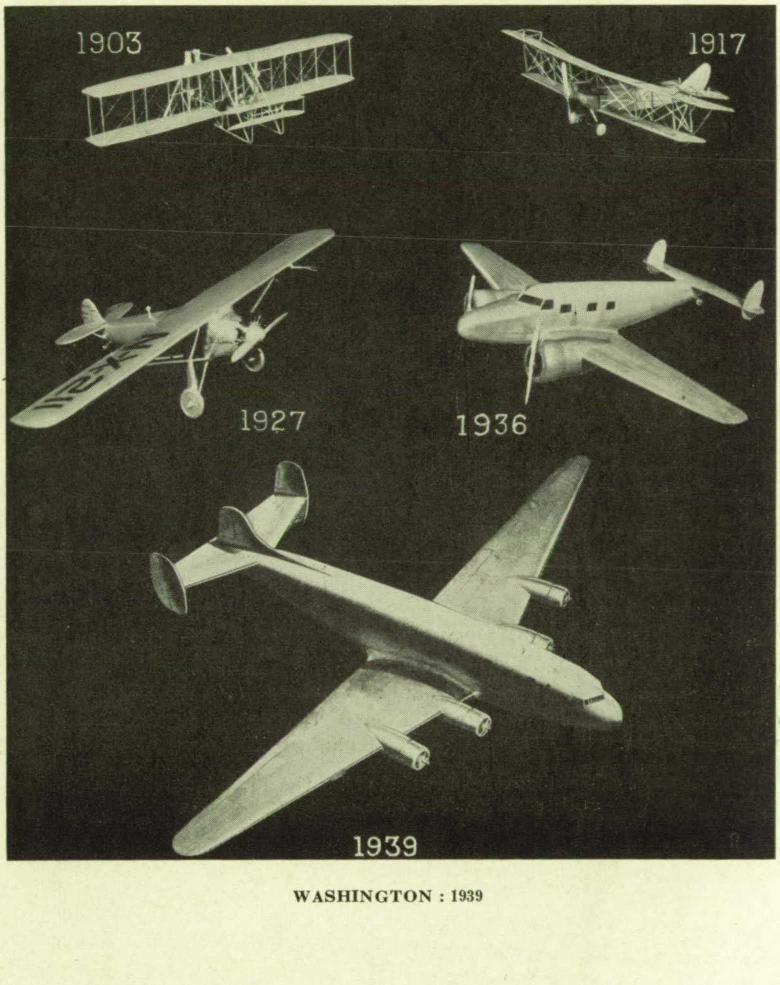
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

A GLIMPSE OF SCIENTIFIC RESEARCH ON FUNDAMENTAL PROBLEMS OF MILITARY AND CIVIL AERONAUTICS



WASHINGTON : 1939

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Supervision and direction of scientific study of the problems of flight

Established by Act of Congress approved March 3, 1915

SUBCOMMITTEES

Aerodynamics
Power Plants for Aircraft
Aircraft Materials
Aircraft Structures
Aircraft Accidents
Inventions and Designs

Coordination of research needs of military and civil aviation

Preparation of research programs

Allocation of problems

LANGLEY MEMORIAL AERONAUTICAL LABORATORY
Langley Field, Va.

Unified conduct, for all agencies, of scientific research on the fundamental problems of flight.

OFFICE OF AERONAUTICAL INTELLIGENCE
Washington, D. C.

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

Members are appointed by the President and serve as such without compensation

Among the outstanding accomplishments of the last century is man's conquest of the air. That conquest began in 1903 when the Wright brothers made the first successful flight of an airplane at Kitty Hawk, N. C.

Five years later the United States Government purchased its first airplane for the use of the Army, and began the training of officers for military flying. During the years immediately preceding the outbreak of the World War the Government and a meager aircraft industry had made important progress, but the Government, practically the only customer, had purchased less than 100 airplanes.

In the meantime, leading European nations, sensing acutely the potentialities of aircraft in warfare, had made greater progress and had begun laying the foundations for the new science of aeronautics. The World War gave a remarkable impetus to the development of aeronautics and emphasized the need for organized research on the fundamental problems of flight.

By act of Congress approved March 3, 1915, the National Advisory Committee for Aeronautics was created and charged with the duty of supervising, directing, and conducting fundamental scientific research and experiment in aeronautics. With the farsighted support of the Congress the Committee has led the world in the development of unique aeronautical research facilities in its laboratories at Langley Field, Va. The research programs include problems initiated by the Committee and its subcommittees and also investigations requested by the Army, the Navy, and the Civil Aeronautics Authority. The results of researches conducted under one control, serve without duplication of effort, the needs of all branches of aviation, civil and military, and exert a profound influence on the progress of aeronautics by improving the performance, efficiency, and safety of aircraft.

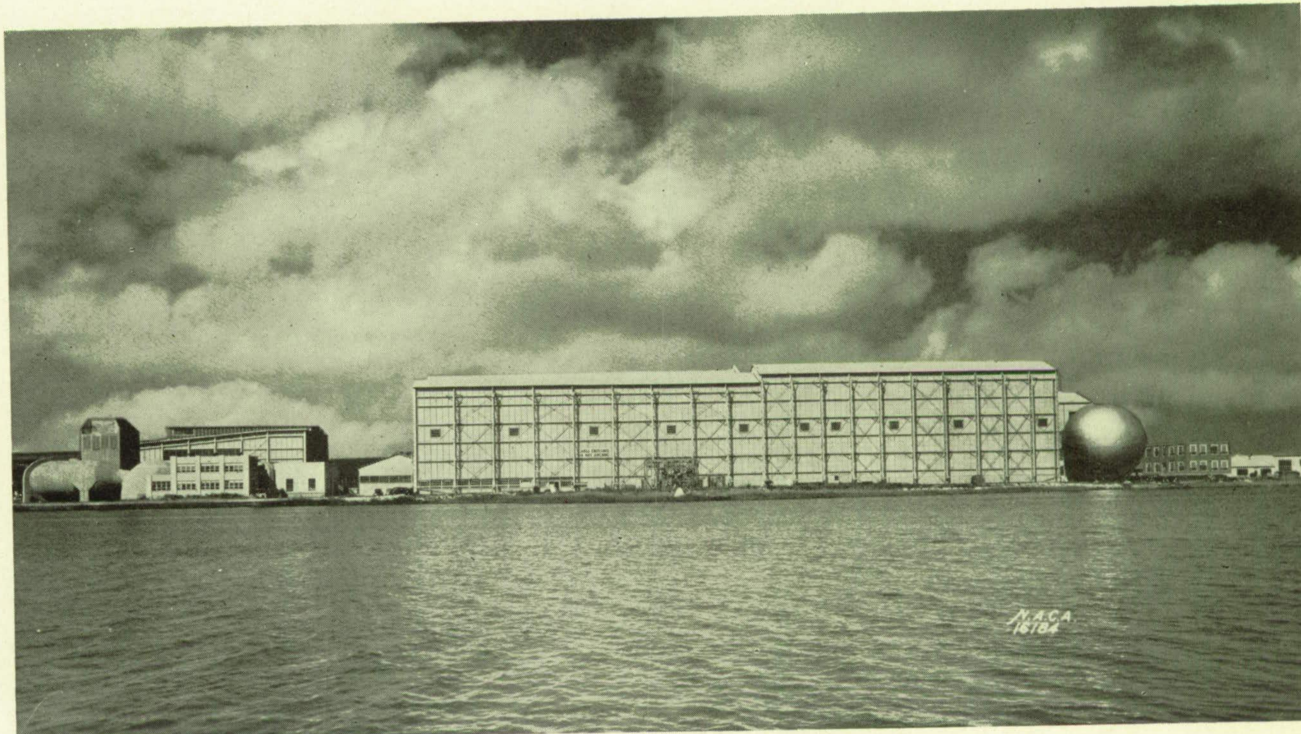
A brief description of the results of some of the committee's researches and of the equipment employed will be found in the following pages.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

