# LANGLEY AERONAUTICAL LABORATORY

## 1949 INSPECTION

NACA

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

# welcome

1

It is my privilege to welcome you to the 1949 Biennial Inspection of the Langley Aeronautical Laboratory of the NACA. On each of these occasions, we enjoy greeting old friends, who are familiar with the NACA research centers, and making new friends of those who are visiting us for the first time.

Since its creation in 1915, the National Advisory Committee for Aeronautics has been engaged in scientific research to provide basic aeronautical information needed for the continued development of aircraft.

The end product of our research efforts are technical reports which are made available to you as they are completed. These inspections are planned to supplement our research reports by providing a summary of significant technical trends as indicated by research conducted since your last visit with us.

We are honored by your presence and trust that you will profit, as we will, by this meeting.

J C Hunsaker
Chairman
National Advisory Committee for Aeronautics

# PROGRAM

1. WELCOME
2. INTRODUCTION
3. BOUNDARY-LAYER CONTROL
4. MAXIMUM LIFT OF WINGS
5. PILOTLESS AIRCRAFT RESEARCH
6. SPINNING
7. DYNAMIC STABILITY
8. TRANSONIC STABILITY AND CONTROL
9. 4-BY 4-FOOT SUPERSONIC PRESSURE TUNNEL
10. HIGH SPEED TUNNEL STUDIES
11. CASCADE RESEARCH
12. FLUTTER RESEARCH
13. AERODYNAMIC LOADS
14. PROPELLERS
15. AIR INLETS
16. AIRCRAFT STRUCTURES RESEARCH
17. HYDRODYNAMICS
18. HELICOPTERS
19. FLIGHT RESEARCH

# INTRODUCTION

During the past year the research effort of the Langley and Ames Aeronautical Laboratories has continued to emphasize the problems of high-speed flight in the transonic and supersonic speed ranges. This work has included extensive programs of experimental and theoretical studies aimed at broadening and strengthening the foundations of knowledge required for the design of satisfactory aircraft of improved performance.

The historic success of the Bell X-1 research airplane in penetrating the sonic barrier in October 1947, gave added urgency to this program. This success did not signify that the problems of transonic and supersonic flight had been solved, but rather constituted a major step in defining those problems and making them amenable to solution.

An important trend of investigation is in the direction of developing more accurate wing theories by including additional nonlinear terms and by including terms representing viscous forces. Nonsteady flows are also receiving much attention for use in analysis of flutter, gust loads, and airplane dynamics. Accomplishments of theoretical workers in these and related fields provide the knowledge which will enable design improvements in the future.

An area in which much intensive research is being done is that of transonic flow in which there are regions of both subsonic and supersonic flow. Difficulty is encountered by the theorist since the partial differential equation with which he works changes character in the field; and, of necessity, solutions obtained in the subsonic and supersonic portions of the flow must match on the boundary. The available mathematical knowledge is insufficient.

Moreover, experimentation has not yet established clearly the extent to which the fluid can be idealized. In two dimensions the interaction of shock waves existing in the field with the boundary layer is known to depend on the Reynolds number, the type of shock-wave formation being different depending on whether the flow in the boundary layer is laminar or turbulent. These variations produce differences in the pressure distribution on airfoils, but it is not definitely known whether an adequate treatment can be achieved without the inclusion of viscous effects.

Among the most interesting explorations in aeronautical research are those being conducted in the fields of rarefied-gas flow and hypersonic flow. Interest in these fields arises from the directions of development of jet power plants and missiles. Missiles have already penetrated to extreme altitudes in the atmosphere, and it is well known that the power required for supersonic flight is greatly reduced as the altitude is increased. There is every practical incentive to develop air-breathing jet-propulsion devices capable of operating at very high altitudes. A research program which looks to the future must give further attention to basic work in this area.

In the procurement of lift, drag, and stability data for airplane configurations at speeds approaching and exceeding the speed of sound, it has been necessary to supplement the wind tunnel, particularly in the "blind spot" which has existed in the region near the speed of sound, the transonic region.

Among equipment used to obtain this data has been the free-falling, heavily-weighted model, dropped from an airplane at high altitude, from which considerable information has been secured on drag. The wing-flow method, utilizing the fact that there is a region of supersonic speed over a part of the upper surface of the wing of a fighter airplane diving at speeds of Mach 0.7, has similarly been employed to give very useful data, though the Reynolds number has been low because of the small size of the models used. The same principle has been applied to wind tunnels, by installing a suitably-shaped bump on the wall of a high-speed subsonic tunnel.

Perhaps the most useful of these tools has been the rocket-propelled, ground-launched research model which enables measurements at high Reynolds number and a broad range of Mach numbers. The models carry various measuring instruments whose indications are telemetered to the ground. Radar is used for speed and deceleration measurements, this work being done at the NACA Wallops Island Station.

