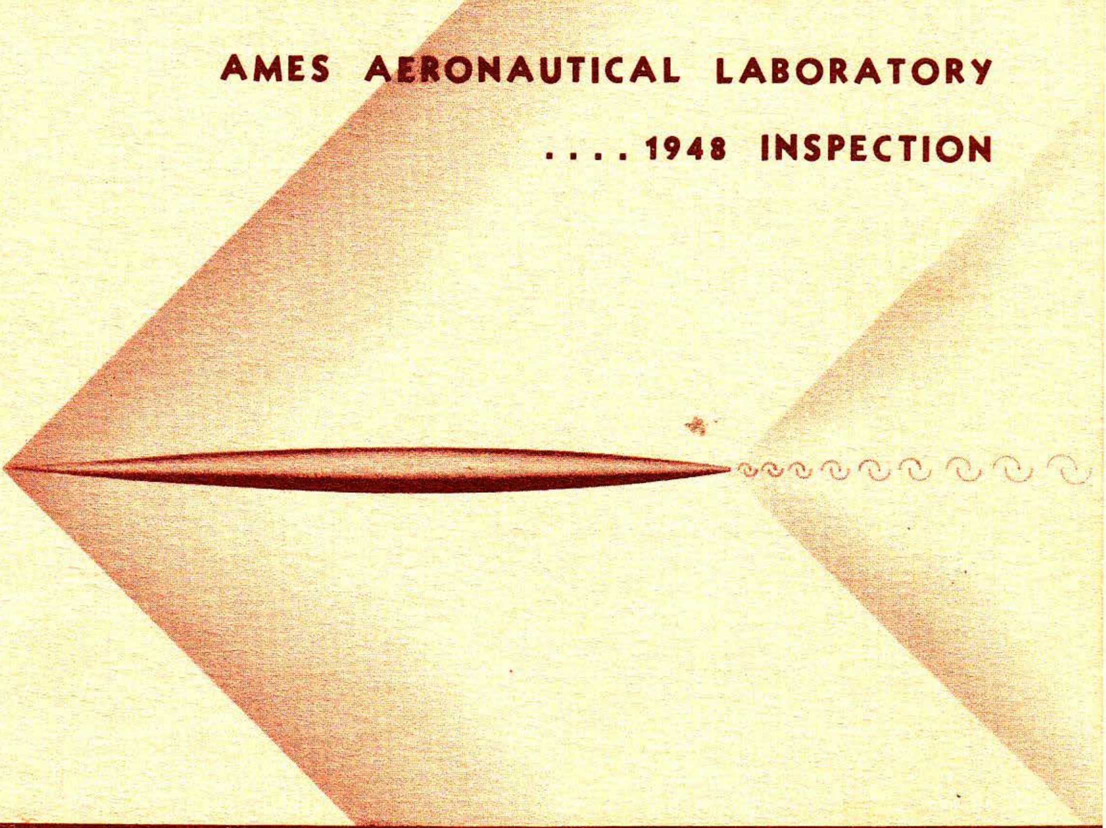
AMES AERONAUTICAL LABORATORY

. . . . 1948 INSPECTION



NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

welcome —

In the name of the National Advisory Committee for Aeronautics it is my privilege to welcome you to this Inspection of the Ames Aeronautical Laboratory. Many of you have attended similar inspections at this and other of the Committee research centers and need no introduction to the scope of our endeavors. For some of you, however, this may be a first visit to an NACA installation.

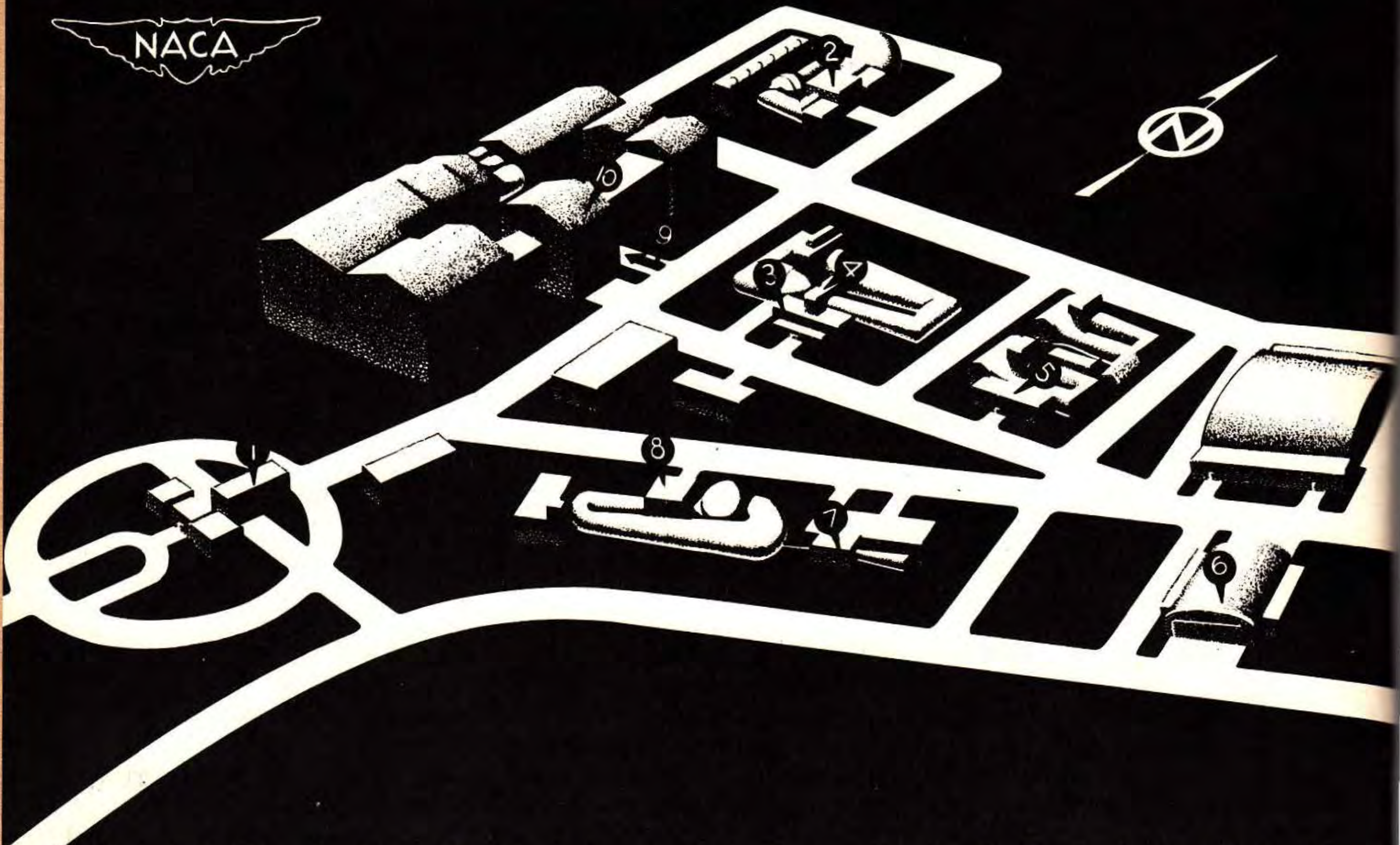
The National Advisory Committee for Aeronautics was established by act of Congress in 1915 to "supervise and direct the scientific study of the problems of flight with a view to their practical solution." We interpret this to mean that our primary objective is to provide the aircraft industry and the military services with information and technical data of a fundamental nature that will assist them in constantly improving military and civilian aircraft. The only measure of the success of our efforts lies in the extent to which you, the representatives of the industry and the armed forces, make use of our product. These inspection tours were conceived as a means to make you more familiar with what the NACA currently has to offer in our joint task.

We sincerely hope that your visit will be both a profitable and an enjoyable one.

J C Hunsaker

Chairman

National Advisory Committee for Aeronautics



AMES AERONAUTICAL LABORATORY

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1 INTRODUCTION

While all three principal laboratories of the NACA are engaged in the problems of high-speed flight, the Ames Aeronautical Laboratory is conducting research mainly in the field of aerodynamics associated with the transonic and supersonic flight regimes.

The supersonic research flights of the Bell XS-1 airplane at Muroc Lake are yielding valuable technical data. Of great importance is the fact that such flights are clearly defining the large number of problems to be solved by scientific research before supersonic flight becomes an everyday, practical operation.

