that combustion could be controlled and restricted to the desired space and that the mechanical structure was feasible for operating at the conditions required to give a reasonable efficiency at attainable flight speeds. The results were checked with theoretical calculations and were used as the basis for initial recommendations relative to jet-propulsion aircraft. Performance estimations were made for several possible airplanes with this type of power plant.

Research at the Cleveland laboratory has been devoted to investigation of the performance of typical turbojet engines. One of the principal problems was the investigation of methods of predicting performance at altitude from results of tests at ground level. Engine manufacturers lacked equipment for running tests at altitude. Flight tests could not be relied upon for providing the information because the detailed information desired required the use of extensive instrumentation not practicable for flight work and, in many cases, flight tests would have been very hazardous. The Cleveland altitude wind tunnel provided means of simulating air pressures and temperatures at altitude and made it possible to observe the effects of altitude on all component parts of the engine. Four turbojet engines had been investigated in the altitude wind tunnel. Two of the engines incorporated a double-entry centrifugal compressor and two incorporated multistage axial-flow compressors. The most significant finding of these researches was the existence of altitude limits above which combustion could not be maintained. With some designs blow-out was encountered at altitudes as low as 20,000 feet; with other designs the blow-out limit was at altitudes about 40,000 feet. The investigations proved that results of ground level tests could be used to predict the performance at altitudes below the blow-out limit. This prediction involves the use of special performance parameters derived by dimensional analysis.

The drag, or windmilling, characteristics of a "dead" turbojet engine were also investigated because the drag value must be known for the design of multiple-engine airplanes where it might be desirable or necessary to fly with one or more engines dead. The values of windmilling drag of 15 percent of the maximum net thrust at 500 miles per hour and 25 percent of the maximum net thrust at 650 miles per hour indicate that closing the inlet to the engine when the engine is inoperative in flight is desirable.

The acceleration characteristics of a turbojet engine were investigated because quick response to the throttle is essential during landing maneuvers. The engine was found to pick up speed and thrust at an undesirably low rate. If landing maneuvers were made at maximum engine speed and low thrust was obtained by means of a variable-area tail-pipe nozzle, maximum thrust could be regained almost instantly by changing the nozzle area.

Although the performance of the turbojet engine surpasses the performance of the reciprocating engine and propeller at high flight speeds, the thrust of the turbojet engine is low at the low speeds corresponding to take-off. Three methods were investigated for increasing take-off thrust: (1) Spraying coolants into the compressor inlet; (2) burning additional fuel in the tail pipe of the engine; and (3) bleeding air from the compressor discharge into an auxiliary combustion chamber from which products of combustion discharge through a nozzle.

The injection of water or other coolant into the inlet of the engine cools the air and results in higher com-

pression pressures and increased air flow. The higher compression pressures and increased air flow, in turn, produce higher thrust and better thermal efficiency. When water was sprayed into the inlet of a turbojet engine having a centrifugal compressor, a maximum thrust increase of 35 percent was obtained. Mixtures of alcohol and water were also investigated.

The burning of additional fuel in the tail pipe of a turbojet engine increases the jet velocity in proportion to the square root of the increase in absolute temperature of the jet, and the take-off thrust increases in direct proportion to the jet velocity. Maximum jet temperatures from turbojets are limited to about 1700° F. because of temperature limitation set by turbine materials. The burning of fuel in the tail pipe avoids this limitation and the jet temperature can be raised to about 4,000° F. An experimental investigation of thrust augmentation by tail pipe burning was made in the jet propulsion static laboratory and a thrust augmentation of 40 percent was obtained by this means for the zero ram condition (take-off).

Because of the change in the discharge gas density when the tailpipe burner is operated it is necessary to provide an adjustable-area discharge nozzle for permitting change from the non-burning to the burning condition in flight. An adjustable-area nozzle was developed that showed no indication of overheating or failure during the tests. An experimental investigation of this type of nozzle indicated that it imposed no loss in thrust on the turbojet engine as compared with a conventional nozzle.

The limit imposed on jet temperatures by the turbine materials can also be obviated by bleeding air from the compressor discharge, burning it in an auxiliary combustion chamber, and discharging it as a jet that produces thrust. The deficiency of air entering the turbine can be replaced by injecting water into the combustion chamber; the volume of the generated steam replaces the air. Experiments with the turbojet engine showed that a 66 percent increase in thrust could be obtained with a total liquid consumption of 8.9 pounds per hour per pound of thrust.

RESEARCH ON RAMJET ENGINES

Steady Flow Ramjet

A theoretical investigation of the performance of the ramjet engine was undertaken to determine the interrelation of the pertinent fundamental variables. On the basis of the theory, a series of performance parameters was chosen for presentation and correlation of the experimental data. The investigation of a 20-inch ramjet engine in the altitude wind tunnel confirmed the theoretical trends and provided experimental data for a ramjet engine at altitudes up to 47,000 feet and equivalent flight Mach numbers up to 1.84. By comparison of the experimental thrust coefficients of the ramjet engine with corresponding drag coefficients obtained in supersonic wind tunnels, the feasibility of the ramjet engine as a power plant for supersonic aircraft was established.

During the course of the research, a systematic study of the various engine components was undertaken. An extended investigation of flame holders produced several burners that would allow the ramjet to operate at altitude and at high Mach numbers.

Experiments were also conducted to determine the increase in the combustion efficiency that might be achieved by the use of preheated fuel. When the transition was made from unheated to preheated fuel, the long yellow flame of the exit jet shortened and became a pale blue. Simultaneously, the operation of the engine was less erratic and the combustion efficiency improved by about 10 percent. Concomitant increases were obtained in the temperature ratio across the unit, the over-all efficiency, and the net thrust.

