AMES AERONAUTICAL LABORATORY
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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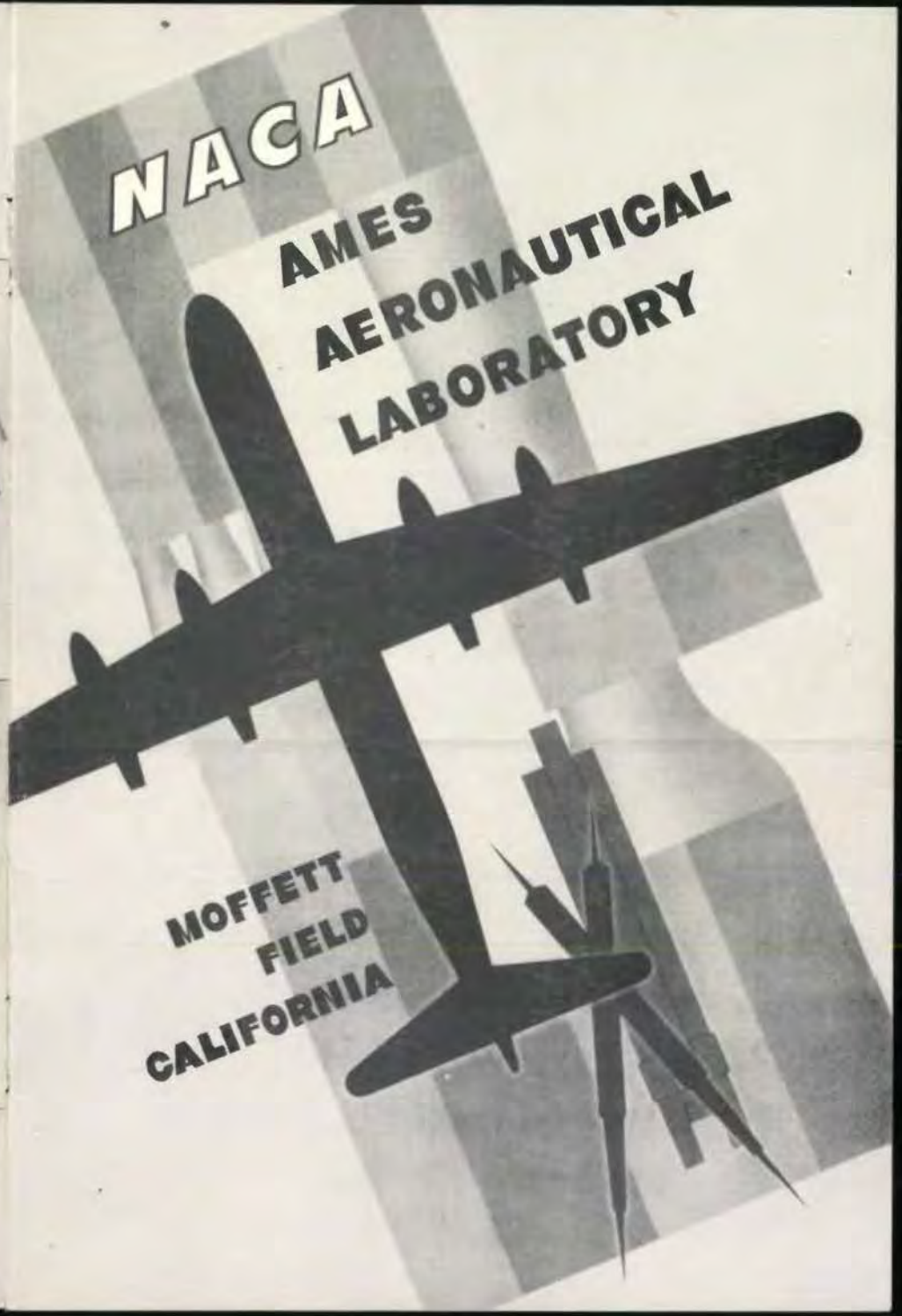
NACA

AMES AERONAUTICAL LABORATORY



MOFFETT FIELD CALIFORNIA

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

In March 1915, the Congress of the United States established the National Advisory Committee for Aeronautics in recognition of the need for organized scientific study of the problems of aeronautics. Since that time, the NACA has been continually identified with aeronautical progress and has made a large share of the important contributions to the science of aeronautics.