October 20, 1938

Left to right: Clinton M. Hester, A. B., LL. B.; Sydney M. Kraus, Capt., U. S. N.; Augustine W. Robins, Brig. Gen., U. S. A.; Lyman J. Briggs, Ph. D.; Edward P. Warner, Sc. D.; Orville Wright, Sc. D., Joseph S. Ames, Ph. D., Chairman; Charles G. Abbot, Sc. D.; John F. Victory, LL. M., Secretary; Arthur B. Cook, Rear Admiral, U. S. N.; Edward J. Noble, A. B.; Vannevar Bush, Sc. D., Vice Chairman; Jerome C. Hunsaker, Sc. D.; George W. Lewis, Sc.D., Director of Aeronautical Research.

Absent: Henry H. Arnold, Maj. Gen., U. S. A.; Charles A. Lindbergh, LL. D.; Francis W. Reichelderfer, A. B.

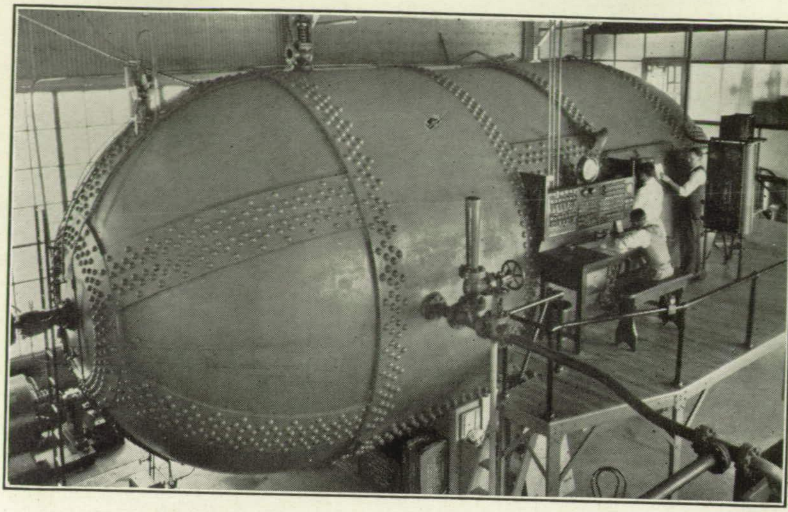


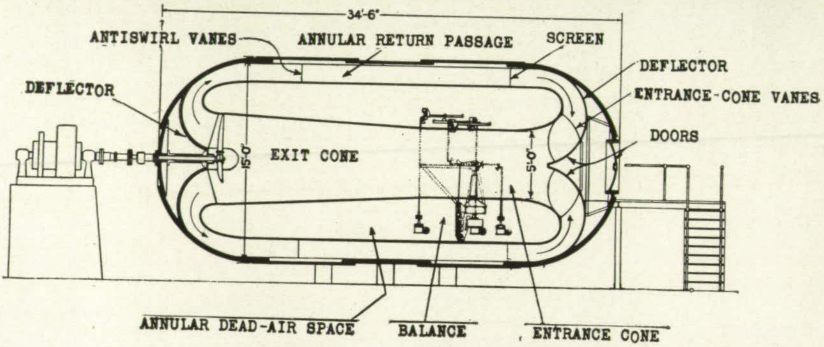
THE N. A. C. A. SKYLINE AT LANGLEY FIELD, VA.

Structures comprising the N. A. C. A. Laboratories are as follows:

Administrative Building
Atmospheric Wind Tunnel
Variable-Density Wind Tunnel
Service Building
Propeller-Research Tunnel
Maintenance Building
Full-Scale Wind Tunnel
Seaplane Towing Tank
Flight-Research Laboratory
Aircraft Engine Research Laboratory
2-Foot High-Speed Wind Tunnel
Free-Spinning Wind Tunnel
8-Foot High-Speed Wind Tunnel
Refrigerated Wind Tunnel
Shop Building
12-Foot Free-Flight Tunnel
19-Foot Pressure Tunnel
Two-dimensional Flow Wind Tunnel