Further research showed that there was sufficient heat rejected to the shell of the ramjet engine to preheat the fuel. An automatic system was devised to combine the operation of fuel preheating and shell cooling. On the 20-inch ramjet engine, the heat rejected to the shell amounted to about 0.2 percent of the total heat released by the combustion process per foot of combustion chamber and nozzle length.

Experiments undertaken to determine the feasibility of the two-dimensional ramjet indicated uniform, smooth combustion and quite satisfactory operation.

Intermittent Flow Ramjet

The pulse-jet engine in the form introduced by the Germans as the propulsive unit for the V–1 bomb is severely limited by its performance and operating life. An analysis of the ideal processes involved in the operating cycle of the pulse-jet engine was made, and the results showed that the German engine operates substantially below its theoretical performance. A study of the mechanism of combustion occurring within the pulse-jet engine was made on a model equipped with a glass window through which high speed photographic records of the flow and combustion processes were taken. Various methods of controlling the combustion process to obtain a working cycle more closely approaching the idealized cycle were investigated. The motion of the pressure waves within the combustion chamber, as photographed during operation, qualitatively agree with the recently advanced wave theory of the operation of the engine. Low-loss inlet-air valves and intermittent fuel injection into the combustion chamber were investigated.

Thrust stand investigations were conducted on a replica of the German pulse-jet engine with several valve modifications to determine sea level performance at simulated airspeeds of 0, 190, 280, and 340 miles per hour.

ROCKET ENGINE RESEARCH

The chief problems of the rocket power plant, as analyzed, were found to be: (1) To obtain high thrust for low weight flow and low volume flow of propellant in order to increase range and pay load; (2) to increase combustion chamber and nozzle life; and (3) to achieve ease and safety of operation and control. Virtually the entire effort in rocket research at the Cleveland laboratory was directed toward finding propellants capable of giving high specific impulse and devising ways in which to use the high energy reactions without burning the combustion chamber and nozzle.

The study of high performance propellants was initiated with a complete survey of those reactions capable of highest energy release. Because high energy release means high temperatures and therefore dissociation, subsequent computations of theoretical performance of propellant systems utilized thermal data and equilibrium constants. Graphical aids for these computations were devised. An investigation was then started to evaluate the performance of propellants and to find ways of approaching experimentally the optimum theoretical performance. Another investigation was a study of the ignition characteristics of propellants. A short ignition lag is desired because of the attendant hazard that occurs when unignited propellant accumulates in a motor and then ignites. Two lines of attack were followed in experiments directed at seeking ways and means of cooling the inner walls of the rocket chamber and nozzle.

ENGINE INSTALLATIONS

Reciprocating Engine Installations

An investigation was conducted in the altitude wind tunnel to evaluate the effect on engine cooling and nacelle drag of several modifications to the cowling of a four-engine heavy bomber. The substitution of a 43-inch-diameter cowl inlet for the original 38.5- by 35-inch oval inlet reduced the cooling drag by an amount equivalent to a saving of about 60 horsepower per engine at cruising power at an altitude of 15,000 feet and an indicated airspeed of 190 miles per hour. Modified cowl-exit flaps on a slightly enlarged cowl afterbody caused a further drag reduction equivalent to about 35 horsepower per engine under the same conditions. Engine cooling baffles modified to direct more air to the region of the rear-row cylinder exhaust ports were found to appreciably reduce the temperatures of the rear spark-plug gaskets, rear spark-plug bosses, and the exhaust valve seats of rear row cylinders.

A study was also made in the altitude wind tunnel of the installation in a torpedo bomber of a 28-cylinder air-cooled engine with a dual-rotation propeller. Low pressure recoveries at the face of the engine were found to be caused by propeller interference. At high angles of attack the air flow into the upper half of the cowling was further blocked by the long spinner.

A flight investigation was conducted to determine the cruising performance of a four-engine heavy bomber when equipped with engines modified by the incorporation of the NACA fuel-injection supercharger impeller and ducted head baffles. The use of the NACA injection impeller reduced the spread of fuel-air ratios among the cylinders to less than one-half its original value. The temperatures of the exhaust-valve seats were reduced approximately 50° F. by the ducted head baffles. Analysis of the flight data indicated that the cooling improvements allowed either an increase of more than 10,000 feet in operating altitude at a given airplane weight or a gross weight increase of from 10,000 pounds at sea level to 35,000 pounds at all operating altitudes above 10,000 feet.

Turbojet Engine Installations

A revised nacelle configuration for a two-engine turbojet-propelled fighter airplane was compared in the altitude wind tunnel with the original configuration. The revised boundary-layer removal duct was found to reduce the boundary layer in the plane of the nacelle inlets approximately 60 percent at the high speed of the airplane. Use of the revised nacelle inlet and boundary-layer removal duct increased the total pressure recovery at the compressor inlets approximately 16 percent over the pressure recovery with the original configuration. A revised cooling-air seal reduced the quantity of cooling air approximately 75 percent without causing excessive nacelle temperatures.

The power plant installation of a single-engine turbojet-propelled fighter airplane was investigated in the altitude wind tunnel. The losses in the induction system were evaluated over a wide range of altitudes and ram ratios, and data were obtained on the engine performance and operational characteristics.

Ejector Cooling

An investigation was conducted on a single-cylinder engine to provide criteria for designing an exhaust ejector cooling system. The effectiveness of exhaust ejector systems as a means of increasing the cooling air flow through air-cooled engines has been studied in flight on a twin-engine airplane. The investigation was conducted to permit a direct comparison between the

engine cooling provided by the ejector installation and that provided by the conventional installation. It was found that at low speeds, where the cooling with the conventional installation was insufficient, large increases in cooling air flow were obtained by use of the ejectors. Slight increases in cooling-air flow were also obtained at high speeds.