Because the conditions of air flow relative to wings and bodies are different in the subsonic, transonic, and supersonic speed regimes, the design of shapes for optimum performance in one speed regime may result in unsatisfactory performance in another. For example, some of the most difficult problems of flight today are concerned with performance of supersonic aircraft in the subsonic flight range, and with the performance of both subsonic and supersonic aircraft in the transonic speed range.

Radically different wing plan forms give rise to new problems in stability and control. New types of air inlets are needed to supply efficiently the large quantities of air required for jet-propulsion systems.

Buffeting and flutter at transonic speeds

require careful investigation. The effects of friction and compression of the air stream in raising the temperature of the aircraft must be considered. Boundary-layer suction suggests interesting possibilities for increasing lift and reducing drag, primarily at subsonic speeds but also at transonic speeds. More effective high-lift devices are needed to improve the take-off and landing characteristics of wings designed for supersonic flight. Substantial research progress has been made in each of these fields and the trends are briefly related in this booklet.

All aircraft will not be flying at supersonic speeds, so research in the special requirements of slow-speed aircraft is continuing. Propellers demand considerable attention in regard to performance, vibrations, and icing. Design criteria for helicopters and personal aircraft are also the object of current research programs.

The research program at Ames is closely coordinated with those of the Cleveland Laboratory, which specializes in propulsion problems, and the Langley Laboratory, which is engaged in aerodynamic research in all speed ranges as well as the increasingly difficult problems of aircraft structures. The aerodynamic research results of the Ames and Langley Laboratories are integrated for presentation at this 1948 Inspection of the Ames Aeronautical Laboratory.

2 RESEARCH PROBLEMS AND TECHNIQUES

The transonic speed range is difficult to explore either by theoretical analysis or by experimental means. Few mathematical solutions have been found which relate to the mixed subsonic and supersonic flow characteristic of this speed range.

There are numerous experimental means of exploration, each having certain advantages and many disadvantages.

Some of the most important data, at this stage of research, are derived from full-scale flight tests such as those being conducted with the XS-1. Not only are the data immediately applicable, but they serve to calibrate other less costly experimental tools capable of yielding data in less time.

At the present time, wind tunnels are able only to provide reliable data partially through the transonic range. Model sizes are small with respect to tunnel sizes as a result of the choking phenomenon. Nevertheless, highly valuable data are obtainable within certain limits and it is probable that techniques will evolve by which reliable data will be obtainable throughout the transonic speed ranges with larger models in wind tunnels.

Two other transonic research methods utilize the local regions of near-sonic flow that occur over wings and bodies moving at high subsonic speeds. In this "wing-flow" method a small model is mounted in a region of high induced velocity on the wing of a high-speed airplane and data are recorded automatically by instruments inside the wing. The "bump" method utilizes a suitably-shaped body in a subsonic wind tunnel to create the same effect. Both methods suffer from the small sizes required for the models because of the limited chordwise distance over which a substantially constant Mach number exists on the wing or bump.

Rocket-propelled and freely-falling models are also in use for research in the transonic speed range. In both methods, radio equipment within the models transmits data to receiving stations on the ground as the paths of the models are tracked by radar, or the data are recorded by instruments within the models which are then recovered by parachute. Much valuable information has been obtained by these techniques despite the difficulties of launching, instrumentation, and data analysis.

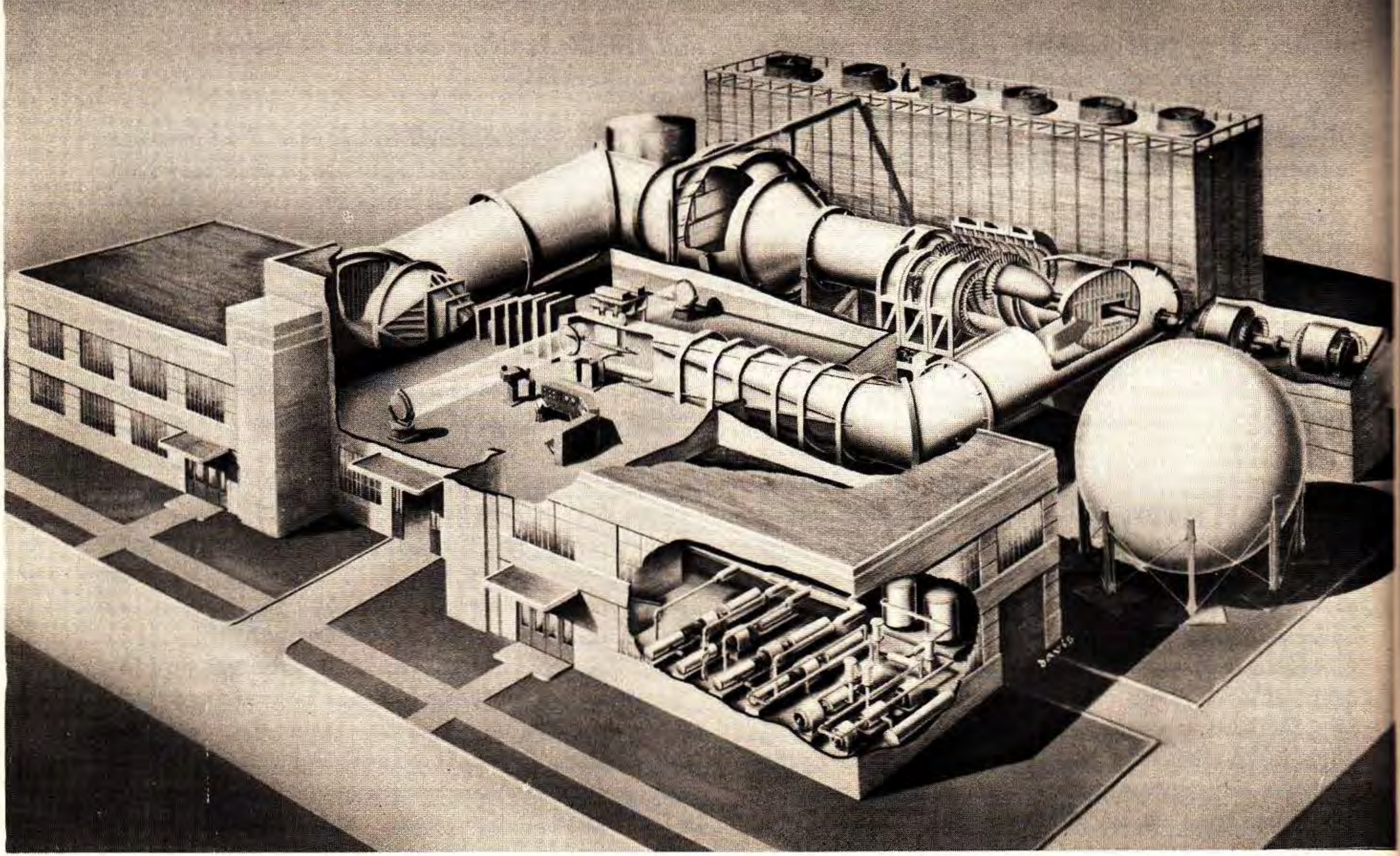
In the supersonic regime, mathematical analysis is more readily applied and serves as a guide for experimental research. In this speed range, wind tunnels of moderate size are being used to good advantage, although difficult problems of design, construction, and operation are encountered.

Speed variation, for example poses a problem in supersonic tunnels. The speed of a subsonic wind tunnel is easily varied by varying the speed of the fan which propels the air stream. In a supersonic wind tunnel, however, the airspeed can be varied only by changing the size of the throat relative to the test section. This may be accomplished either by substituting a number of fixed-sized nozzles, each for a different Mach number, or by using a single adjustable nozzle. Since small surface irregularities cause serious disturbances in a supersonic air stream, exceptionally smooth and precise interior surfaces of the wind tunnel are essential.

The power required to operate a supersonic wind tunnel which will provide adequately high Reynolds numbers is very large. It would be desirable to have supersonic wind tunnels several times larger than any existing at the present time, but from our present knowledge, such tunnels would require power in virtually unobtainable amounts. Consequently, methods to reduce the power required are currently an urgent objective of NACA study.

The latest major addition to the facilities of the Ames Laboratory is the 6- by 6-foot supersonic wind tunnel, which was built with the assistance of the U. S. Navy. The test speed may be varied from 500 to 1200 miles per hour. The pressure within the tunnel is variable and test Reynolds numbers corresponding to full-scale flight at altitudes of 60,000 feet and up are obtainable. Its relatively large size makes it possible to conduct research with reasonably large models at speeds in the difficult transonic regime only slightly above or slightly below the speed of sound.