VARIABLE-DENSITY WIND TUNNEL

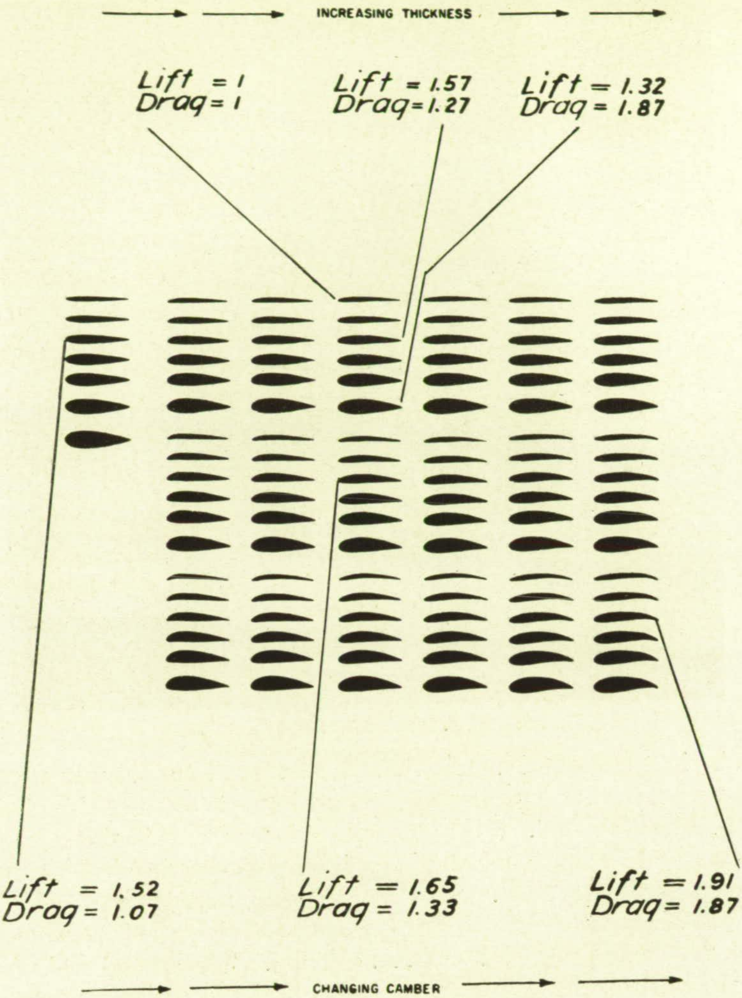




DIAGRAMMATIC LONGITUDINAL SECTION OF THE VARIABLE-DENSITY WIND TUNNEL

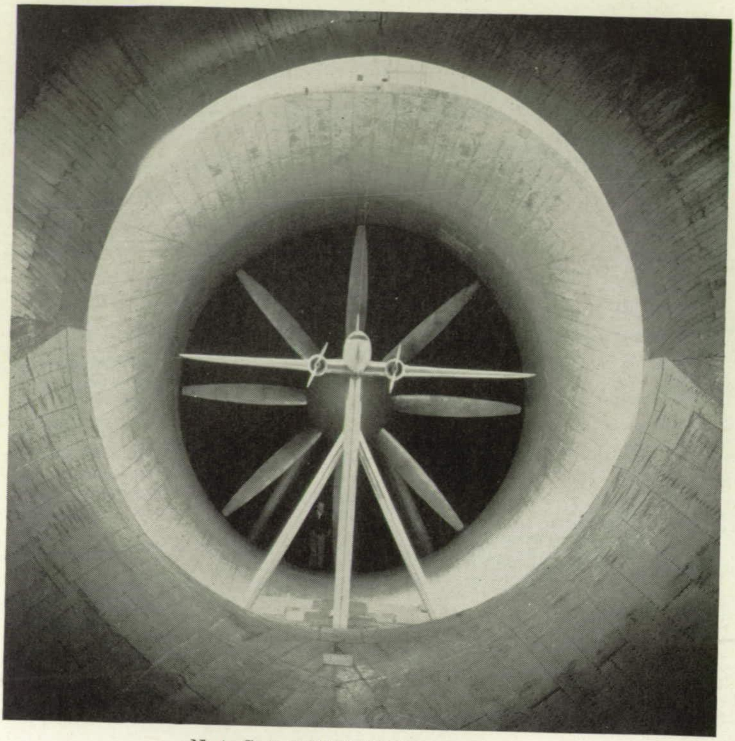
This is the only type of wind tunnel in which small models may be used to obtain full-scale results. This wind tunnel is built within a steel tank, so that the models may be tested in compressed air, the purpose being to increase the air pressure-forces on the model. These forces on the model are then made the same, in relation to the skin-friction forces, as on the actual airplane in flight. If, for example, a model 1/20 the size of an airplane is tested, the air is compressed to 20 times its normal density or to 300 pounds per square inch. In the determination of the lift and drag characteristics of wing sections the results obtained with this equipment are accepted as standard.

N. A. C. A. AIRFOIL SECTIONS



The aerodynamic characteristics of many members of this family of airfoils have been measured by the N. A. C. A. in the variable density wind tunnel. Typical results are shown here to indicate how changes of shape affect the aerodynamic properties of the airfoil section.

EARLY LARGE-SCALE INVESTIGATIONS



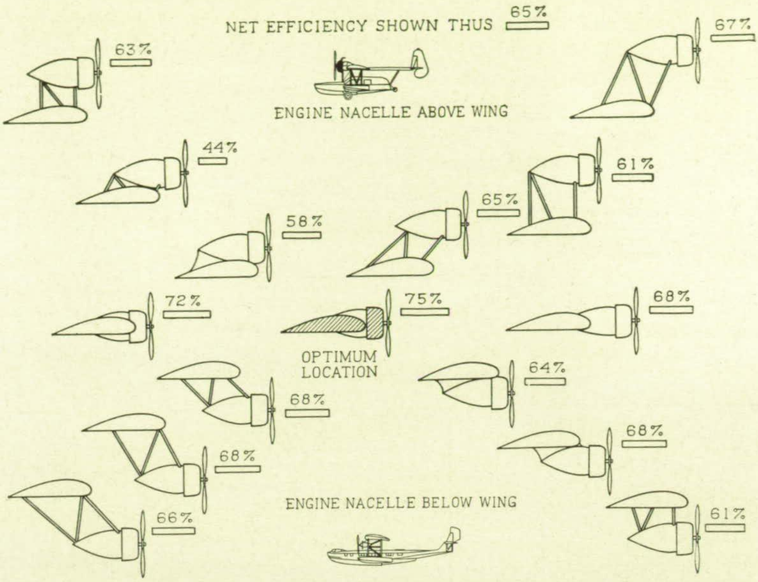
N. A. C. A. 20-FOOT WIND TUNNEL

Built in 1926, the N. A. C. A. 20-foot wind tunnel was the first wind tunnel in the world in which the main parts of a full-size airplane could be investigated. For 5 or 6 years it was used in the researches that served as a basis for the large improvements in airplane design between 1928 and 1933. Two factors were mainly involved. The first was a means for reducing the drag of the air-cooled radial engine, which was done by the N. A. C. A. cowling. The second main factor was the position in multiengine airplanes of the cowled engines and their nacelles relative to the wing and the rest of the airplane.

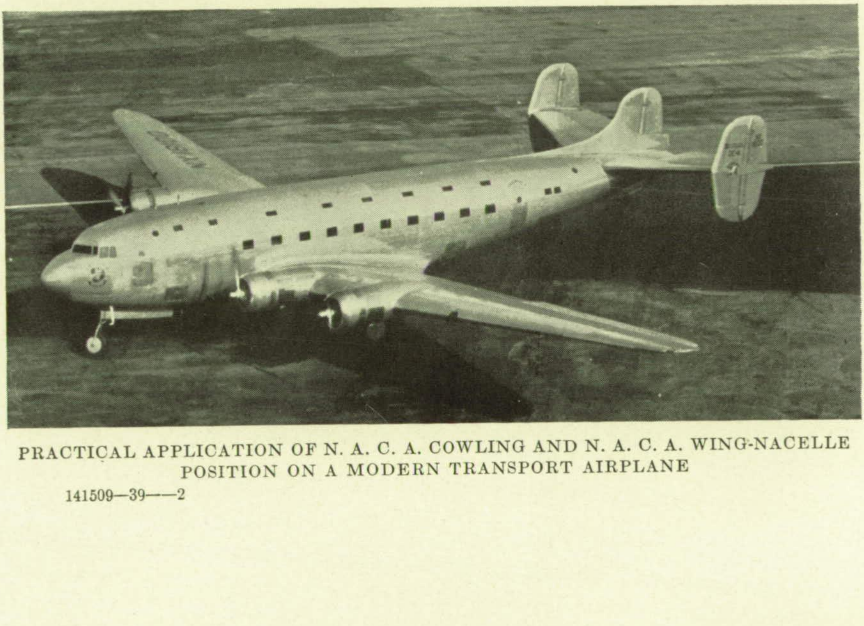
These two main factors in the development from the high-wing three-engine airplane, with underslung exposed engines, to the modern multiengine monoplane with cowled engines installed in the optimum location, contributed enormously to aerodynamic efficiency and increased the maximum speed of otherwise comparable aircraft by some 50 miles per hour.