An independent Government agency, reporting directly to the President, the Committee consists of fifteen prominent aeronautical authorities appointed by the President to serve without compensation. The members include the head and the principal technical officer of the Army and Navy air branches, heads of other Government agencies cognizant of aviation affairs, and six outstanding scientists and engineers from private life.

To assist with counsel and guidance in specialized problems and research, eight technical committees and twenty-two subcommittees supplement the main Committee. These committees comprise nearly 300 top-ranking engineers, scientists, and operating specialists from the military services, private industry, various government agencies, and other scientific institutions.

Research is conducted in three of the finest equipped laboratories in the world. Dr. George W. Lewis, internationally-renowned scientist, directs the research work of over 5,000 employees, including a highly trained staff of engineers, scientists and technicians.

The original NACA research laboratory was begun in 1916 at Langley Field, Virginia. More than any single establishment, the Langley Laboratory has been most instrumental in establishing new frontiers in the aeronautical sciences. As early as 1928, for example, the first of the NACA's many compressibility wind tunnels was erected to study ultra-high-speed air flows, now referred to as supersonic aerodynamics.

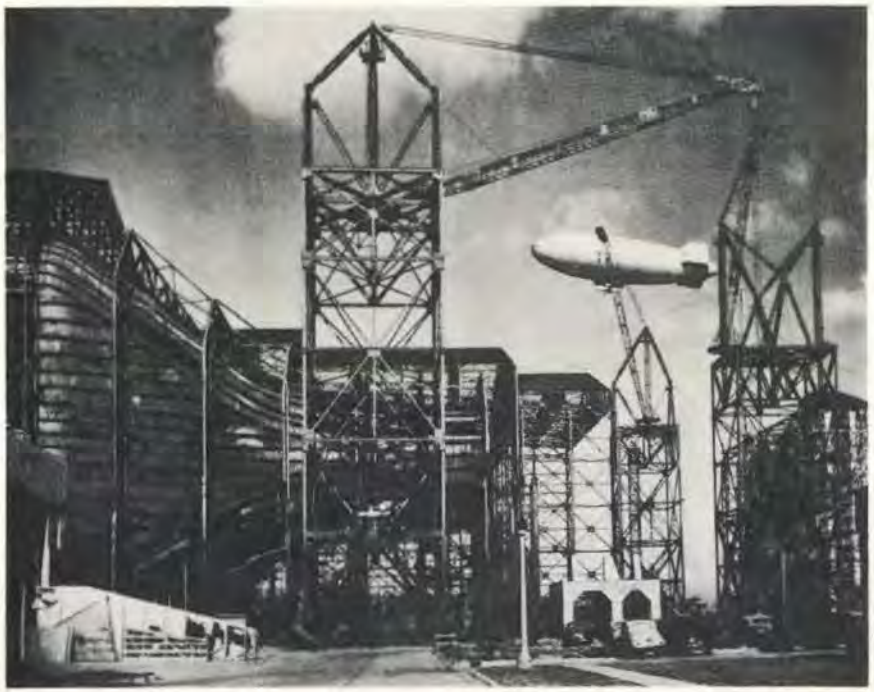
The latest of the NACA's three laboratories is the Aircraft Engine Research Laboratory, located at Cleveland, Ohio. This large station, inaugurated in 1941, is devoted solely to research in the fields of aircraft propulsion.

The Ames Aeronautical Laboratory at Moffett Field, California, is an extension of NACA facilities in the fields of high speed and large scale research. The purpose of this booklet is to describe in detail the research activities and equipment of this laboratory.

AMES AERONAUTICAL LABORATORY

The Ames Aeronautical Laboratory was named for the late Dr. Joseph Sweetman Ames, outstanding physicist and President of Johns Hopkins University, and one of President Wilson's original appointees to the NACA. Dr. Ames served as Chairman of the NACA Executive Committee from 1919 to 1936 and as Chairman of the Main Committee from 1927 to 1939. He was a great force behind the planning of the laboratory which bears his name.