High-Altitude Cooling

The increase in altitude of aircraft operation during the war introduced additional problems in the cooling of air-cooled engines. The problems are a result principally of the low density of the air at high altitude, which increases the cooling-air pressure drop required for cooling and at the same time decreases the available pressure drop.

In order to obtain information on the cooling characteristics of air-cooled engines at altitude conditions and, in particular, to check existing methods of extrapolating the data obtained from sea-level or low-altitude cooling tests to high-altitude conditions, a flight cooling investigation was conducted on an 18-cylinder, twin-row radial, air-cooled engine installed in a high-performance pursuit airplane. The investigation consisted of flights at variable engine and flight operating conditions at altitudes ranging from 5,000 to 35,000 feet. The cooling data obtained were correlated by the previously developed cooling-correlation method, modified to account for compressibility effects. The satisfactory correlation of the data obtained, irrespective of altitude, indicated that sea-level tests may be used to predict cooling at altitude when the test results are plotted in accordance with the correlation method.

A flight investigation of the cooling performance of a two-row radial aircraft engine in a twin-engine medium bomber revealed that the temperature-distribution patterns among the cylinders are determined chiefly by fuel-air ratio and cooling-air distribution. The cooling-air distribution was, however, appreciably affected by airplane flight conditions. Satisfactory correlation of the cooling variables was obtained at both low and medium altitudes. Analysis of the correlation equation indicated that cooling performance at medium altitudes (20,000 ft.) may be predicted with sufficient accuracy by use of the low-altitude correlation equations.

ENGINE AUXILIARIES AND CONTROLS

Reciprocating Engines

Fuel and air metering. Fuel and air metering were the first control functions to receive attention at the Cleveland laboratory. Research in fuel metering consisted of investigations of the mass air-flow metering-control system and the engine parameter-type metering-control system. Considerable improvement in fuel distribution was achieved by the use of the supercharger impeller to distribute the fuel and by means of an improved carburetor spray bar.

Ignition and ignition systems. Investigations of ignition and ignition systems included means of reducing lead fouling of spark plugs and the effect of variable ignition conditions on combustion in reciprocating engines. Several methods were found of alleviating lead fouling in reciprocating engines.

Gas Turbine Engines

Turbojet-engine controls. Control requirements of the basic turbojet engine with direct-coupled compressor and turbine and with fixed exhaust nozzle area were analyzed. This analysis resulted in the selection of parameters suitable for engine control during steady-state operation, acceleration, and deceleration, as dictated by engine requirements and limitations. Restricted control possibilities of the basic turbojet engine indicate that additional controllable variables, such as variable exhaust nozzle area and throttled inlet, may provide information to improve both engine control and performance.

Fuel systems. Methods of improving the fuel distribution to burners were investigated. New methods evolved indicate that variations in fuel distribution may be reduced to approximately 1.5 percent. New methods also indicate the feasibility of a low pressure fuel system with its attendant advantages.

AIRCRAFT CONSTRUCTION AND MATERIALS

THE Committee's program relating to aircraft construction and materials has centered around the work of the Structures Research Division at Langley Field and a considerable number of research contracts with educational and other non-profit organizations. In the past year and a half, however, materials programs initiated at the Cleveland laboratory have shown promise of being sufficiently fundamental to be applicable to airframe materials as well as power plant materials. Because Cleveland's work is directed toward power plant problems it is not included herein but is outlined under the section on Propulsion Systems.

For the sake of presenting the various parts of this program in an orderly fashion, it will be divided into three sections; one on aircraft structures, one on wood and plastics, and one on structural metals.

Part II
EXTENSION OF FACILITIES

Construction Since 1940

AMES LABORATORY

The year 1940 saw the beginning of the Ames Aeronautical Laboratory at Moffet Field, Calif. The facilities of this laboratory were built to extend aeronautical research to higher speeds and larger scale, in a location less limited by space considerations and electric power supply than the more crowded area at Langley Field.

The first unit completed was the flight research laboratory, which went immediately to work on the problem of aircraft icing. In August of 1941, three new wind tunnels were put into operation. The first two were the 7- by 10-foot tunnels, extensively used for general aerodynamics and stability and control studies. They provide a much needed addition to the facilities at Langley Field for this type of work. The third tunnel was the 16-foot high-speed tunnel. This facility makes possible aerodynamic investigation at high speeds, up to 680 miles per hour, and at larger scale than was possible in any other tunnel, at those speeds.

In May of 1942 the science laboratory was completed. This building houses equipment for design and construction of the complex and precise instrumentation required in research.

The administration building, which houses the central management and research offices of the laboratory, was completed in November of 1943.

In 1944 two new wind tunnels came into operation. The 1- by 3½-foot high-speed tunnel, completed in January, provided an economical means for studying problems of high-speed airflows where size was not especially important. Many preliminary investigations are conducted in this tunnel before being extended to larger scale in the 16-foot high-speed tunnel. A full scale tunnel, 40 by 80 feet at the test section, was put in operation in June of 1944. The 40- by 80-foot wind tunnel is the largest in the world. During the war it provided the means for rapid correction of military designs already in or about to go into production. In basic research it allows investigations to be made at very large Reynolds numbers.

By December of 1945 the 8-by-8-inch supersonic tunnel was completed. This is the first of three supersonic facilities at this laboratory. The other two are 1-by-3-foot supersonic tunnels, completed in March and May of 1946. These facilities provide a range of speeds up to Mach number 3.4. In addition, the 1-by-3-foot tunnels are of variable density, providing a range of possible Reynolds numbers. They are the first of the larger supersonic facilities, much needed to provide information for ultra-high-speed aircraft.

In July of 1946, the 12-foot low-turbulence pressure tunnel was placed in operation. This tunnel represents the latest advance in wind-tunnel design, and was built to provide more accurately controlled, low turbulence airflows at speeds up to the speed of sound and also at effective large scale by means of pressurized air.