WING-NACELLE INVESTIGATIONS

NET PROPELLER EFFICIENCY FOR AN ENGINE NACELLE IN VARIOUS POSITIONS WITH RELATION TO AN AIRPLANE WING



ENGINE NACELLE MOUNTED ABOVE THE WING INCREASES THE LIFT; BELOW THE WING REDUCES THE DRAG. ENGINE BUILT INTO OR FAIRED INTO THE WING IS IN THE BEST LOCATION FOR OVER-ALL EFFICIENCY



PRACTICAL APPLICATION OF N. A. C. A. COWLING AND N. A. C. A. WING-NACELLE POSITION ON A MODERN TRANSPORT AIRPLANE

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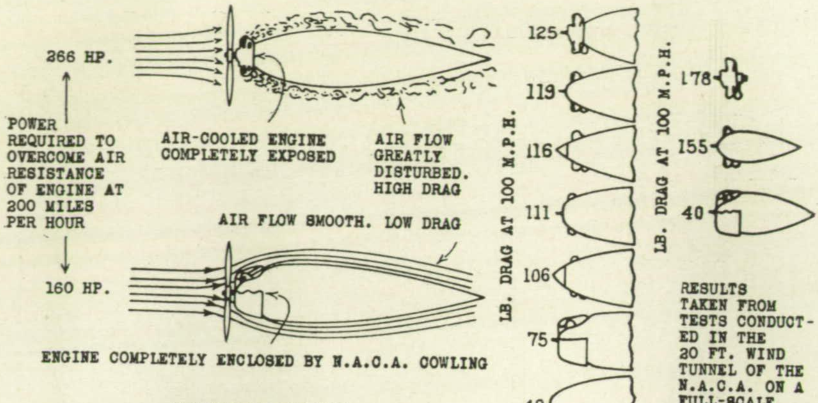
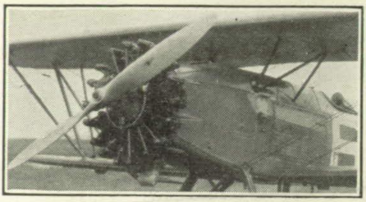
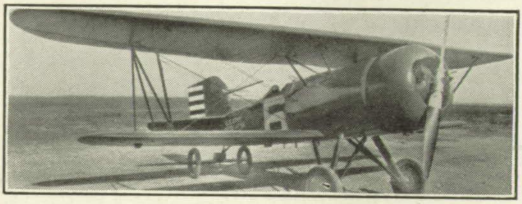
N. A. C. A. COWLING



THE REASON FOR THE LOW RESISTANCE OF THE N.A.C.A. COWLING



UNCOWLED ENGINE
HIGH SPEED 118 MILES PER HOUR



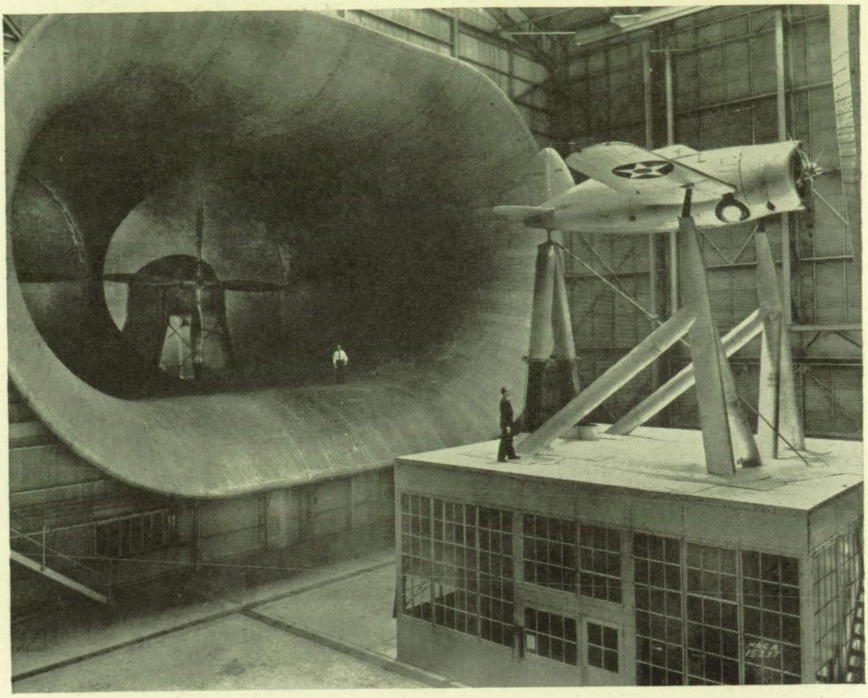
COWLED ENGINE
HIGH SPEED 137 MILES PER HOUR

FIRST APPLICATION OF N. A. C. A. COWLING TO A COMPLETE AIRPLANE, LANGLEY FIELD, OCT. 12, 1928

APPLICATION OF N. A. C. A. COWLING TO A MODERN SINGLE-ENGINE AIRPLANE

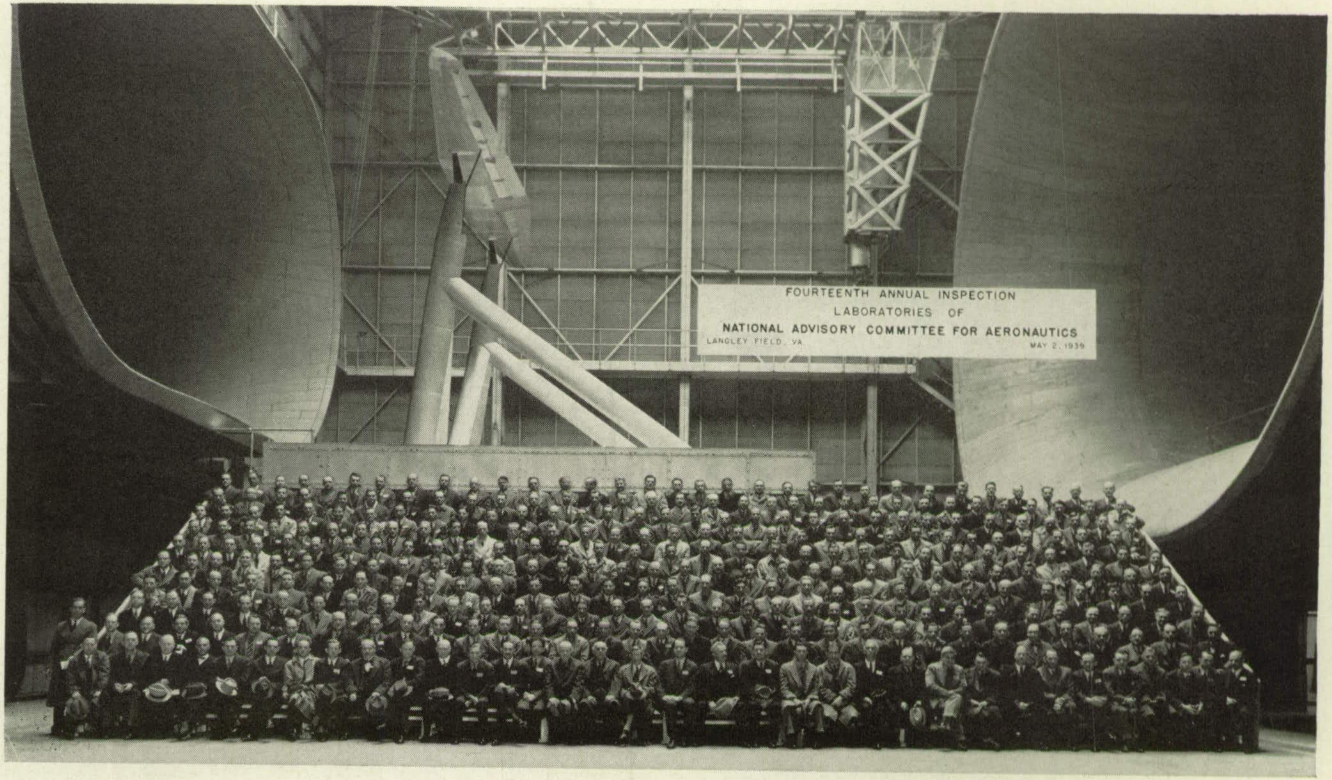
The low-drag N. A. C. A. cowling for air-cooled engines is recognized the world over as an outstanding achievement in aeronautical research. The saving to the Government and to commercial operators from this one research alone amounts to several million dollars annually.