THE 6- BY 6- FOOT SUPERSONIC WIND TUNNEL



AIR INDUCTION

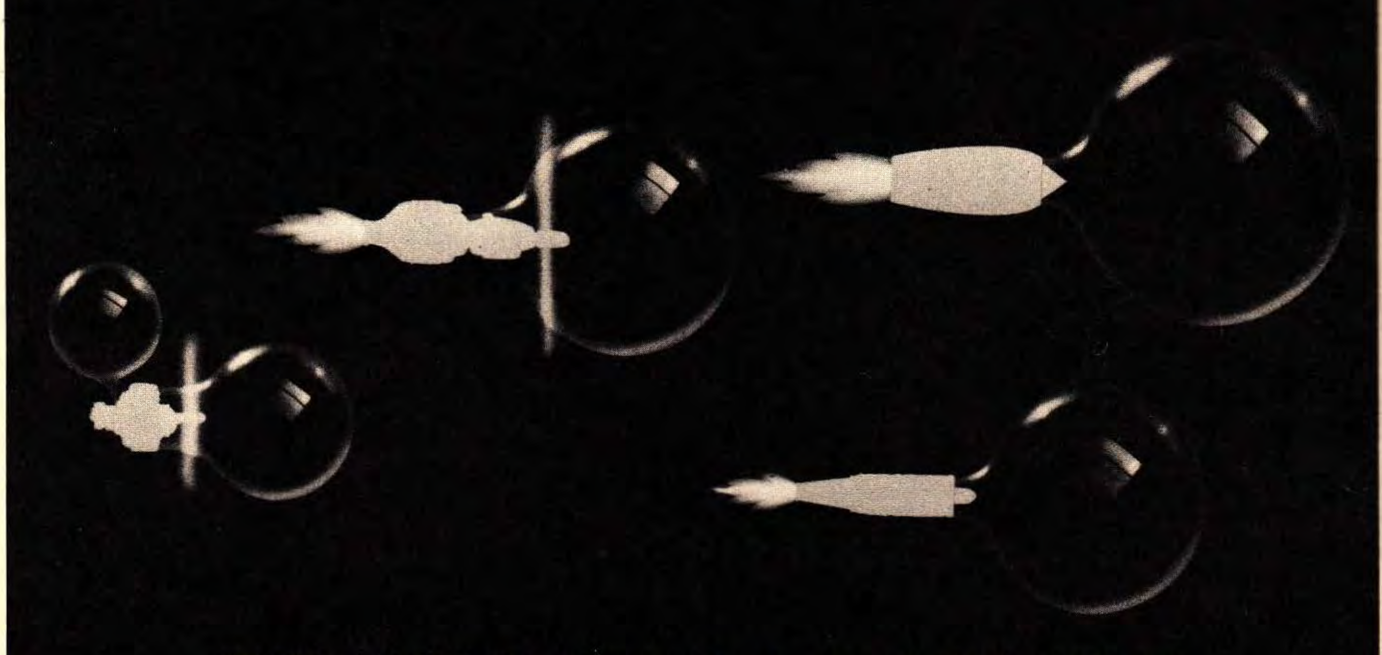
3

The turbojet, turboprop, and ram-jet power plants of current and proposed high-speed aircraft require many times the quantity of air used by reciprocating engines. Upon the efficiency and minimum drag of the induction system in collecting, compressing, and delivering large quantities of air at low relative speed, depends the speed and range of aircraft utilizing these power plants. All three NACA laboratories have undertaken coordinated research to provide a basis for the practical design of efficient air-induction systems.

Even for a given speed, there is no one best type of air inlet because compromises are necessary to arrive at the over-all best combination of the components comprising the complete aircraft. NACA research is aimed, therefore, at establishing methods for the design of various types of inlets for optimum performance over a wide range of conditions at both subsonic and supersonic speeds.

For subsonic flight speeds, criteria

AIR REQUIREMENTS



SPHERES SHOW, TO SAME SCALE AS ENGINES, VOLUME OF AIR USED EACH SECOND AT 40,000 FEET ALTITUDE.

THE LARGE QUANTITIES OF AIR REQUIRED BY TURBOPROP, TURBOJET, AND RAM-JET POWER PLANTS HAS PLACED NEW EMPHASIS ON THE EFFICIENCY OF AIR INDUCTION SYSTEMS. HIGHLY EFFICIENT INDUCTION MUST BE ATTAINED TO PREVENT LARGE THRUST LOSSES.

have been established for the design of inlets in the noses of fuselages and nacelles. Data for the design of inlets in the leading edges of unswept wings are available, and research on inlets for the leading edges of swept wings, which may prove to be effective at transonic speeds, is being conducted.

At supersonic speeds, the efficient deceleration from supersonic to subsonic air flow in the induction system is complicated by shock waves. For efficient operation, the flow should be reduced to the lowest possible supersonic Mach number before the normal shock wave and transition to subsonic speed occur. Some designs accomplish this supersonic speed reduction through oblique shocks, some by contraction of the duct behind the inlet. As in the case of subsonic inlets, supersonic inlets have been developed for fuselage noses, wing leading edges, and locations farther back on the fuselage where relatively thick boundary layers are encountered.

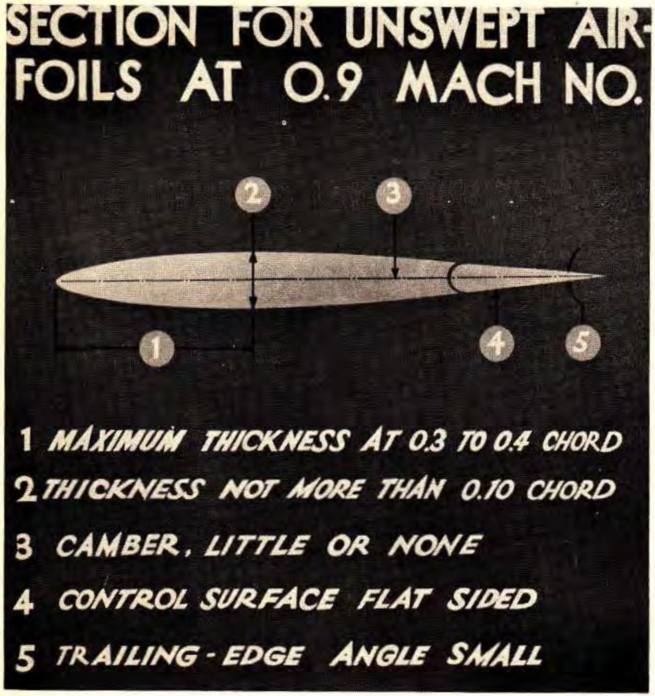
4 TRANSONIC STABILITY AND CONTROL

When a conventional airplane attains flight velocities near the speed of sound, local regions of supersonic flow are induced over portions of the wing and tail. Shock waves are usually formed where the flow decelerates again to subsonic speed. There is a strong tendency for the air flow to separate from the surfaces aft of these shock waves. When the flow separates, the wing suffers a loss of lift which generally causes dangerous nose-down trim changes. Since the flow is separated from the after portions of the wing and tail, the effectiveness of the control surfaces is drastically reduced. In addition, the hinge moments and stick forces required to effect a given control deflection may be greatly increased. Consequently, control may be, in some cases, beyond the strength of the pilot.

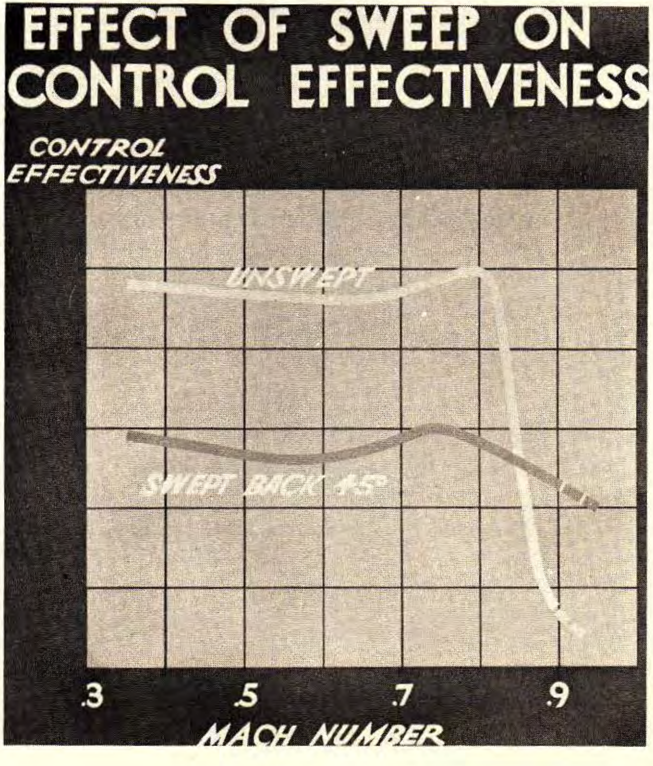
Investigations have revealed that careful design can reduce these trim, stability, and control difficulties. Several factors have been found to be important in achieving this result. The use of thin wings and tails limits the extent of the transonic flow conditions. If the trailing-edge angle of the airfoil is small and the control surfaces have flat sides, the tendency of the flow to separate is minimized. Airfoil sections with little or no camber lessen the adverse changes in the aerodynamic characteristics of the wing and the consequent trim changes at high speeds. The contours of aerodynamic balances must be properly selected. Structural rigidity should be maintained to prevent contour changes and relative deformation of the wing and tail.