CLEVELAND LABORATORY

The NACA Aircraft Engine Research Laboratory at Cleveland, Ohio, authorized in November of 1940, has provided urgently needed facilities for studying the problems of aircraft propulsion systems. With the advent of new engine types these problems have multiplied and the research equipment has been correspondingly converted and enlarged.

The year 1942 brought completion of some of the initial construction at Cleveland. The flight research laboratory was placed in operation, extending the facilities for flight investigations at the Langley and Ames laboratories. Research on fuels and engine cooling have been among the principal studies. The first of two engine-propeller research buildings was completed in August. In November, the fuels and lubricants building was completed. The building is provided with equipment for the scientific study of fuel and lubricant characteristics and their improvement.

In March of 1943 the administration building was completed, providing the laboratory with its central offices, library, and auditorium. By August the engine research building was completed. This facility provides for investigation of complete engines and their components. Included are combustion research, compressor and turbine research, and friction and wear studies. The equipment involves engine test cells and extensive services for supplying refrigerated, com-

pressed, and evacuted air in the large volumes demanded by jet-propulsion engines and compressors.

In 1944 most of the originally planned propulsion research facilities at Cleveland were completed. The altitude wind tunnel was placed in operation in January. This tunnel provides altitude pressures up to 50,000 feet and temperatures of 40° F. below zero, at speeds up to 500 miles per hour. It is the only facility where full-scale engines of all kinds may be investigated in operation under accurately controlled conditions of high altitude. The icing research tunnel was completed in March. It is cooled by a large capacity refrigeration plant that also serves the altitude tunnel. It provides the means for studying every type of aircraft icing, including engine and propeller icing during operation, under controlled conditions not possible in flight. In May, a second engine-propelled research facility was completed. A jet propulsion static test laboratory was completed in August, providing much needed facilities for investigating the performance of complete jet engines. By November the compressor and turbine research facilities were completed. These are located in the engine research building, and constitute an important part of the equipment for study of major engine components.

In June of 1945 two supersonic wind tunnels were put into operation. These are the 18- by 18-inch tunnel and the 20-inch tunnel. They provide the laboratory with the means of studying the special problems of propulsion at supersonic speeds, including aircraft and engine shapes and ducts for air.

The high-pressure combustion laboratory was completed in October. This facility is devoted to the study of rocket fuels and their cumbustion for high-speed propulsion.

Close of the year 1946 has brought an addition to the jet-propulsion static-test laboratory, extending these facilities to accommodate a larger number of jet engines, which have almost entirely replaced the reciprocating engine in fundamental propulsion research.

LANGLEY LABORATORY

Facilities at the Langley Memorial Aeronautical Laboratory at Langley Field, Va., have been continually modernized, enlarged, and extended as the need has arisen. In June of 1941, a stability research wind tunnel and laboratory were placed in operation. This laboratory makes possible specialized study of stability problems under controlled conditions. In December, the electric power supply for the laboratory was augmented by installation of a 10,000-horsepower Diesel-electric generating plant, that was to permit the required operation of high-powered wind tunnels in the critical war period.

In January of 1942 the 16-foot high-speed tunnel was placed in operation. This tunnel is similar to the one constructed at Ames Laboratory but it is of slightly lower speed. It provides the means for high speed aerodynamic research at large scale. By July the 9-inch supersonic tunnel was completed, providing the laboratory with a facility for general supersonic aerodynamic research. A second hydrodynamic towing tank was completed in October, as well as the seaplane impact basin for studying water-landing loads. These facilities amplify the laboratory's equipment for hydrodynamic research, and have made possible more extensive work on land problems, many of which were of immediate specific importance during the war.

The next important additions come in 1945. The physical research laboratory was completed in April to provide for the study of fundamental and abstract problems in physics. A large number of these problems have to do with high-speed and supersonic flight. In August the gust tunnel was completed. This is a unique facility designed for research on aircraft loads produced by atmospheric turbulence, under accurately controlled conditions impossible to duplicate at will in flight. In September the flutter tunnel of the physical research division was completed. This is one of several specialized facilities, for investigation of the flutter and vibration phenomena that occur at high speeds. In November a new 7- by 10-foot high-speed tunnel was completed. This is similar to those constructed at Ames laboratory, except that it is equipped with variable test sections which provide speeds up to 700 miles per hour.

The end of 1946 has brought one more addition to the physical research division in the form of a helicopter test tower. Valuable work has been performed by this division on basic problems of the helicopter rotor. The tower is designed to permit research on rotors high enough from the ground to be substantially free of "ground effect." Another smaller addition has been a stratosphere chamber for instrument testing. Accurate instrumentation, calibrated for all conditions to be encountered, is a vital part of research equipment, and one that must keep abreast of the search for new knowledge.

Part III

COMMITTEE ORGANIZATION AND MEMBERSHIP

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 49, sec. 241). Its members are appointed by the President and include 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 Authority (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. The representatives of the Government organizations serve for indefinite periods. All members serve as such without compensation.

During the period since the publication of the Committee's last annual report, for the year 1942, the following changes have occurred in the membership of the main Committee:

Rear Adm. Sidney M. Kraus, U. S. N., was relieved on April 9, 1943, because of his transfer to duty away from Washington. Rear Adm. Edward M. Pace was appointed to succeed him.

Mr. William Littlewood, vice president (Engineering), of American Airlines, was appointed February 10, 1944, for a term expiring October 1, 1948, to succeed Dr. George J. Mead, who resigned because of ill health.

Vice Adm. John S. McCain, U. S. N., was relieved on August 17, 1944, because of his transfer to duty away from Washington, and Vice Adm. Aubrey W. Fitch, his successor as Deputy Chief of Naval Operations (Air), was appointed a member to succeed Admiral McCain.