FULL-SCALE WIND TUNNEL



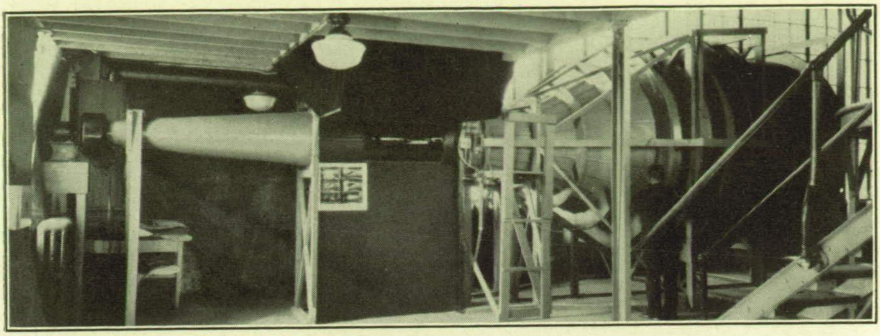
BREWSTER XF2A-1 AIRPLANE MOUNTED ON THE BALANCE OF THE N. A. C. A. FULL-SCALE WIND TUNNEL, LANGLEY FIELD, VA.

Inspired by the success of the 20-foot wind tunnel built in 1926, the Committee placed in operation in May 1931 a still larger tunnel having a jet 30 feet high and 60 feet wide. This tunnel can accommodate small and medium-size airplanes in its 120-mile-an-hour wind stream. This tunnel has been useful for investigating detailed aerodynamic features that are too minute to investigate with small-size models. Careful studies of detailed modifications to aircraft, such as the single-seat fighter shown mounted on the balance, have resulted in improvements of stability, control, and efficiency. By such investigations on prototype airplanes the top speeds attained by the type have been increased by as much as 35 miles per hour.

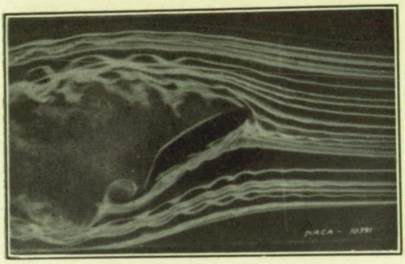


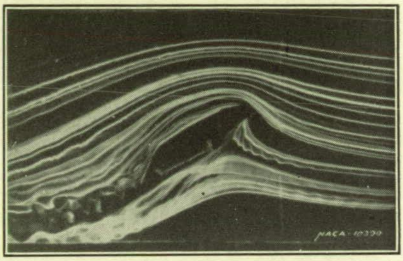
FULL-SCALE WIND TUNNEL

THE SMOKE TUNNEL



Visualization of the nature of air flow around objects is made possible by the use of this tunnel. Streamers of smoke are introduced into the air stream and flow around the model under observation.

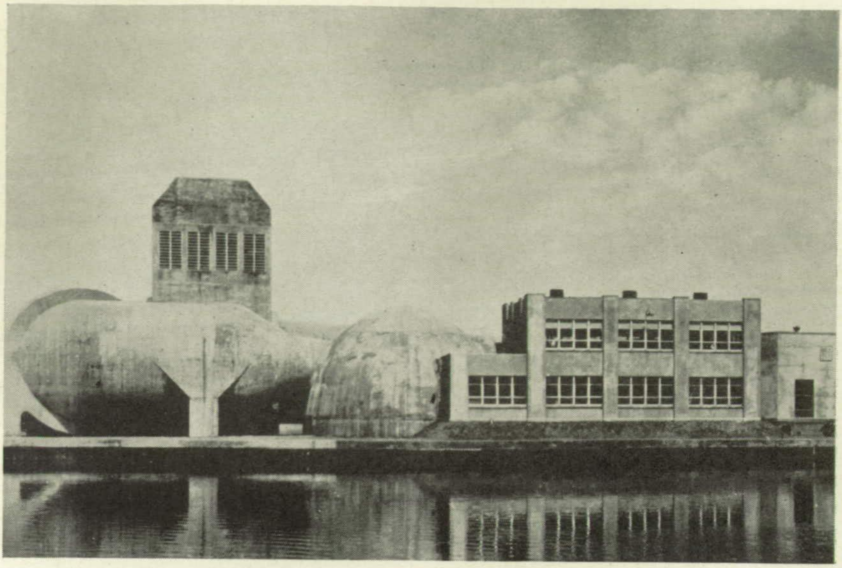




METHOD FOR DELAYING THE STALL OF A WING

The smoke-flow pictures show the nature of air flow over a wing at a stalling angle. On the left the flow breaks away from the top surface of the ordinary type of wing, a condition always accompanied by a loss in lift known as stalling. On the right the air flows over the same wing at the same angle, adhering closely to the top surface, the wing being in an unstalled condition and suffering no loss in lift. This is made possible by the application of suction to the top surface of the wing through a small slot located near the nose, through which the dead air is drawn into the wing. This method of preventing the breakaway of the air flow results in increased lift and is one way of obtaining slower landing speeds and better take-off characteristics for airplanes.