Swept-back wings may be used to delay the onset of these compressibility difficulties to appreciably higher speeds as discussed at the 1- by 3-foot wind tunnel.

The required effectiveness of a control system and the change in stability and trim that can be tolerated are interrelated and each is dependent upon the other. Since power boost systems may be used to deflect the control surfaces in spite of high hinge moments, a control-surface arrangement which retains its effectiveness at transonic speeds will allow the pilot to counteract minor transonic stability and trim changes. Controllable stabilizers have also been found useful in maintaining control through the transonic range.



A WING SECTION HAVING THE CHARACTERISTICS NECESSARY FOR OPTIMUM PERFORMANCE AT HIGH SUBSONIC SPEEDS, AS INDICATED BY SYSTEMATIC AIRFOIL INVESTIGATIONS.



SWEEPBACK DIMINISHES CHANGES IN CONTROL EFFECTIVENESS THROUGH THE TRANSONIC SPEED RANGE.

4 TRANSONIC FLUTTER

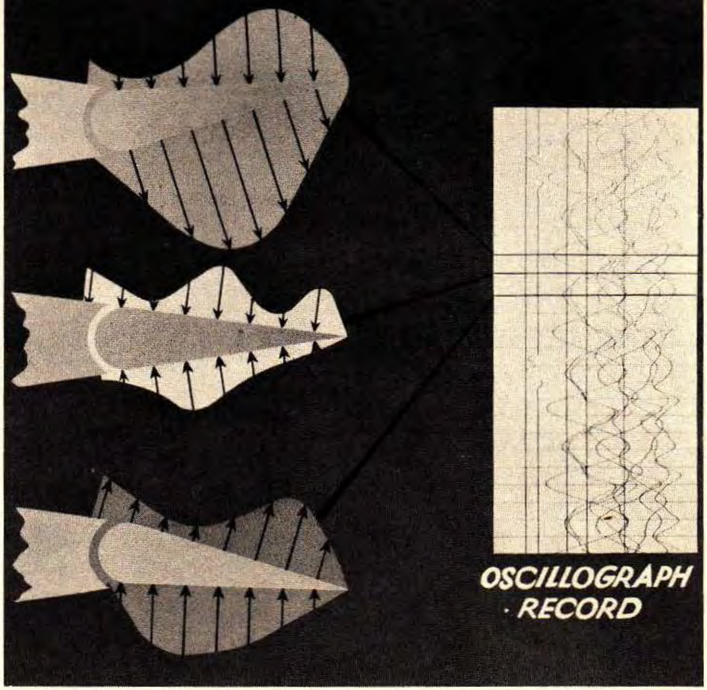
Classical types of flutter always involve two or more interrelated motions. Theoretical analysis of such flutter, with correlated experiments, has long been an important part of NACA research. Recently, at transonic flight speeds, controls have fluttered dangerously with no essential interrelation of another motion. This distinct type of flutter is called "transonic flutter" or "buzz."

Transonic flutter is under investigation in high-speed wind tunnels, with rockets, and by theory. Its cause is associated with the fact that when a control surface moves, the effect of this motion on the flow travels forward on the wing slowly if the local airspeed over the wing is nearly sonic. Consequently, the reaction to the initial motion may return to the control surface just in time to push it in such a direction as to feed back energy and cause flutter.

In order to explore further and understand transonic flutter, a new experimental technique has been developed in which instantaneous values of the pressures over airfoils and controls are measured as they vary rapidly during flutter. These pressures and their relation to the flutter motion are being studied to determine the fundamentals involved. Integration of plots of the instantaneous pressures gives instantaneous values of the aerodynamic hinge moment acting on the fluttering surface. By this procedure, the usual complications resulting from friction and other extraneous forces are avoided.

PRESSURE DISTRIBUTION DURING FLUTTER

IN RESEARCH ON TRANSONIC FLUTTER THE FLUCTUATING PRESSURES ON THE SURFACES ARE RECORDED. INSTANTANEOUS DISTRIBUTIONS OF PRESSURE ARE THEN PLOTTED AND INTEGRATED TO EVALUATE THE AERODYNAMIC HINGE MOMENTS DURING FLUTTER.



5 BOUNDARY-LAYER CONTROL

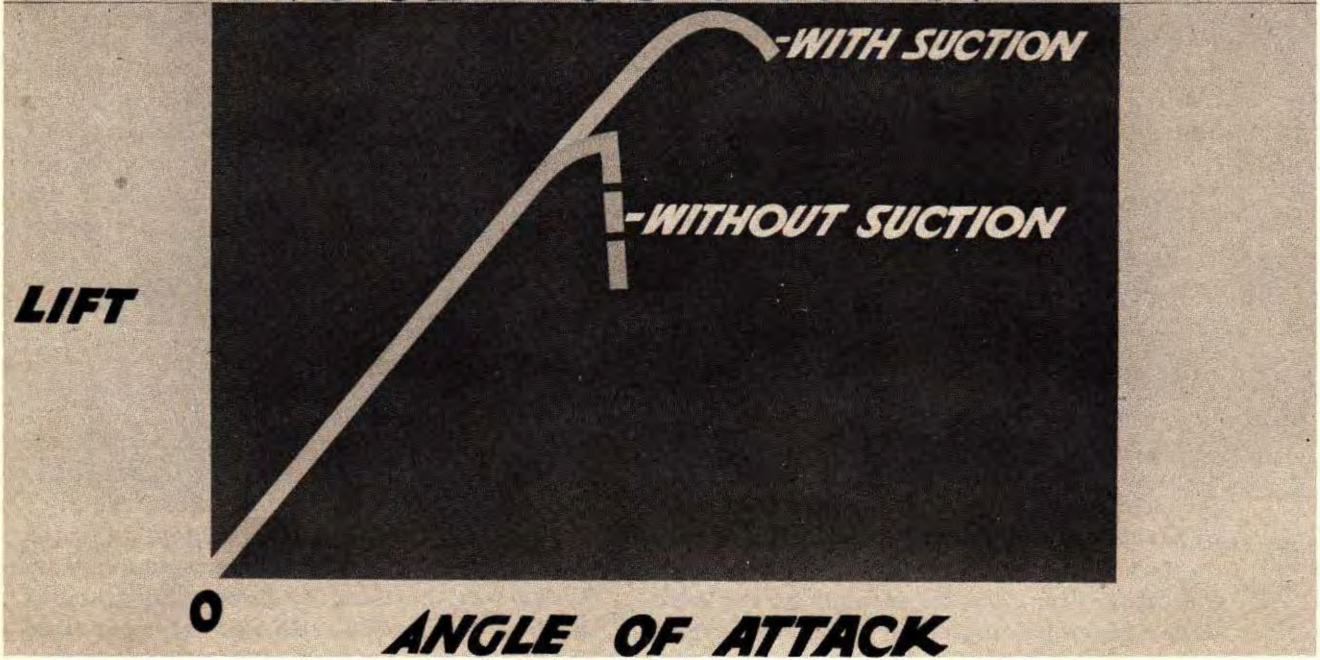
Modern high-speed airplanes are designed with thinner wing sections than has been customary in the past in order to reduce the large increase in drag encountered at flight velocities approaching the speed of sound. However, thin wings have a tendency to stall abruptly at relatively low angles of attack because of separation of the laminar boundary layer near the leading edge. The maximum lift coefficient is consequently low, even though the wing is provided with trailing-edge flaps, resulting in dangerously high landing speeds.

A number of methods of delaying separation of the laminar boundary layer have been investigated. One utilizes a narrow, spanwise slot in the leading edge of the wing, another a wider porous strip in the same location. When suction is applied to the slot or the strip, higher angles of attack and consequently higher lift coefficients can be attained before the flow separates. In addition, separation starts at the trailing edge and moves forward with increasing angle of attack. This type of stall is more gradual and generally gives the pilot advance warning in the form of vibration or buffeting.