Construction began on the Ames Laboratory on February 21, 1940 and the first structure, the



made in three large military airplanes. These airplanes were successfully flown in icing conditions which grounded conventional aircraft.

The icing research is being continued with the aid of a thermally-de-iced airplane to establish the weather conditions which cause icing and to gain further insight into the problems of ice prevention. This group is also conducting research on airplane-cabin heating and ventilation, cockpit cooling at high speeds, the prevention of interior fog on windshields, and airspeed measurement.

A Flight Research Section conducts investigations in actual flight on problems such as maneuverability and dynamic stability which are not readily subject to exploration by other testing facilities. They also determine flight characteristics of aircraft to furnish checks on the reliability of wind-tunnel and analytical investigations. The final proof of the value of aeronautical developments rests in the measured performance of aircraft in actual flight.

Flight test data are obtained by means of specialized instruments which record on photographic film such information as airspeed, altitude, attitude, temperature, acceleration, and air pressures over any portion of the airplane. The motions of the airplane, the angular deflections of the control surfaces, and the push or pull on the cockpit controls are also automatically recorded while the pilot puts the airplane through specified maneuvers. From these data, the engineers of this section obtain quantitative values of the factors involved in the problem under study. Proper analysis gives an understanding of the phenomena and leads to methods for improving the aircraft's control and maneuverability.

The Flight Operations Section consists of a group of highly trained test pilots who do the flying for both of the flight sections. These men are not only qualified pilots, but must be expert in the technique of test flying in order that satisfactory flight data may be obtained.

FLIGHT SECTIONS

The work of the Flight Engineering Section has been devoted principally to increasing the safety of airplane operations through the reduction of the icing hazard. This research was initiated at the Langley Laboratory and was subsequently transferred to the Ames Laboratory. It was, in fact, the first research program undertaken at Ames.

The insidious nature of ice formation on aircraft is well known and results from the fact that the potential dangers are not immediately evident to the pilot. The method of attack used to combat this problem was to determine the practicability of utilizing the waste heat in the engine exhaust gas for ice prevention. A system was devised whereby heat from the engine exhaust gases was transferred to air, which in turn was circulated through the wings, tail surfaces, and windshield to heat these vulnerable portions of the airplane. A commercial airplane incorporating this idea was successfully flown in icing conditions by the Flight Engineering group in 1941. Later, when the icing hazard became an important consideration during the bombing operations of the recent war, similar installations were

Flight Research Building, was completed August 7, 1940. In the meantime, work was in progress on other facilities, and the first wind tunnel, 7- by 10-foot wind tunnel No. 1, was put in operation on April 16, 1941. Now, six years later, the Laboratory comprises nine wind tunnels, two large hangar buildings with shops and office space, and four other buildings to house the administrative, technical, and shop facilities necessary to the functioning of the Laboratory. Still another wind tunnel, the 6- by 6-foot supersonic tunnel, is currently under construction.

At the present time the staff of the Laboratory numbers around 800 persons. Since its inception, the Laboratory has been under the supervision of Mr. Smith J. DeFrance, Engineer-in-Charge, who joined the NACA in 1922 and was in charge of four large wind tunnels at the Langley Field Laboratory prior to his transfer to Moffett Field.

Research Activities at Ames

Commencement of research at the Ames Laboratory coincided with the war emergency and consequently the entire facility was made available to assisting the armed services and the aircraft industry with immediate problems of specific nature. The wind tunnels and flight groups were devoted principally to the improvement of military performance of aircraft and the solution of aerodynamic problems having immediate application to new military designs.