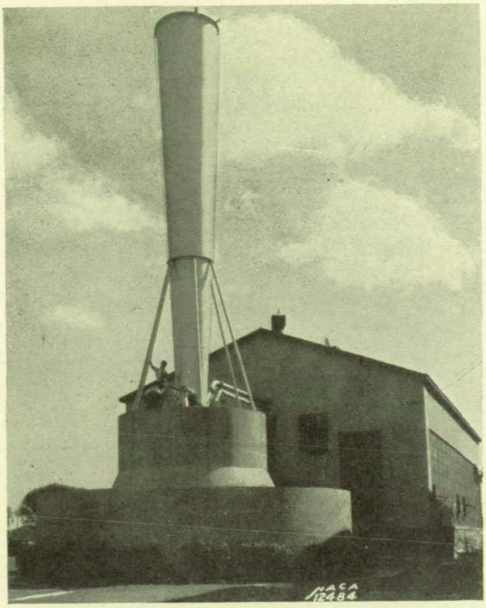
N. A. C. A. EIGHT-FOOT HIGH-SPEED WIND TUNNEL



Recognizing that improvements already achieved were pushing the maximum speed of aircraft beyond that attainable in existing wind tunnels, the N. A. C. A. in 1935 placed in operation still another unique wind tunnel having a throat diameter of only 8 feet but capable of reaching air speeds in excess of 500 miles per hour. Here the phenomena of high-speed flight not found in low-speed wind tunnels can be investigated. In this tunnel the N. A. C. A. scientists have determined changes of shape required to avoid serious losses in aerodynamic efficiency as speeds go up, and also the strength and stiffness of wings necessary to avoid wing flutter and to provide safety in flight for high-speed airplanes.

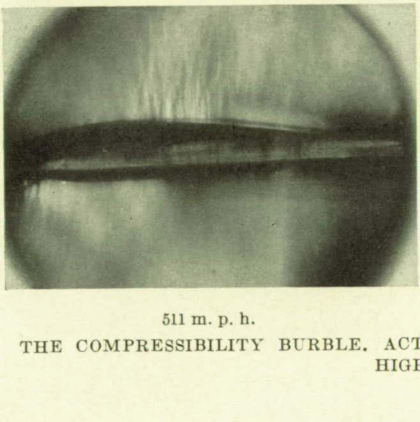
HIGH-SPEED FLOW RESEARCH

N. A. C. A. TWO-FOOT HIGH-SPEED WIND TUNNEL

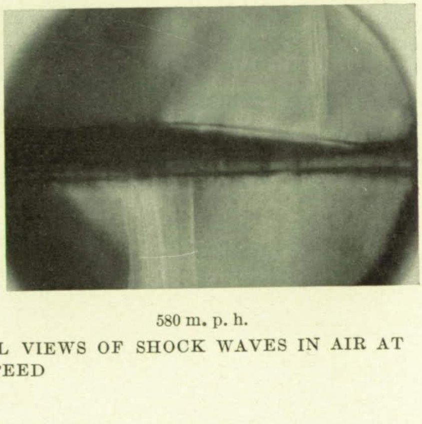


Using the compressed air from the variable-density tunnel as its source of power, the tunnel illustrated is capable of generating speeds up to that of sound in air.

The speed of sound in air is about 765 miles per hour, which means that pressure impulses are transmitted at that speed. When wings travel at a lower speed, pressures transmitted ahead deflect the air into the smooth streamline flows shown by the smoke tunnel. As a wing approaches the speed of sound, however, air speeds near the surface actually exceed this speed and the oncoming air receives an impulse shock resulting in a large dissipation of energy and correspondingly large increase of drag. The wavy lines radiating from the airfoil surface in the photographs show the sudden changes of pressure that take place when "shock waves" form.



511 m. p. h.

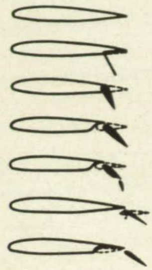


580 m. p. h.

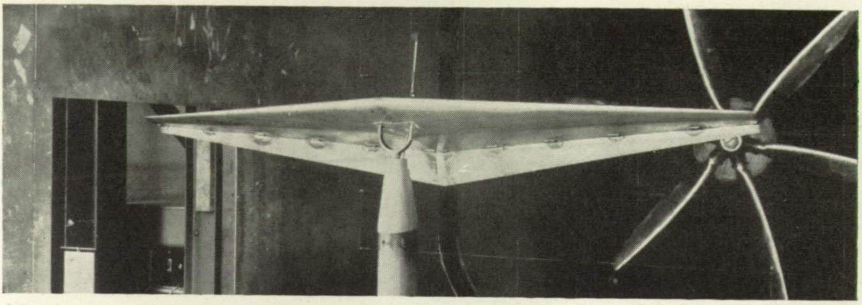
THE COMPRESSIBILITY BURBLE. ACTUAL VIEWS OF SHOCK WAVES IN AIR AT HIGH SPEED

INVESTIGATION OF HIGH-LIFT DEVICES

N.A.C.A. HIGH-LIFT DEVICES
(REYNOLDS NUMBER = 3,500,000)



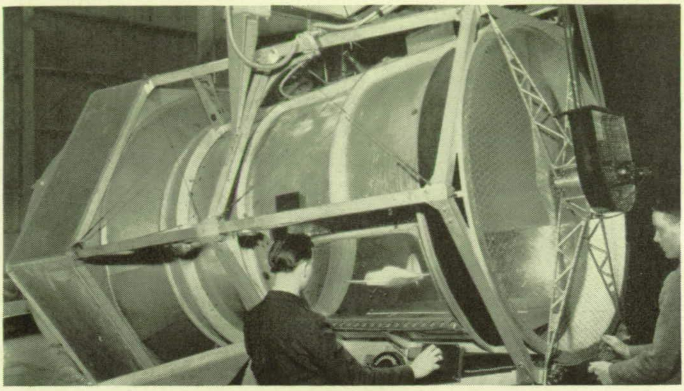
	LIFT
N.A.C.A. 23012 AIRFOIL	1.55
SPLIT FLAP	2.56
PLAIN FLAP	2.40
N.A.C.A. SLOTTED FLAP	2.80
N.A.C.A. DOUBLE SLOTTED FLAP	3.01
EXTERNAL-AIRFOIL FLAP	2.37
FOWLER FLAP	2.90



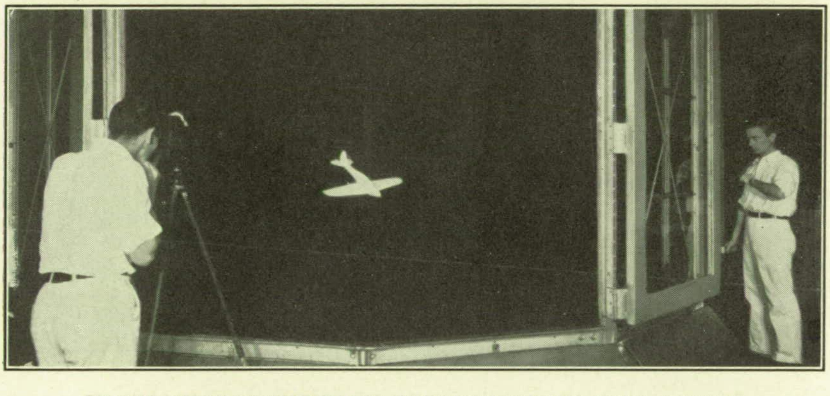
A MODEL WING WITH SPLIT FLAP IN 7- BY 10-FOOT WIND TUNNEL

The N. A. C. A. has investigated many devices that gave promise of increasing the maximum lifting capacity of wings. The table shows results obtained on several types of wing flaps, one of which is shown mounted on the balance in a wind tunnel. The maximum lifting capacity is measured by the maximum lift coefficient, which for a plain wing (without flap) amounts to about 1.5, or 15 pounds per square foot at 60 miles per hour (a typical landing speed). As shown by the chart, the N. A. C. A. has found devices giving about double this amount, corresponding to a lift of 30 pounds per square foot at 60 miles per hour. These investigations have assisted materially in the development of modern high-speed airplanes whose take-off and landing characteristics are consistent with basic safety requirements.