Airfoils with the entire surface made of porous material or with multiple slots have been used to investigate the effect of boundary-layer suction on drag. A substantial decrease in external drag is indicated by preliminary experiments. However, the total drag chargeable to the airfoils with suction includes the power required to effect the suction. With this factor included, the drag of the porous airfoil was still somewhat less than that of a smooth airfoil without the boundary-layer removal.

The benefits to be derived from boundary-layer control appear promising, but they must be considered with due regard to the power required, the added structural complexity, and the equipment necessary to provide the suction.

LIFT INCREASE WITH NOSE SUCTION



BOUNDARY-LAYER REMOVAL AT THE LEADING EDGE OF A THIN WING DELAYS LAMINAR SEPARATION AND ALLOWS THE WING TO ATTAIN HIGHER LIFT AND A MORE GRADUAL STALL.

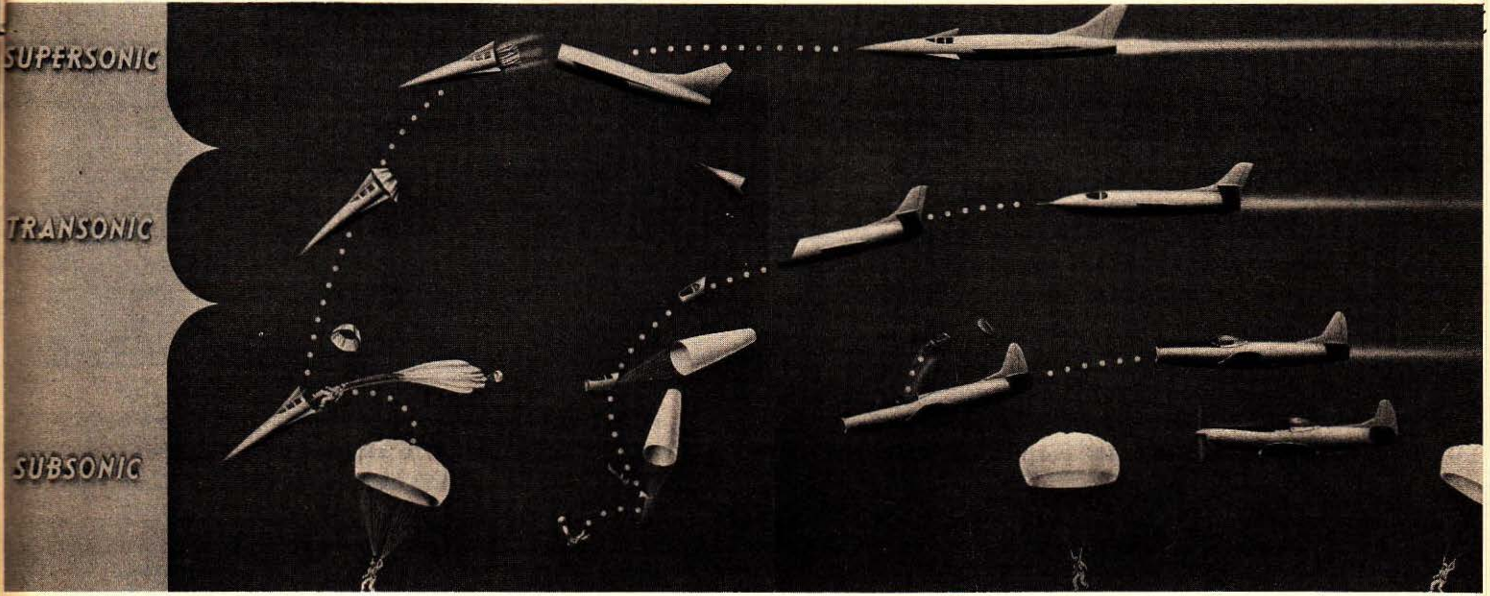
6 PILOT ESCAPE

The problem of pilot escape from disabled aircraft becomes more complicated as aircraft speeds and operating altitudes increase. Parachutes are adequate up to speeds of about 350 miles per hour. For higher speeds, ejection seats have been developed to throw the pilot clear of the airplane and to support his body against high airstream pressures until his airspeed is lowered to within safe parachute speed range.

For speeds in excess of approximately 500 miles per hour, the pilot requires protection from the air stream. Furthermore, at high altitudes, oxygen, and at extreme altitudes, pressure, must be provided. Jettisonable capsules or jettisonable portions of fuselages are being considered for this purpose. Several airplane designs now anticipate provision for jettisoning the nose of the fuselage, including the pilot's compartment.

In order to adequately serve the pilot in time of emergency, the jettisoned fuselage nose must: separate cleanly from the airplane and not collide with it, be propelled or have low enough drag to avoid dangerous deceleration, and be aerodynamically stable so as to remain at a low-drag attitude and avoid the tumbling which would injure the occupant. After the initial deceleration, drag brakes may be required for further deceleration to a speed safe for the pilot to start the final phase of descent by parachute.

The NACA is seeking the aerodynamic knowledge needed to design jettisonable portions of airplanes to meet these requirements. Research on this subject is under way in its free-flight and free-spinning wind tunnels at the Langley Laboratory, and at higher airspeeds with rocket-propelled models.



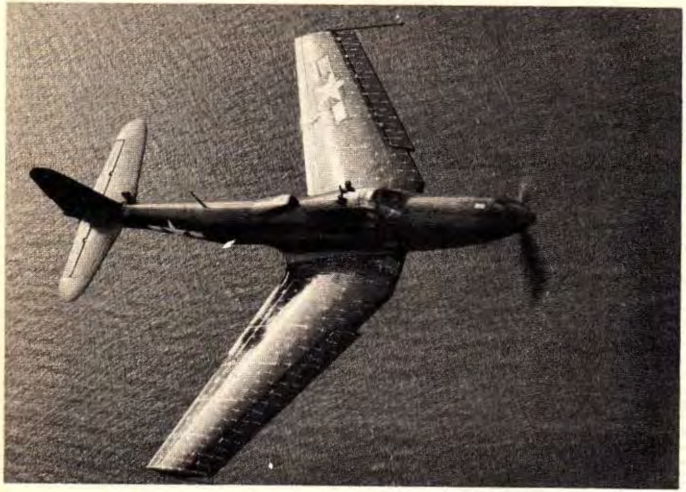
PARACHUTES SERVE FOR PILOT ESCAPE UP TO ABOUT 350 MILES PER HOUR. FOR USE FROM THERE TO ABOUT 500 MILES PER HOUR, EJECTION SEATS HAVE BEEN DEVELOPED. FOR HIGHER SPEEDS, JETTISONABLE CAPSULES OR PORTIONS OF FUSELAGES ARE BEING DESIGNED. THE N.A.C.A. IS STUDYING MEANS TO STABILIZE THESE TO PREVENT RAPID TUMBLING OR DECELERATION WHICH WOULD INJURE THE OCCUPANT.

6 LOW-SPEED PROBLEMS OF HIGH-SPEED AIRPLANES

Although swept-back and triangular wings are effective in reducing the effects of compressibility in the transonic speed range, their poor stability and control characteristics at high lift coefficients give rise to new difficulties in landing. In order to determine the flight procedure and design considerations which are necessary to permit the fullest practicable use of these wings, their low-speed characteristics require evaluation. As part of extensive research on this problem, the Langley Laboratory has made low-speed flight tests of an airplane with the wing swept back 35° and has investigated the low-speed characteristics of a series of triangular wings in a free-flight wind tunnel.