On October 11, 1944, the President appointed Rear Adm. Lawrence B. Richardson, U. S. N., to succeed Rear Adm. Edward M. Pace, transferred to duty outside of Washington.

Dr. Alexander Wetmore, Secretary, Smithsonian Institution, was appointed a member on January 20, 1945, to succeed Dr. Charles G. Abbot, who had recently retired as secretary of that institution.

On June 11, 1945, the President appointed Brig. Gen. (now Major General) Edward M. Powers, U. S. A., Assistant Chief of Air Staff-4, to succeed Maj. Gen. Oliver P. Echols, relieved, on his transfer to duty away from Washington.

On his appointment as Deputy Chief of Naval Operations (Air), Vice Adm. Marc A. Mitscher, U. S. N., was appointed a member of the NACA July 24, 1945, to succeed Admiral Fitch, relieved.

Dr. William F. Durand, the last of the twelve original NACA members to serve on the Committee, resigned August 24, 1945, to retire to his home at Stanford University, Calif., after serving two terms of membership of 18 years and 3 years, respectively.

On September 20, 1945, Dr. Edward Warner, vice chairman of the Civil Aeronautics Board, resigned from the Committee to accept the presidency of the Interim Council of the Provisional International Civil Aviation Organization at Montreal.

Dr. Edward U. Condon, newly appointed Director of the National Bureau of Standards, was appointed to the Committee November 19, 1945, to succeed Dr. Lyman J. Briggs, retiring Director of the Bureau and NACA member for many years.

Vice Adm. Arthur W. Radford, U. S. N., was appointed a member of the Committee January 17, 1946, to succeed Rear Admiral Mitscher, transferred to other duty.

Under date of April 8, 1946, President Truman filled the vacancies caused by the resignation of Dr. Durand and Dr. Warner by appointing Dr. Theodore P. Wright, Administrator of Civil Aeronautics, who had previously been appointed a member from private life, as a member representing the Civil Aeronautics Administration succeeding Dr. Warner; appointing Arthur E. Raymond, vice president (Engineering), Douglas Aircraft Co., to succeed Dr. Wright for a term expiring December 1, 1946; and appointing Mr. Ronald M. Hazen, chief engineer, Allison division, General Motors Corporation, as member to succeed Dr. Durand for a term expiring December 1, 1949.

General Carl A. Spaatz, Commanding General of the Army Air Forces, was appointed a member of the Com-

mittee April 12, 1946, succeeding Gen. Henry H. Arnold, his predecessor as Commanding General.

In accordance with the regulations governing the organization 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.

Since 1942, Dr. Jerome C. Hunsaker has been reelected annually as Chairman of the NACA and of the Executive Committee. As Vice Chairman of the NACA, Dr. Lyman J. Briggs served from his election in October 1942 to October 25, 1945, just prior to his retirement as a member, and on the latter date Dr. Theodore P. Wright was elected Vice Chairman.

Dr. Charles G. Abbot served as Vice Chairman of the executive committee until his retirement from the committee, January 20, 1945. At the following annual meeting, October 25, 1945, Dr. Francis W. Reichelderfer was elected Vice Chairman of the Executive Committee.

The main committee is supplemented by a system of technical committees and subcommittees to prepare and recommended to the main Committee the programs of research to be conducted in their respective special fields. In addition, these subcommittees assist in coordinating research programs, and act as mediums of interchange of ideas and information among all groups concerned with a particular field of research.

Due to the increase in complexity and specialization of aeronautical research, the number of technical committees has been increased to cover the needs of this broadening field. In addition it is necessary from time to time to set up a special committee to deal with some particular project. All these committees change according to the need for them.

There are now 8 technical committees and 23 subcommittees. Their titles and membership are as follows:

COMMITTEE ON AERODYNAMICS

Dr. Theodore P. Wright, Administrator of Civil Aeronautics, Chairman.
Dr. Hugh L. Dryden, National Bureau of Standards, Vice Chairman.
Maj. Gen. L. C. Craigie, Air Corps, Air Matériel Command.
Col. Paul H. Kemmer, Air Corps, Air Matériel Command.
Col. Paul H. Dahe, Air Corps, Air Matériel Command.
Capt. Walter S. Diehl, U. S. N., Bureau of Aeronautics.
Capt. Robert S. Hatcher, U. S. N., Bureau of Aeronautics.
Rear Adm. L. C. Stevens, U. S. N., Bureau of Aeronautics.
Mr. Harold D. Hoekstra, Civil Aeronautics Administration.
Mr. John F. Parsons, National Advisory Committee for Aeronautics.
Mr. Floyd L. Thompson, National Advisory Committee for Aeronautics.
Dr. G. W. Lewis (ex officio), National Advisory Committee for Aeronautics.
Mr. Abe Silverstein, National Advisory Committee for Aeronautics.
Mr. Paul S. Baker, United Aircraft Corp.
Mr. John G. Borger, Pan American Airways System.
Prof. John R. Markham, Massachusetts Institute of Technology.
Mr. L. E. Root, Douglas Aircraft Co.
Mr. George S. Schairer, Boeing Aircraft Co.
Dr. Theodore von Karman, California Institute of Technology.

Subcommittee on Seaplanes

Mr. Grover Loening, Chairman.
Mr. H. L. Anderson, Air Matériel Command.
Capt. H. C. Richardson, U. S. N., Naval Air Matériel Center.
Capt. Walter S. Diehl, U. S. N., Bureau of Aeronautics.
Capt. H. E. Saunders, U. S. N., David Taylor Model Basin.
Capt. C. H. Schildhauer, U. S. N. R., Navy Department.
Mr. Albert A. Vollmecke, Civil Aeronautics Administration.
Mr. John B. Parkinson, National Advisory Committee for Aeronautics.
Prof. K. S. M. Davidson, Stevens Institute of Technology.
Capt. H. E. Gray, Pan American Airways System.
Mr. B. V. Korvin-Kroukovsky, Edo Aircraft Corp.
Mr. J. D. Pierson, Glenn L. Martin Co.
Mr. E. G. Stout, Consolidated Vultee Aircraft Corp.