Since the end of hostilities, emphasis of work at the Laboratory has been shifting steadily to research of a more fundamental nature. At the same time, certain portions of the war emergency work are being extended and incorporated into the long-range research program because of fundamental aspects of that work. The Ames Laboratory research, which is fully coordinated with the research programs of the other NACA laboratories, may be roughly classified

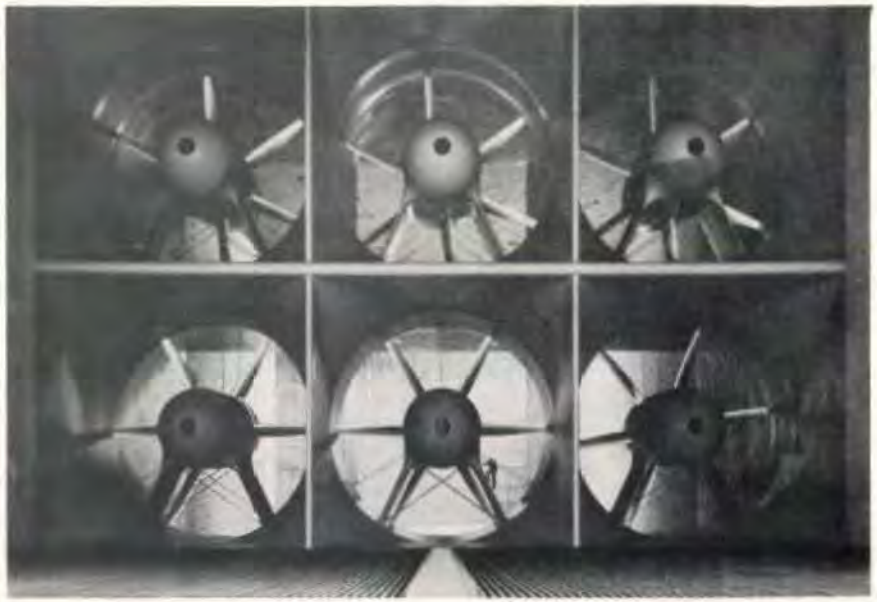
under four general headings.

1. General Aerodynamic Research. The evolution of optimum aerodynamic shapes stems directly from fuller knowledge of the fundamental physical laws of fluid motion. The research field in the regions of subsonic flow is still vast and occupies a substantial portion of the Ames Laboratory effort. Of equal importance are the but partially explored regions of transonic and supersonic air flow now to be encountered as new forms of propulsion make supersonic flight possible. The Ames Laboratory staff is attacking these problems with its ultra-modern supersonic research facilities.

2. Airplane Performance Improvement. Upon the effects of component parts acting in concert depends the overall performance of the airplane throughout the wide range of modern flight conditions. Only through persistent and systematic research can the criteria for efficient design of these components be established. Extension of investigations of this nature is a key factor in the Ames Laboratory research program as new demands are made for higher performance of subsonic aircraft and, for the time being at least, minimum requirements are met for new aircraft designed to operate in the transonic and supersonic speed regions.

3. Airplane Stability and Control. Airplane safety and ease of handling depend directly on the degree of stability and control inherently possessed by the airplane. As sizes and speeds of aircraft are increased, the stability and control problems become more complex. Through laboratory research, requirements for satisfactory characteristics are established, efficient means of obtaining the necessary degree of stability and control are evolved, and aircraft designers are provided with convenient and rational methods of applying the results of such research to specific designs.

4. Propulsion Aerodynamics. Effective operation of an aircraft propulsion system can be assured only if its installation and the overall airplane configuration provide for the necessary flow of air for both combustion and cooling under all flight conditions. At the Ames Laboratory particular emphasis is being given to the study of requirements of jet propulsion engines with regard to introduction and distribution of the required air flow with a minimum of internal and external drag.



40- BY 80-FOOT WIND TUNNEL SECTION

EQUIPMENT

Wind Tunnel

Test Section:	40- by 80-foot, closed throat
Power:	36,000 horsepower
Speed:	250 miles per hour
Pressure:	Atmospheric

The 40- by 80-foot wind tunnel is the largest in the world, and has been used to study airplanes and panels with spans of over 70 feet. The entire structure covers an area of 8 acres. In completing a circuit of the tunnel the air travels nearly one-half mile. The maximum size of the air passage, which is just ahead of the test section, is 172 feet wide by 132 feet high.

Airplanes can be studied in the tunnel with engines operating, whether powered with conventional engine-propeller arrangements or gas-turbine installations. All of the tunnel operational controls as well as those for the airplane engines are located in the "balance house" directly beneath the tunnel test section.