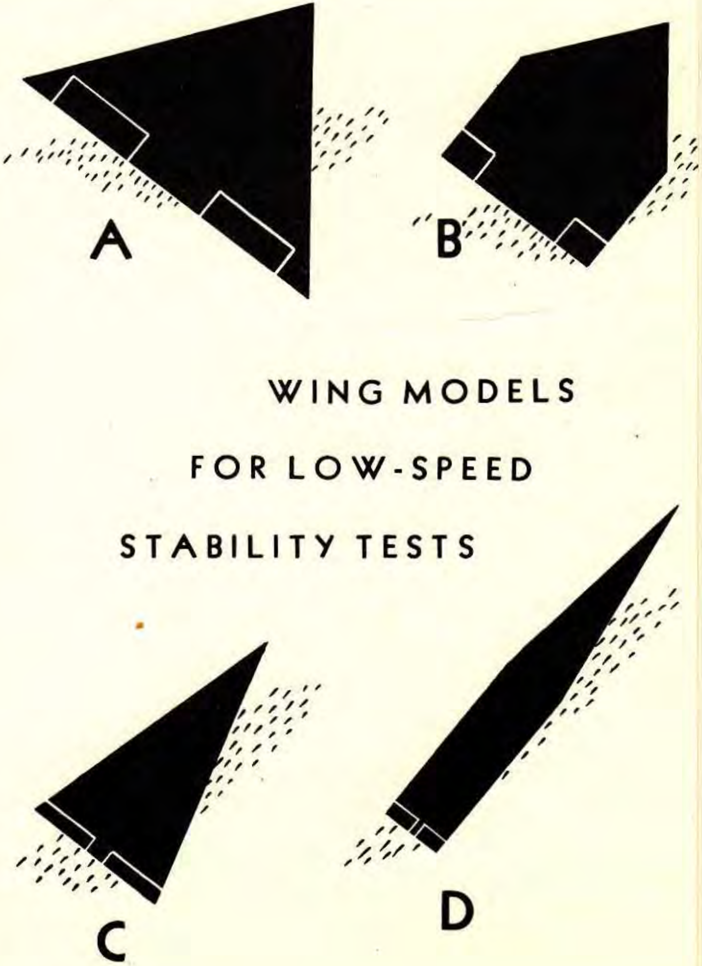
In flight, the longitudinal, lateral, and directional stability parameters were evaluated for the swept-wing airplane. The most objectionable characteristic was the large variation of dihedral effect with lift coefficient. At high speeds the dihedral effect was negative and consequently the control motions necessary to maintain equilibrium in a sideslip were reversed. As the speed decreased and the lift coefficient increased, the dihedral effect became more and more positive. Although adequate control was maintained, the rolling velocity resulting from a given aileron deflection decreased, resulting in the inability of the pilot to fly smoothly.

In the free-flight wind tunnel, the stability characteristics of the triangular wings were found to vary with the aspect ratio. Wings having an aspect ratio of 1 or less were indicated to be unsatisfactory because of large-amplitude rolling oscillations at high lift coefficients. The stability and control characteristics of triangular wings having aspect ratios between 2 and 3 were satisfactory at low lift coefficients. The power-off glide angles, however, were very steep at high lift coefficients and indicated excessively high sinking speeds during landing approaches.



THE BELL L-39 AIRPLANE USED TO INVESTIGATE THE LOW-SPEED CHARACTERISTICS OF SWEPT-BACK WINGS.

WING MODELS FOR LOW-SPEED STABILITY TESTS



THESE ARE EXAMPLES OF THE SERIES OF HIGH-SPEED WINGS TESTED FOR LOW-SPEED STABILITY IN THE LANGLEY FREE-FLIGHT WIND TUNNEL. MODELS B AND D WERE PRACTICALLY UNFLYABLE.

7 SWEPT-BACK WINGS

The velocity of air over a swept-back wing in flight can be considered to be the resultant of two components, one normal to the wing and one parallel to the wing. The pressures acting on the wing depend only on the normal velocity and are not affected by the parallel component. Since the normal velocity is less than the flight velocity, an airplane with swept wings can fly faster before encountering serious compressibility effects than a straight-wing airplane.

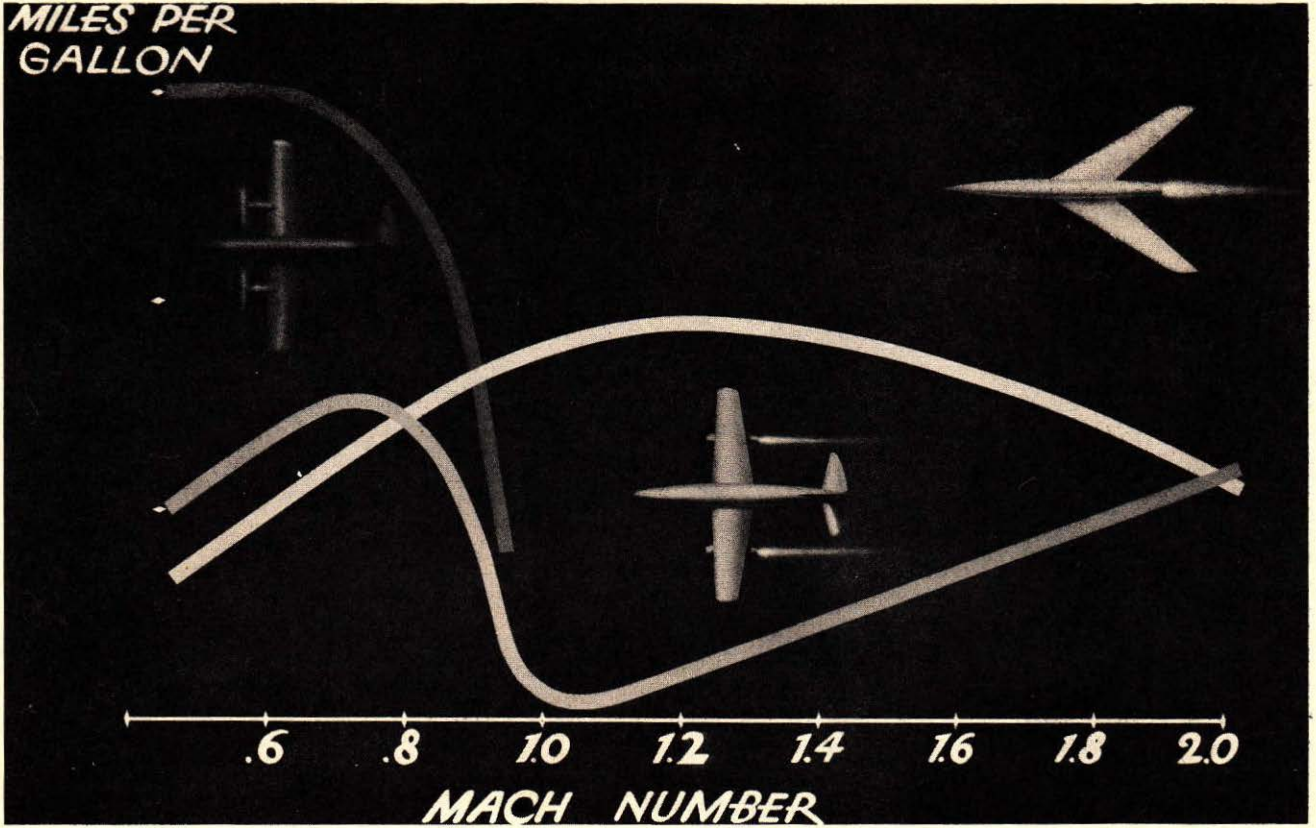
For example, if a straight wing that normally encounters compressibility difficulties at a Mach number of 0.8 is swept back sufficiently, these difficulties would be delayed to a Mach number of about 2. Between Mach numbers of 0.8 and 2 the swept-wing airplane would be superior in performance. It would maintain a higher lift-drag ratio and therefore its thrust requirements and fuel consumption would be less. In addition, the stability and control characteristics of the swept-wing airplane would not change as much as those of the straight-wing airplane in the transonic range.

Although it is possible for an adequately-powered straight-wing airplane to fly at transonic and supersonic speeds, it is evident that such speeds can be attained more efficiently with a swept-back wing. Its relatively high lift-drag ratio at these speeds makes the swept wing especially attractive for long-range airplanes such as transports and bombers.

Since there is a practical limit to the sweepback angle that can be employed, and since sweepback only delays but does not eliminate compressibility difficulties, there is a limit to the speed range through which sweepback can be used to advantage. It is indicated that above a Mach number of approximately 2, for instance, a straight wing becomes superior to the swept wing.

The greatest disadvantage of the swept-back wing is its inherently high landing speed resulting from the fact that a swept-back wing stalls at a much lower lift coefficient than does a straight wing.