FREE-FLIGHT INVESTIGATION



To carry further the investigations of stability and control the N. A. C. A. has developed a 12-foot free-flight wind tunnel. In this tunnel the behavior of the model while flying freely can be observed. Investigations are conducted and correlated with other flight and wind tunnel results to improve the safety of airplanes.



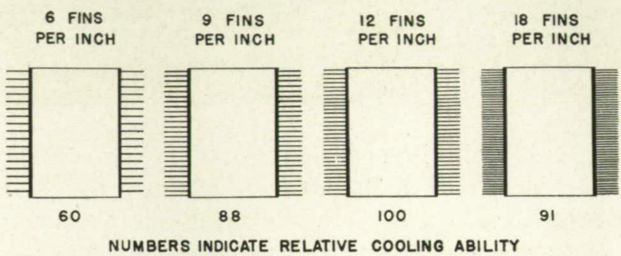
MODEL UNDERGOING TESTS IN FREE-SPINNING WIND TUNNEL

Models of airplanes are launched in a tail-spin in the rising air-stream of the free-spinning wind tunnel, and spin freely in front of the observer's window, as shown in the picture directly above. After the spin has become fully developed, a clock work, contained within the model, automatically sets the controls for recovery from the spin, the resulting effects being recorded by a motion-picture camera. By simple tests such as these it is possible to obtain an indication of whether an airplane will be controllable or uncontrollable in a spin before the airplane is actually built, thus preventing costly mistakes in design and construction.

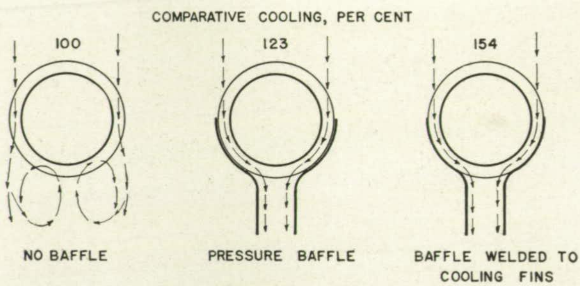
AIRCRAFT ENGINE RESEARCH

The aircraft power plant should provide the greatest possible power from the smallest possible bulk and weight, and should also use as little fuel as possible commensurate with the other requirements. Recent investigations made with the N. A. C. A. two-stroke-cycle single-cylinder Diesel engine warrant the belief that this type of engine promises to provide an acceptable combination of these requirements.

AIR COOLING OF AIRCRAFT ENGINES



EFFECT OF FIN SPACING ON ENGINE COOLING

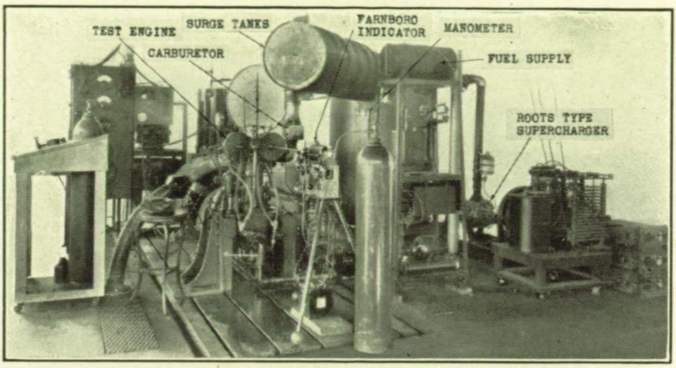


IMPROVING ENGINE COOLING WITH CYLINDER BAFFLES

Increasing power requirements of modern aircraft make it necessary to study the fundamentals of engine cooling. Two general methods of increasing the cooling ability of air-cooled cylinders are available, changing the dimensions of the cooling fins and improving the flow of air over the fins. The N. A. C. A. has made tests in a wind tunnel on the effect on cylinder cooling of fin spacing, fin width, fin thickness, and material. Tests have also been made using many different types of baffles to direct the cooling air toward the rear of the cylinders.

INCREASING THE POWER OF AIRCRAFT ENGINES

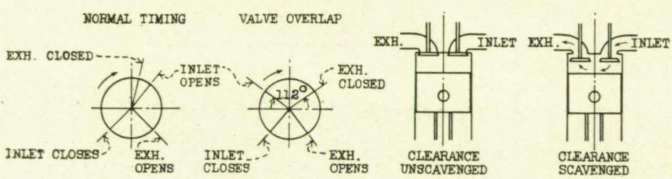
Supercharging



ENGINE AND ACCESSORIES USED IN SUPERCHARGING TESTS

The power of aircraft engines can be increased by using an air pump to compress the mixture delivered to the cylinders. An investigation to determine the effect of supercharging on the engine performance indicates that the increase in power is directly proportional to the increase in the weight of the mixture. That is, to double the weight of the air inducted into the cylinders is to double the horsepower of the engine.

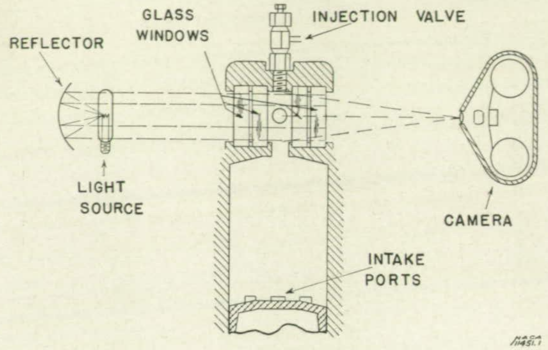
Valve Overlap



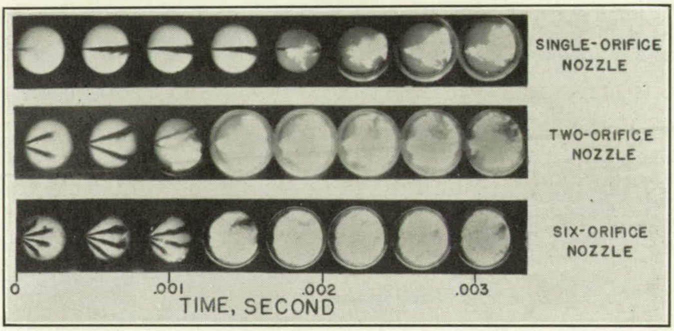
IMPROVED SCAVENGING WITH VALVE OVERLAP

The power of an aircraft engine can also be increased by completely removing the burnt gases from the cylinders by opening the inlet valves before the exhaust valves close and sweeping out the cylinders with air from the inlet manifolds. The usual carburetor is replaced by a fuel-injection system which introduces the fuel after both the inlet and the exhaust valves are closed. Using a boost pressure of 1.5 pounds per square inch, the power of an engine having a compression ratio of 5.5 has been increased 18 percent at sea level.