During the two years the tunnel has been in operation its efforts have been devoted to the improvement of newly-designed military aircraft in which unforeseen shortcomings appeared during initial test flights. These include fighters and medium bombers for both the Army and Navy. Improvements have been made in stability and control characteristics and in the performance of airplanes through drag reductions and increased effectiveness of power-plant operation. Now that the pressing necessity of wartime developmental work has passed, the activities of this tunnel will be directed more toward fundamental research problems.

RESEARCH DIVISIONS AND EQUIPMENT

THEORETICAL AND APPLIED RESEARCH DIVISION

7- BY 10-FOOT WIND TUNNEL SECTION

EQUIPMENT

Tunnels No. 1 and No. 2

Test Section:	7- by 10-foot rectangular, closed throat
Power:	1,600 horsepower
Speed:	300 miles per hour
Pressure:	Atmospheric

The 7- by 10-Foot Section operates two nearly identical wind tunnels which differ only in minor details of the model mounting systems. The size and speed of these tunnels are such as to make them ideal for low-speed stability and control development work. During the war many complete models of military aircraft were investigated. From the data obtained, predictions of the handling qualities (that is, stability and control characteristics as they would be observed by the pilot) were made, and where deficiencies were encountered, corrective measures were applied until the predicted handling qualities successfully met the military requirements. The value of this work has been demonstrated by the good correlation obtained between wind-tunnel predictions and the same qualities subsequently obtained from flight tests.

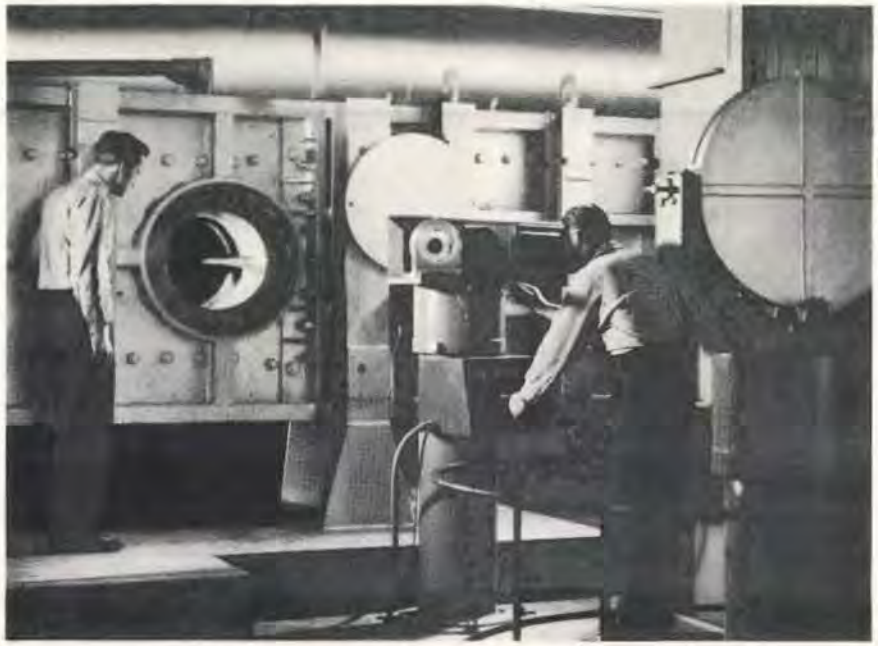
The work of these tunnels has by no means been confined to developmental work on three-dimensional models. Considerable fundamental research has been carried out on such problems as high-lift devices, the prediction of control-surface hinge moments, and the effect of heat on airfoil drag and boundary-layer characteristics.

FULL SCALE AND FLIGHT RESEARCH DIVISION

There are two 1- by 3-foot supersonic wind tunnels. The air in Tunnel No. 1 is circulated by four centrifugal compressors driven by electric motors of 10,000-horsepower total capacity. In Tunnel No. 2 the compressed air of the 12-foot pressure tunnel is used as a source of power. In both tunnels the air flows through a nozzle whose shape determines the speed at the tunnel test section. By changing this shape the speed can be varied from 1.0 to 2.2 times the speed of sound in Tunnel No. 1 and from 1.0 to 3.4 times the speed of sound in Tunnel No. 2. This corresponds to an over-all speed range from 760 to 2,580 miles per hour at sea level.