ESTIMATED FUEL MILEAGE



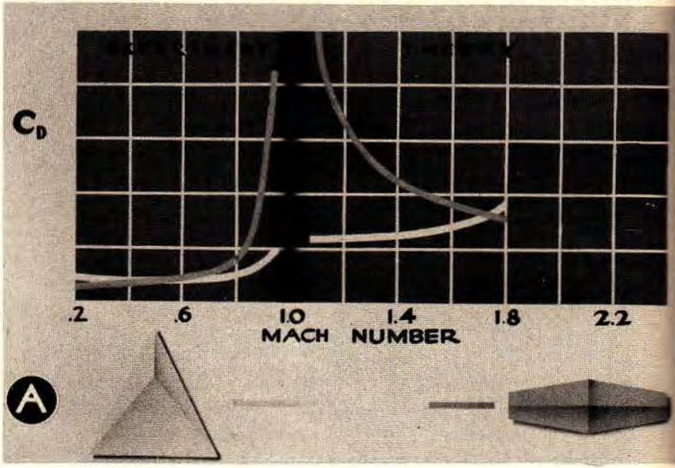
REDUCED DRAG RESULTING FROM SWEEPBACK OFFERS THE POSSIBILITY OF SUBSTANTIAL INCREASES IN PAYLOAD AND RANGE AT TRANSONIC AND MODERATELY SUPERSONIC SPEEDS.

8 LOW-ASPECT-RATIO WINGS

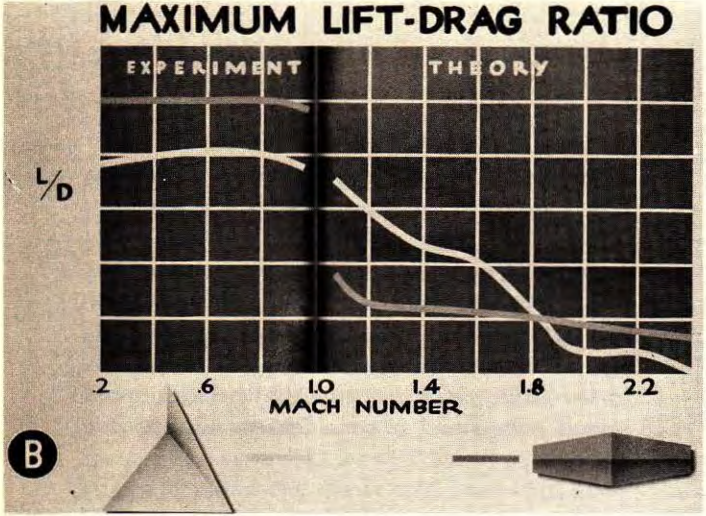
High speed and maneuverability are of paramount importance for fighter airplanes and missiles. Theoretical and experimental research have shown that for transonic and supersonic speeds wings of low aspect ratio offer advantages in connection with both these requirements. These advantages lie in aerodynamic effects and in the inherently high structural strength and rigidity. The most commonly considered plan forms of this type are the triangular wing and the low-aspect-ratio straight wing. Comparison of the characteristics of these two plan forms reveals that each has its field of application.

At Mach numbers below about 0.8, the minimum drag is approximately the same for the two wings if they are of the same thickness and both have sharp-edged supersonic sections. The straight wing produces a higher lift-drag ratio and consequently is more efficient.

DRAG OF LOW-ASPECT-RATIO WINGS

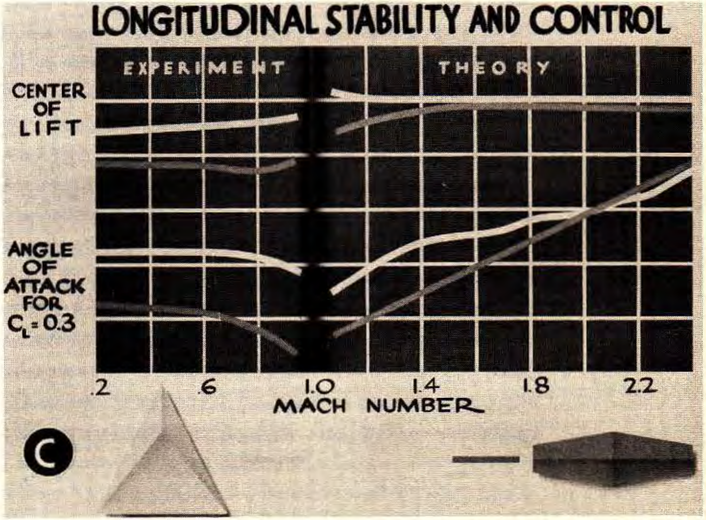


Ⓐ TRIANGULAR WINGS HAVE SUBSTANTIALLY LESS DRAG THAN STRAIGHT WINGS IN THE TRANSONIC AND MODERATE SUPERSONIC SPEED RANGES.



Ⓑ RELATIVE TO ITS DRAG THE TRIANGULAR WING GIVES MORE LIFT AT MODERATE SUPERSONIC SPEEDS BUT THE STRAIGHT WING IS BETTER AT SUBSONIC AND HIGHER SUPERSONIC SPEEDS.

Ⓒ IN ADDITION TO MORE EFFICIENT PERFORMANCE THE TRIANGULAR WING IS SUBJECTED TO SMALLER STABILITY AND CONTROL CHANGES AS INDICATED BY THE SMALLER VARIATION OF THE PARAMETERS SHOWN.



At a Mach number of about 0.8, depending on the thickness, the drag of the straight wing rises rapidly due to the formation of shock waves. On the triangular wing, shock losses are delayed until a higher flight Mach number, since the effective velocity component in this respect is that normal to the line of maximum wing thickness. This critical Mach number increases with the sweepback angle of the leading edge, but practical considerations limit this angle so that a Mach number in the neighborhood of 2 is believed to be the maximum to which compressibility effects can thus be delayed. In this range of flight Mach numbers between 0.8 and 2, theoretical calculations indicate that the triangular wing produces a higher lift-drag ratio and is more efficient than the straight wing. Above this range, the straight wing may again be superior in performance.

Stability considerations require that the forces acting on a wing show a minimum variation with Mach number. In this respect, the triangular wing is superior to the straight wing through the transonic speed range and for moderate supersonic speeds.

Wing loadings must be high for efficient supersonic flight. This, with the low maximum lift coefficients, will necessitate high landing speeds. Even more difficult to cope with, will be the high sinking velocities in power-off landings. Research is under way on various types of flaps to ease landing problems.

AERODYNAMIC HEATING

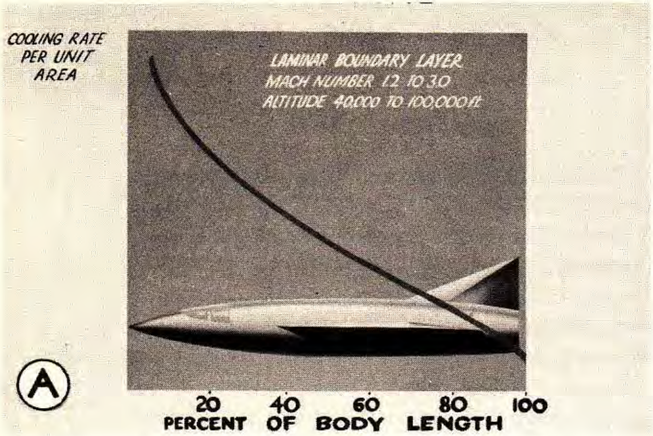
9

A body traveling through the atmosphere at high speeds generates heat by compression of the air and by friction. This heat appears in the boundary layer and is transferred to the surface of the body. Especially at high altitudes, solar radiation adds to the heat. If aircraft are to fly for prolonged periods at supersonic speeds, provisions must be made to dissipate the heat generated in order to protect the occupants and the structure from the high temperatures.

The amount and distribution of cooling required to maintain a given temperature limit depends on the distribution of the aerodynamic heating along the surface. The rate of heat transfer at any point is a function of the shape of the body, the altitude, the flight Mach number, and the thickness and type of boundary layer at that point. Investigations are under way to evaluate the effects of these parameters and thereby establish criteria for the design of cooling systems for high-speed airplanes and missiles.

To facilitate analysis, the atmosphere of the earth may be divided into three regimes with respect to air density: The regime of conventional aeronautics where the air can be considered a continuous medium, the molecular regime at extremely high altitudes where the effects of the individual molecules must be considered, and an intermediate region known as the slip-flow regime, which has some of the properties of each of the other two and consequently is most difficult to treat mathematically. The ratio of the mean free path of the air molecules to the length of the body in question dictates the flow regime. Below about 40 miles altitude, the ratio of mean free path to body length is

COOLING DISTRIBUTION TO MAINTAIN UNIFORM SURFACE TEMPERATURE
THEORETICAL

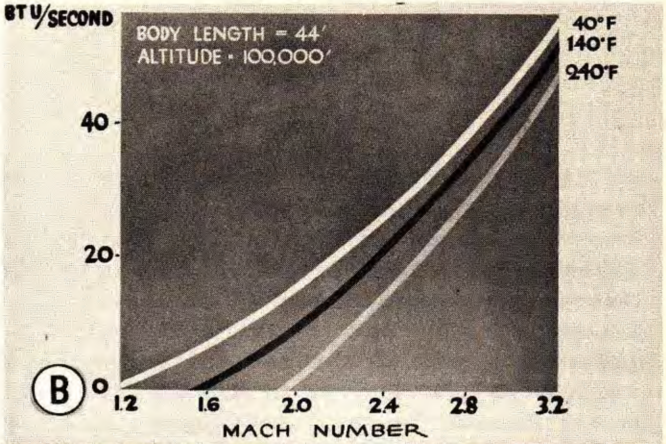


Ⓐ AT HIGH SPEEDS, THE COOLING RATE NECESSARY TO MAINTAIN A UNIFORM SURFACE TEMPERATURE VARIES ALONG THE LENGTH OF A FUSELAGE.