Subcommittee on Vibration and Flutter

Dr. E. J. Reid, National Advisory Committee for Aeronautics, Chairman.
Mr. Benjamin Smilg, Air Corps, Air Matériel Command.
Mr. L. S. Wasserman, Air Matériel Command.
Capt. Walter S. Diehl, U. S. N., Bureau of Aeronautics.
Mr. Bernard A. Wiener, Bureau of Aeronautics, Navy Department, Washington, D. C.
Mr. E. Forest Critchlow, Civil Aeronautics Administration.
Dr. Walter Ramberg, National Bureau of Standards.
Dr. Theodore Theodorsen, National Advisory Committee for Aeronautics.
Mr. Sam Loring.

Subcommittee on Propellers for Aircraft

Mr. Frank W. Caldwell, United Aircraft Corp., Chairman.
Dr. Roscoe H. Mills, Air Matériel Command.
Mr. Daniel A. Dickey, Air Matériel Command.
Lt. Comdr. David W. Watkins, Jr., Bureau of Aeronautics.
Mr. Gerald L. Desmond, Bureau of Aeronautics.
Mr. John C. Morse, Civil Aeronautics Administration.
Mr. E. C. Draley, National Advisory Committee for Aeronautics.
Prof. Shatswell Ober, Massachusetts Institute of Technology.
Mr. Werner J. Blanchard, General Motors Corp.
Mr. George W. Brady, Curtiss-Wright Corp.
Mr. Erle Martin, Hamilton Standard Propellers.
Mr. Fred E. Weick, Engineering & Research Corp.

Subcommittee on Helicopters

Mr. Grover Loening, Chairman.
Lt. Col. K. S. Wilson, Air Corps, Air Matériel Command.
Maj. W. E. Zins, Air Corps, Air Matériel Command.
Capt. Walter S. Diehl, U. S. N., Bureau of Aeronautics.
Commander J. C. Lawrence, U. S. C. G., Bureau of Aeronautics.
Commander James W. Klopp, U. S. N., Bureau of Aeronautics.
Mr. B. L. Springer, Civil Aeronautics Administration.

Mr. Frederick J. Bailey, National Advisory Committee for Aeronautics.
Dr. Theodore Theodorsen, National Advisory Committee for Aeronautics.
Mr. Donnell W. Dutton, Georgia School of Technology.
Mr. Michael Gluhareff, Sikorsky Aircraft.
Mr. F. N. Piasecki, Piasecki Helicopter Corp.
Mr. Richard H. Prewitt.
Mr. Arthur M. Young, Bell Aircraft Corp.
Mr. H. L. Hanson, Bureau of Aeronautics, Navy Department.

Subcommittee on High-Speed Aerodynamics

Dr. Hugh L. Dryden, National Bureau of Standards, Chairman.
Mr. R. G. Robinson, National Advisory Committee for Aeronautics, Vice Chairman.
Mr. John Stack, National Advisory Committee for Aeronautics.
Mr. H. Julian Allen, National Advisory Committee for Aeronautics.
Mr. Abe Silverstein, National Advisory Committee for Aeronautics.
Commander Cedric W. Stirling, U. S. N., Bureau of Aeronautics.
Mr. F. A. Louden, Bureau of Aeronautics.
Lt. David Shore, Air Matériel Command.
Prof. John von Neuman, The Institute for Advanced Study.
Prof. Howard W. Emmons, Harvard University.
Dr. Francis H. Clauser, John Hopkins University.
Mr. Vladimir Morkovin, Navy Department.
Mr. Paul O. Spiess, Civil Aeronautics Administration, Washington 25, D. C.

Subcommittee on Stability and Control

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Mr. Paul C. Emmons, Bell Aircraft Corp.
Mr. Harry J. Goett, National Advisory Committee for Aeronautics.
Mr. Edward J. Horkey, North American Aviation.
Prof. Otto Koppen, Massachusetts Institute of Technology.
Prof. C. D. Perkins, Princeton University.
Mr. Joseph Matulaitis, Civil Aeronautics Administration.

Special Subcommittee on the Upper Atmosphere, Committee on Aerodynamics

Dr. Harry Wexler, U. S. Weather Bureau, Chairman.
Col. D. N. Yates, Army Air Forces Weather Service.
Col. Paul H. Dane, Air Corps, Air Matériel Command.
Capt. H. T. Orville, U. S. N., Navy Department.
Capt. Walter S. Diehl, U. S. N., Bureau of Aeronautics.
Commander Harvey Hall, U. S. N. R., Bureau of Aeronautics.
Dr. Fred L. Whipple, Harvard University.
Dr. C. N. Warfield, National Advisory Committee for Aeronautics.
Dr. E. H. Krause, Naval Research Laboratory.
Dr. W. G. Brombacher, National Bureau of Standards.
Dr. L. V. Berkner, Executive Secretary, Joint Research and Development Board, Washington 25, D. C.
Dr. B. Gutenberg, California Institute of Technology.

Subcommittee on Internal Aerodynamics

Membership not yet decided upon.

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Col. R. J. Minty, Air Corps, Air Matériel Command.
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Mr. Stephen Rolle, Civil Aeronautics Administration.
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Dr. Marcus A. Grossmann, Carnegie-Illinois Steel Corp.
Mr. Norman L. Mochel, Westinghouse Electric Corp.
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Mr. Willson H. Hunter, National Advisory Committee for Aeronautics.
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Mr. J. B. Johnson, Air Matériel Command.
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Mr. Paul F. Voigt, Jr., Carnegie-Illinois Steel Co.
Mr. A. A. Vollmecke, Civil Aeronautics Administration.
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Mr. S. K. Colby, Aluminum Co., of America.
Mr. R. L. Templin, Aluminum Co. of America.