The test section of each tunnel is one foot wide and three feet high. In general, the models which are tested have bodies about ten inches in length and wings about eight inches in span. To compensate for this small size, provision is made to raise the total pressure of the air in the tunnels above atmospheric pressure and thus increase the effective scale of the test. Apparatus is provided to maintain the humidity in the tunnels to the low level required for accurate supersonic testing.

As an adjunct to the two 1- by 3-foot supersonic wind tunnels, a third tunnel, the 8- by 8-Inch Supersonic Wind Tunnel is also in operation. Powered by centrifugal compressors totaling 4,000 horsepower. It is capable of operating at speeds up to 2.3 times the speed of sound. This equipment is mainly useful in the investigation of duct entries and exits of supersonic aircraft and missiles.



16-Foot Wind Tunnel Section

EQUIPMENT

Wind Tunnel

Test Section:	16-foot-diameter, circular, closed throat
Power:	27,000 horsepower
Speed:	680 miles per hour (0.9 Mach number)
Pressure:	Atmospheric

Research problems associated with high-speed subsonic flight are the specialty of the 16-Foot High-Speed Wind Tunnel Section. As the ever-increasing speed of aircraft has approached the speed of sound, new phenomena have appeared to complicate airplane design. One well-known airplane became so stable in high-speed dives that pilots were able to effect the pull-out only with great difficulty, if at all. Another developed such an extremely annoying rumble and vibration as to cause pilots to fear an otherwise excellent airplane. The ailerons and adjacent wing sections of a third airplane twisted and fluttered at high speed. Solutions to these and other similar difficulties were effected in the wind tunnel with the excellent cooperation of the contractors involved at no risk of life and with a great saving of time.

In addition to the war-necessary assignment of performance-refining existing aircraft, the 16-foot wind-tunnel staff undertakes such basic high-speed research projects as the study of air loads on aircraft, the aerodynamics of propulsive units, stability and control characteristics, guided-missile research, and methods of analysis of flutter problems.

12-Foot Wind Tunnel Section

EQUIPMENT

Wind Tunnel

Test Section:	12-foot-diameter, circular, closed
Power:	11,000 horsepower
Speed:	Up to the speed of sound depending on the pressure
Pressure:	Variable from 1/6 to 6 atmospheres

The 12-Foot Low Turbulence Pressure Tunnel is the latest addition to the research facilities of the Ames Laboratory. Principal features of this tunnel are the provision for varying the pressure of the circulated air and the elimination of turbulence in the air flow. The complete circuit of the tunnel and the chamber enclosing the equipment for measuring aerodynamic forces form a continuous sealed tank capable of withstanding internal pressures either below or above atmospheric. The design range is from about 2.5 to 88 pounds per square inch absolute pressure. The tunnel is pressurized or evacuated by means of multi-stage centrifugal compressors. The increased pressure of the circulated air has the same effect as increased size of the test model. Thus, the test data obtained for a model airplane of 10-foot span at 6 atmospheres pressure would be equivalent to the same data obtained for a 60-foot-span model at atmospheric pressure. The purpose of partially evacuating the tunnel is to achieve greater speeds than are obtainable at higher pressures.

Because of the large contraction ratio (25 to 1) and the presence of fine-mesh screens in the large section, the turbulence level of the air jet approaches the low value characteristics of free air. This fact, coupled with the variable-pressure feature makes this wind tunnel a particularly adaptable instrument for new research fields.

The Ames 12-Foot Tunnel is the only wind tunnel where low turbulence flows may be studied on three-dimensional bodies at either very high Reynolds Number or at very high speeds.

1- by 3-Foot Supersonic Wind Tunnel Section

EQUIPMENT

Wind Tunnel No. 1

Test Section:	1- by 3-foot, rectangular
Power:	Centrifugal compressors of 10,000 horsepower total capacity
Speed:	Mach number 1.0 to 2.2
Pressure:	Variable

Wind Tunnel No. 2

Test Section:	1- by 3-foot, rectangular
Power:	Compressed air from 12-foot pressure tunnel
Speed:	Mach number of 1.0 to 3.4
Pressure:	Variable

Examples of the latest developments in advanced aerodynamic research are to be seen in the 1- by 3-foot supersonic wind tunnels. In these tunnels, which are among the largest supersonic tunnels in operation in this country, investigations are being made to determine the design of airplanes and missiles to fly at speeds above the speed of sound.