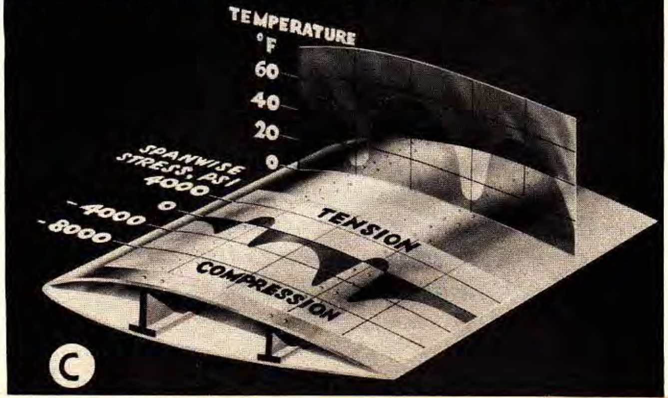
Ⓑ AERODYNAMIC HEATING BECOMES A SERIOUS PROBLEM AT HIGH MACH NUMBERS AND LIMITS THE SPEED WHICH AIRCRAFT MAY ATTAIN WITHOUT A COOLING SYSTEM.

Ⓒ FAST DIVES SUBJECT STRUCTURES TO THERMAL STRESSES AS A RESULT OF THE RAPID CHANGES OF THE SURFACE TEMPERATURE RELATIVE TO THE TEMPERATURE OF THE INTERNAL STRUCTURAL MEMBERS.

COOLING REQUIRED TO MAINTAIN A GIVEN SURFACE TEMPERATURE
THEORETICAL



SURFACE TEMPERATURES AND RESULTING STRESSES AT END OF DIVE



generally small enough to be neglected and conventional aerodynamic theory may be assumed to apply. Seventy-five miles is probably the lowest altitude at which molecular-flow theory can safely be applied for normal-sized aircraft.

In the conventional regime, a method has been developed for calculating the rate of heat transfer on bodies of revolution traveling at supersonic speeds, with laminar boundary layers. The rates of heat transfer for cones calculated by this method agree satisfactorily with measured values.

The kinetic theory of rarified gases can be applied to aerodynamic heating phenomena in the molecular-flow regime but progress in this and the slip-flow regime has been hampered by lack of test facilities. A small, low-density wind tunnel for research in this regime has recently been completed at the Ames Laboratory.

Adverse temperature effects on airplane structures may also be encountered at high subsonic speeds. Thermal stresses are induced in the structure as the result of rapid changes of the surface temperature relative to the temperatures of the internal structural members. These temperature gradients may be caused by rapid changes of the ambient air temperature resulting from fast dives or climbs, and by sudden changes in speed and the subsequent rate of friction heating. Experimental data have been obtained from dive tests of a high-speed airplane and a theoretical method of predicting temperature gradients and thermal stresses has been developed.

10 PROPELLERS

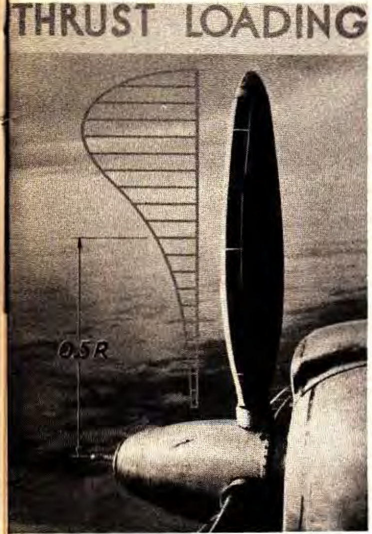
In spite of the extensive development of jet and rocket engines, the propeller remains the most efficient means of aircraft propulsion available for speeds up to about 500 miles per hour. Since high efficiency is essential for long-range flight, the search for methods of improving the performance of propellers and extending their useful range continues.

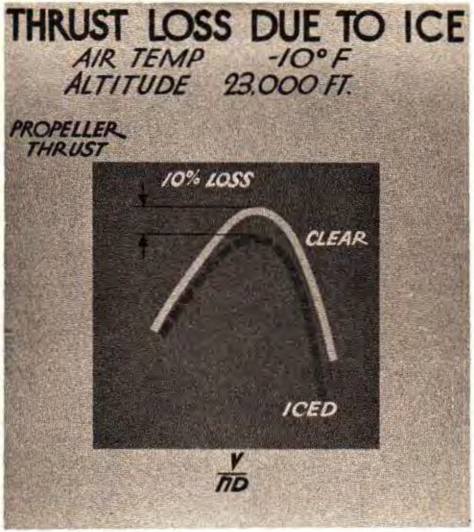
Swept-back propeller blades offer the theoretical possibility of extending efficient operation to higher speeds. This possibility is being investigated experimentally.

Propellers of large diameter with thin blades and shanks have proved to be effective in improving efficiency at high speeds. High stresses, both steady and vibrational are inherent in such propellers. If safety is to be maintained, it is imperative that these stresses be anticipated and evaluated.

A primary source of vibrational stresses is the cyclical change of blade angle of attack during rotation of a propeller which is inclined relative to the air stream. Simplified calculations do not consistently provide accurate predictions of the resulting stresses. Such factors as blade deflection, unsteady flow, and distortion of the flow by other components of the airplane must be given proper consideration.

Another phase of propeller research is concerned with the loss of thrust and the hazard of excessive vibration that occur when ice forms on the blades. Data have been obtained in flight on the effects of ice on propeller performance and on the heating requirements for ice prevention. Prelim-





THE THRUST LOSS DUE TO PROPELLER ICING IS SMALLER THAN GENERALLY REALIZED. AT TEMPERATURES AS LOW AS -10° F, LOSSES OF ONLY 10 PERCENT ARE TYPICAL, AND RARELY EXCEED 10 PERCENT ABOVE +15° F. THE SMALLNESS OF THE LOSS RESULTS FROM THE FACT THAT LESS ICE ADHERES TO THE OUTER PORTIONS OF THE BLADE WHERE MOST PROPELLER THRUST IS GENERATED.

inary analysis of these data reveals that for flight at temperatures from 15° Fahrenheit to freezing, thrust losses in excess of 10 percent are rare even with no protection. The results indicate that by heating the forward portion of the inboard 50 or 60 percent of each blade, thrust losses could be limited to less than 5 percent. At high altitudes and in practically all operations in the Arctic, temperatures below 15° Fahrenheit are the rule, and ice is liable to extend to the blade tips. For such operations, the alcohol system is useless and the only apparent solution is to heat the entire leading edge of each blade with electricity or hot gas if thrust losses of 10 percent or more are to be avoided.

10 HELICOPTERS

The fundamental factors that affect the performance, stability, and control of helicopters are being investigated at the NACA Langley Aeronautical Laboratory. Data are obtained from helicopters in flight, from full-scale wind-tunnel tests, from tests of powered models in a free-flight wind tunnel, and from full-scale rotors on a test tower designed especially for helicopter research. Extensive work has been done to check the validity of existing theory by comparison with experimental results.

The performance of helicopter rotors in hovering or slow flight is investigated on the test tower. Such factors as ground resonance and the effect of wind speed on the power required for hovering flight have been evaluated. The distribution and fluctuation of the air forces on rotor blades are also under study. Recent results indicate that the power required for level forward flight can be reduced considerably by the use of rotors with smooth, rigid surfaces and by twisting the blades to decrease the angle of attack at the tips.

HELICOPTER ROTORS ARE INVESTIGATED FOR VERTICAL FLIGHT AND HOVERING PERFORMANCE ON THIS TEST TOWER AT THE LANGLEY LABORATORY. OTHER CHARACTERISTICS ARE STUDIED IN WIND TUNNELS AND IN FLIGHT.


NACA