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Lt. Col. Benjamin Smilg, Air Corps, Air Matériel Command.
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Mr. Charles B. Lyman, Bureau of Aeronautics.
Mr. E. I. Ryder, Civil Aeronautics Administration.
Mr. George Snyder, Boeing Aircraft Co.

Dr. Walter Ramberg, National Bureau of Standards.
Dr. E. E. Lundquist, National Advisory Committee for Aeronautics.
Mr. Richard V. Rhode, National Advisory Committee for Aeronautics.
Mr. G. L. Bryan, The Glenn L. Martin Co.
Prof. E. W. Conlon, University of Michigan.
Prof. Joseph S. Newell, Massachusetts Institute of Technology.
Mr. R. L. Schleicher, North American Aviation.

Subcommittee on Aircraft Methods

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Mr. J. B. Johnson, Air Matériel Command.
Mr. N. E. Promisel, Bureau of Aeronautics.
Mr. William F. Roeser, National Bureau of Standards.
Mr. E. I. Ryder, Civil Aeronautics Administration.
Mr. John H. Collins, Jr., National Advisory Committee for Aeronautics.
Mr. E. H. Dix, Jr., American Magnesium Corp.
Dr. J. C. McDonald, The Dow Chemical Co.
Dr. Maxwell Gensamer, Pennsylvania State College.
Mr. R. B. Gray, Reynolds Metals Co.

Subcommittee on Wood and Plastics for Aircraft

Dr. Gordon M. Kline, National Bureau of Standards, Chairman.
Mr. Robert Temple, Bureau of Aeronautics.
Mr. James E. Dougherty, Civil Aeronautics Administration.
Mr. L. J. Markwardt, Forest Products Laboratory.
Mr. George H. Clark, Formica Insulation Co.
Dr. Harry C. Engel, The Glenn L. Martin Co.
Dr. Milton Harris, Milton Harris Associates.
Mr. Bernard Budiansky, National Advisory Committee for Aeronautics
Dr. Lorin B. Sebrell, Goodyear Tire & Rubber Co.
Mr. J. H. Tigelaar, Haskelite Manufacturing Co.
Mr. Robert T. Schwartz, Air Technical Service Command.

COMMITTEE ON OPERATING PROBLEMS

Mr. William Littlewood, American Airlines, Chairman.
Brigr. Gen. Haywood F. Hansell, Jr., Air Transport Command.
Col. J. M. Gillespie, Air Corps, Air Matériel Command.
Capt. Robert S. Hatcher, U. S. N., Bureau of Aeronautics.
Commander Homer F. Webster, U. S. N. R., Naval Air Transport Service.
Mr. Donald Stuart, Civil Aeronautics Administration.
Dr. Francis W. Reichelderfer, United States Weather Bureau.
Dr. G. W. Lewis (ex officio), National Advisory Committee for Aeronautics.
Capt. Harold E. Gray, Pan American World Airways.
Mr. Richard V. Rhode, National Advisory Committee for Aeronautics.
Mr. M. G. Beard, American Airlines.
Mr. K. R. Ferguson, Northwest Airlines.
Mr. H. H. Gallup, Transworld Airways.
Mr. Ben O. Howard, Douglas Aircraft Co.
Mr. Jerome Lederer, Aero Insurance Underwriters.
Mr. W. C. Mentzer, United Air Lines Transport Corp.
Mr. Charles F. Dycer, Civil Aeronautics Administration.

Subcommittee on Meteorological Problems

Dr. Francis W. Reichelderfer, United States Weather Bureau, Chairman.
Col. Marcellus Duffy, Air Corps, Headquarters Signal Corps, Ground Signal Agency.
Col. D. N. Yates, Air Corps, American Air Force Weather Service.
Dr. Ross Gunn, Naval Research Laboratory.
Capt. Howard T. Orville, U. S. N., Bureau of Aeronautics.
Mr. Delbert M. Little, United States Weather Bureau.
Mr. George M. French, Civil Aeronautics Board.
Mr. Eugene Sibley, Civil Aeronautics Administration.
Mr. Philip Donely, National Advisory Committee for Aeronautics.
Mr. C. E. Buell, American Airlines.
Mr. E. J. Minser, Transworld Airways.
Dr. Carl G. Rossby, University of Chicago.
Prof. E. J. Workman, University of New Mexico.

Subcommittee on De-Icing Problems

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Mr. Clare I. Valentine, Air Matériel Command.
Mr. H. C. Sontag, Bureau of Aeronautics.
Mr. Alan L. Morse, Civil Aeronautics Authority Experimental Station.
Mr. B. C. Haynes, United States Weather Bureau.
Mr. Duane M. Patterson, Army Air Forces, Air Matériel Command.
Mr. Alun R. Jones, National Advisory Committee for Aeronautics.
Mr. Willson H. Hunter, National Advisory Committee for Aeronautics.
Prof. H. G. Houghton, Massachusetts Institute of Technology.
Mr. R. L. McBrien, The Glenn L. Martin Co.
Mr. Howard Schmidt, Consolidated Vultee Aircraft Corp.