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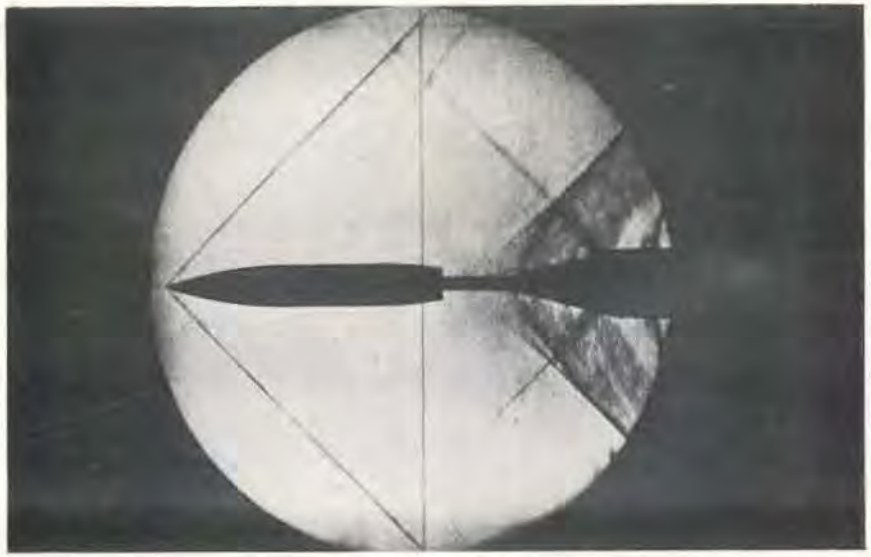

1- BY 3½-FOOT HIGH SPEED WIND TUNNEL SECTION

EQUIPMENT

Wind Tunnel

Test Section:	1- by 3½-foot, rectangular, closed throat
Power:	2,000 horsepower
Speed:	Up to the speed of sound
Pressure:	Atmospheric

The 1- by 3½-Foot High-Speed Wind Tunnel was designed to investigate unknown compressibility phenomena associated with high subsonic flight speeds. Many research problems may be solved in this small wind tunnel at greater economy of time and money than in a larger research facility such as the 16-foot high-speed wind tunnel. One of the features of the wind tunnel is that the lift and pitching-moment forces experienced by the model are obtained by measurement of the aerodynamic reactions on the tunnel walls rather than by means of the usual wind-tunnel balance system.

The compressibility effects of high-speed flow are under investigation for a wide range of airfoil profiles and such lift-control devices as ailerons, spoilers, and dive-recovery flaps. The results of these investigations assist designers of high-speed aircraft with the selection of suitable airfoils.

THEORETICAL AERODYNAMICS SECTION

One of the most important branches of aeronautical science concerns itself with the development of adequate aerodynamic theory. Without theory to point the way, experimental research would degenerate into a mere cut-and-try process; each new fact would have to await the accident of its finding rather than a swifter unveilment made possible by a logically-directed attack. The basis of aeronautical science - the mathematical theory of fluid motion - is not recent in its beginnings. For years mathematicians have exercised their ingenuity on the solution of equations to be found in this general field. Many of these solutions required certain simplifying assumptions. The mass of experimental evidence now available make it possible to examine the validity of many of these assumptions, and offers opportunities of deducing more accurate approximations. When such new improvements are developed their use permits the accurate calculation of many quantities which previously could be obtained only by tedious experiment. This work of testing and refining existing theory coupled with the further extension of the mathematical theory of fluid motion, particularly into the field of supersonic flows, occupies much of the attention of the engineers, mathematicians, and physicists of the Theoretical Aerodynamics Section.

Another valuable service of this group is performed in cooperation with other sections of the Laboratory in the planning of general experimental research programs and in the analysis of experimental results. Frequently these experiments inspire new theories, and again theories are occasionally produced which suggest new experiments.

HIGH SPEED RESEARCH DIVISION