SPRAY-COMBUSTION RESEARCH



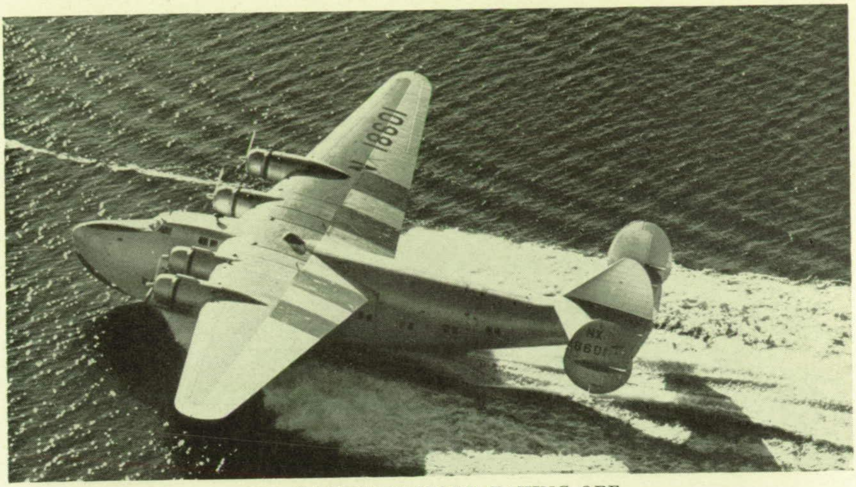
APPARATUS FOR PHOTOGRAPHING COMBUSTION IN A FUEL INJECTION ENGINE CYLINDER



To effect the greatest economy in weight with efficiency in performance, the phenomena connected with the burning of the fuel inside the engine must be studied. Accordingly, 2½ inch diameter windows are fitted in the cylinders through which the process of injecting and burning the fuel can be observed and recorded by means of extremely high-speed motion pictures.

Above are sections from three typical films, taken at 2,500 exposures per second. They show that the fuel is burned more quickly and effectively as the number of orifices in the nozzle is increased from one to six.

RESEARCH ON SEAPLANE FLOATS AND HULLS



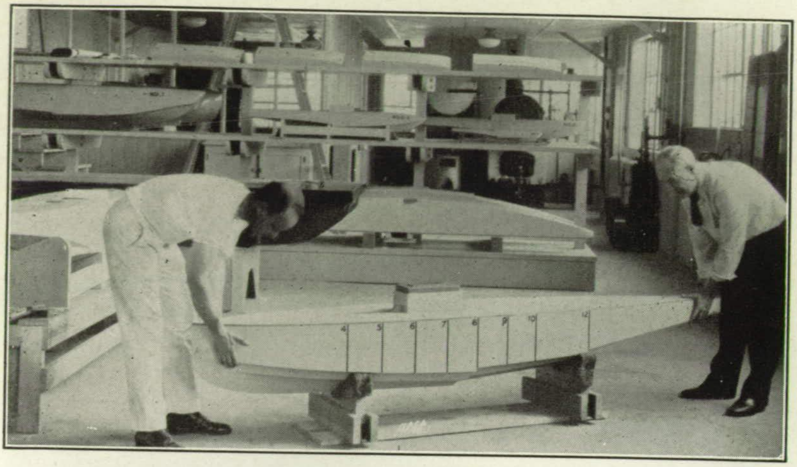
THE YANKEE CLIPPER TAKING OFF

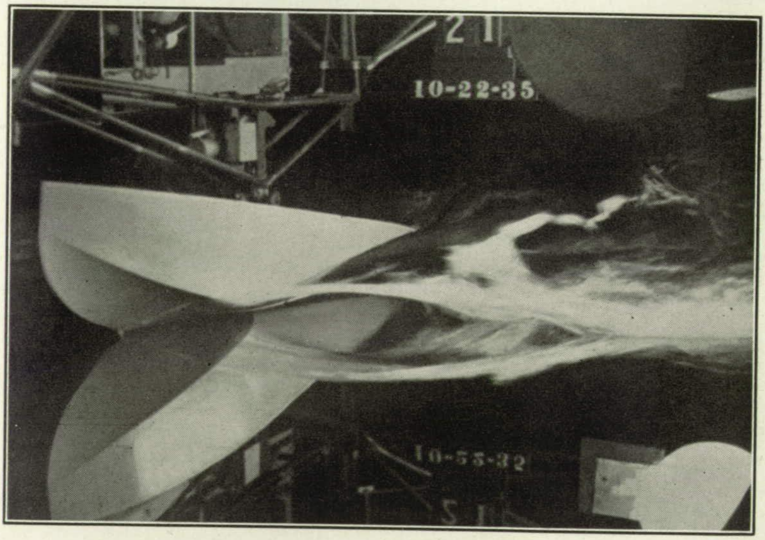
INTERIOR VIEW OF TANK, SHOWING TOWING CARRIAGE WITH MODEL OF FLYING-BOAT HULL MOUNTED READY FOR TEST

The purpose of the N. A. C. A. tank is to enable the committee to provide information and data regarding the performance of seaplanes on water analogous to the information furnished concerning the perform-

N. A. C. A. TANK

Typical Models of Flying-Boat Hulls





ance of airplanes in the air. In this tank large models of seaplane hulls may be towed at high speeds and accurate information obtained for designers as to the resistance and other features of the performance. The tank is 2,900 feet long, 24 feet wide, and 12 feet deep, and the maximum speed of the towing carriage is 80 miles per hour.

The N. A. C. A. was established by act of Congress approved March 3, 1915. The Committee is composed of 15 members appointed by the President and serving as such without compensation. The duties of the Committee are to supervise, direct, and conduct scientific research on the problems of flight with a view to their practical solution. The membership of the Committee includes two representatives each from the War and Navy Departments and the Civil Aeronautics Authority; one each from the Smithsonian Institution, the United States Weather Bureau, and the National Bureau of Standards; and six other persons "acquainted with the needs of aeronautical science, either civil or military, or skilled in aeronautical engineering or its allied sciences."

With the farsighted support of the President and of the Congress, the Committee has developed its research laboratories. It has pioneered in the construction of novel research apparatus and in the use of original methods of attack. Its research has resulted in outstanding improvements to aircraft. As a result the United States has for the 15 years up to 1938 maintained a position of world preeminence in the technical development of aircraft.

PUBLICATIONS

The results of N. A. C. A. researches are made available to the Army, the Navy, the Civil Aeronautics Authority, and the aircraft industry. The final results of the most important research investigations are published as N. A. C. A. Technical Reports. From the Committee's headquarters in Washington these reports are distributed to the aeronautical industry for use in the design and construction of aircraft and aeronautical equipment, and to educational institutions for use in the instruction of scientific and engineering students. They are also available to the public through libraries and through the Superintendent of Documents.

One of the largest collections of scientific and technical data relating to aeronautics is maintained by the N. A. C. A. in Washington. This collection includes published technical information from all over the world and many unpublished reports submitted by private investigators and research groups. In this way much useful scientific information that would not otherwise reach them is made available to those persons and agencies engaged in the development of American aircraft.

U. S. GOVERNMENT PRINTING OFFICE: 1939