SPECIAL COMMITTEE ON MATERIALS RESEARCH COORDINATION

Mr. Russell G. Robinson, National Advisory Committee for Aeronautics, Chairman.
Mr. Bernard Rubinstein, Executive Secretary.
Mr. J. B. Johnson, Air Matériel Command.
Capt. James E. Sullivan, U. S. N. R., Bureau of Aeronautics.
Mr. Albert A. Vollmecke, Civil Aeronautics Administration.
Dr. Clyde Williams, Battelle Memorial Institute.
Lt. Comdr. George Vaux, U. S. N. R., Navy Department.
Mr. Albert Epstein, Republic Aviation Corp.
Mr. A. T. Gregory, Fairchild Engine & Airplane Corp.
Mr. Raymond P. Lansing, Bendix Aviation Corp.
Mr. F. R. Shanley, Lockheed Aircraft Corp.
Mr. Robert Q. Barr, National Advisory Committee for Aeronautics.

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Dr. Hugh L. Dryden, National Bureau of Standards, Chairman.
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Capt. W. T. Rasleur, U. S. N., Navy Department.
Dr J. C. Hunsaker (ex officio), National Advisory Committee for Aeronautics.
Dr. G. W. Lewis (ex officio), National Advisory Committee for Aeronautics.
Mr. R. R. Gilruth, National Advisory Committee for Aeronautics.
Dr. J. C. Boyce.
Capt. Kenneth H. Noble, U. S. N., Navy Department, Bureau of Ordnance.
Col. J. G. Bain, War Department, Rocket Development Division.

Mr. Abe Silverstein, National Advisory Committee for Aeronautics.

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Mr. R. B. Maloy, Civil Aeronautics Administration.
Mr. John W. Crowley, Jr., National Advisory Committee for Aeronautics.
Mr. A. W. Dallas, Air Transport Association of America.
Mr. William Littlewood, American Airlines, Inc.
Mr. I. C. Peterson, Aircraft Industries Association of America, Inc.
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Mr. Lawrence D. Bell, Bell Aircraft Corp.
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Mr. Robert E. Cross, Lockheed Aircraft Corp.
Mr. Fred E. Weick, Engineering & Research Corp.
Mr. C. Bedell Monro, Pennsylvania-Central Airlines.
Mr. William T. Piper, Piper Aircraft Corp.

Part IV
FINANCIAL REPORT

Appropriations for fiscal year 1946. The following funds were appropriated for the Committee for the fiscal year 1946 in the Independent Offices Appropriation Act, 1946, approved May 8, 1945:

Salaries and expenses	$25,999,393
Printing and binding	15,000
Total appropriations	26,014,393

Subsequent actions of the Congress and the Bureau of the Budget reduced the availability of the appropriated funds by $3,000,000, as follows:

First Supplemental Surplus Appropriation Recision Act, 1946, approved February 18, 1946	$2,000,000
Placed in reserve by the Bureau of the Budget, May 22, 1946	1,000,000
Total recisions	3,000,000

Obligations incurred during the fiscal year 1946 are listed below. The figures shown are total obligations and include the costs of personal services, travel expenses, utility services, supplies, equipment, etc.

Activity and obligations—1946

Headquarters Office, Washington, D. C.	$435,934
Langley Memorial Aeronautical Laboratory	9,700,904
Ames Aeronautical Laboratory	2,918,166
Aircraft Engine Research Laboratory	9,473,173
Research contracts—educational institutions	276,204
Transfer to the National Bureau of Standards	127,000
Printing and binding, all activities	14,961
Total obligations	22,946,342
Recisions	3,000,000
Unobligated balance	68,051
Total appropriations	26,014,393

No new appropriations were provided in fiscal year 1946 for the construction and equipment of laboratory facilities. However, the following amounts were obligated during 1946 from construction and equipment appropriations made available in prior fiscal years:

Langley Memorial Aeronautical Laboratory	$4,155,087
Ames Aeronautical Laboratory	4,307,368
Aircraft Engine Research Laboratory	5,548,036
Total	14,010,491

Appropriations for the fiscal year 1947. The following funds have been appropriated for the Committee for the fiscal year 1947 in the Independent Offices Appropriation Act, 1947, approved March 28, 1946:

Salaries and expenses	$26,500,000
Printing and binding	75,000
Construction and equipment of laboratory facilities:	
Langley laboratory	2,990,000
Cleveland laboratory	108,000
Total	29,673,000

Supplemental and deficiency estimates of appropriations for the fiscal year 1947 have also been submitted to the Bureau of the Budget in the following amounts:

Salaries and expenses	$2,089,000
Construction and equipment of laboratory facilities:	
Langley laboratory	5,805,990
Cleveland laboratory	1,674,200
Total	9,569,190

CONCLUSION

Aeronautical science stands on the threshold of a new era. New forms of propulsion, even excluding the possibilities of atomic energy, open up new speed concepts for both military and commercial aviation.

The recent war saw the full development of aerial warfare using conventional aircraft operating at subsonic speeds. The possibilities of supersonic military aircraft and of guided missiles indicate that present types of military aircraft are becoming obsolete. As we prepare to enter the new era, we see no definite limit to the power that may become available for aircraft propulsion, nor to the speed that may be attainable. These possibilities confront the NACA with whole new fields of scientific problems requiring the provision of new facilities for supersonic research. And, after fundamental research has disclosed the design data and new shapes for supersonic aircraft, there will be another entirely new field of research to provide stability and control at the low speeds necessary for take-off and landing.

In the meantime, the aircraft industry remains essential for future national security. It is national policy to sustain that industry with orders for the necessary production of service aircraft and for the design and development of new and improved types. This results in an increased burden on the staff and facilities of the NACA to provide as quickly as possible the fundamental data needed by the military services and the industry as a basis for new designs. Teamwork between the military services, industry, and the NACA was never more essential, nor more effective.

Laboratory facilities of the NACA are being expanded to provide some of the urgently needed research facilities. The basic research activities of the NACA are the foundation of progress in America in improving the performance, efficiency, and safety of both military and civil aircraft.

Respectfully submitted.

JEROME C. HUNSAKER, *Chairman.*
National Advisory Committee for Aeronautics.