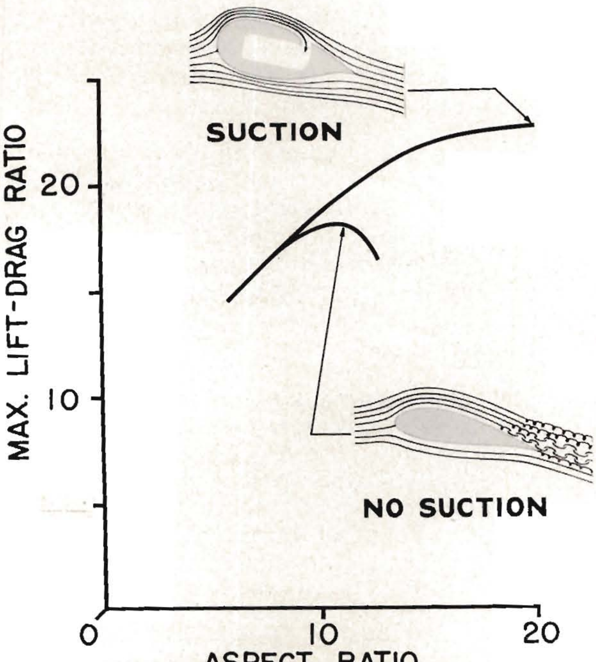
A somewhat different approach has been the use of full-scale aircraft designed especially for research purposes. Carrying as much as 500 pounds of instrumentation and research apparatus these aircraft have, for the past two years, been intensively exploring the transonic and low supersonic regions, bringing back significant information to be used in confirming and evaluating the correctness of existing transonic and supersonic theory. At the present time this program, being conducted at Muroc as a joint cooperative effort in which the Air Force, Bureau of Aeronautics, Aircraft Industry, and NACA are participating, is making use of the X-1, D-558-1, D-558-2, and X-4 research airplanes, with other research aircraft yet to be brought into use.

Intensification of research effort on problems in the transonic and supersonic speed ranges has increased the demand for new instruments, particularly for use in pilotless aircraft at Wallops and full-scale research airplanes at Muroc. Although much remains to be done, important work has been accomplished, developing successful telemetering and radar tracking instrumentation. The techniques are new and a realization of the full potentialities is dependent upon the solution of many problems involving both radar and telemeters.

The need for obtaining test data under conditions of transonic and supersonic flight has required development of more complex electronic and electrical recording equipment. At Muroc, extensive use is being made not only of radar and telemetering techniques, but also of remote indicating pressure and strain instrumentation.

The foregoing has consisted of only the barest outline of principal fields on activity in which the Ames and Langley Laboratories have joint interest. At Langley much other important work is being carried on, including investigations in the fields of structures and impact loads; propellers and air inlets; hydrodynamics, where encouraging progress is being made with planing tail hulls and high-speed configurations; personal aircraft, where studies are being made of spinning characteristics and simplified controls, and helicopters.

# BOUNDARY-LAYER CONTROL



EFFECT OF BOUNDARY LAYER CONTROL

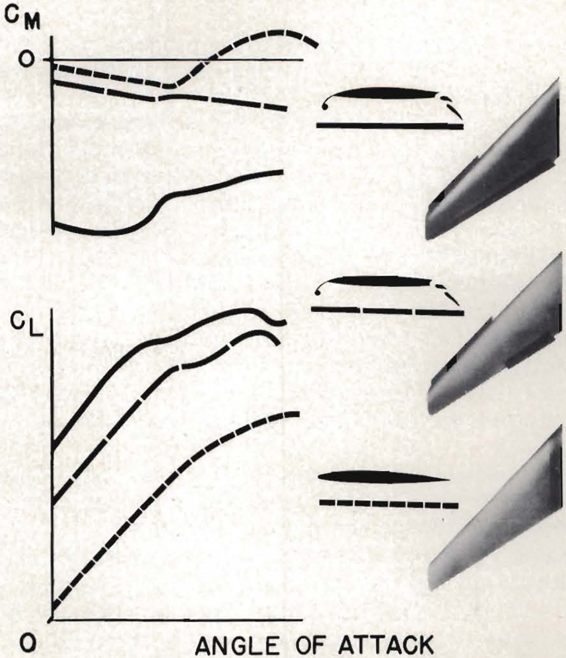
Because skin-friction drag and flow separation are basically boundary-layer phenomena, boundary-layer control has long been considered a possible method of overcoming many aerodynamic difficulties. Applications of boundary-layer control to decrease drag by increasing the relative extent of laminar flow, and to increase maximum lift by delaying both laminar and turbulent boundary-layer separation are being studied. Effectiveness of suction through discreet slots and continuous porous surfaces for stabilizing the laminar boundary layer is the subject of intensive research.

Although these may prove useful, the application of boundary-layer control that offers most immediate possibilities of improved airplane performance is control of the flow about extremely thick airfoil sections such as are required for high-aspect-ratio wings. Estimates, based on section data, have been made of the variation of lift-drag ratio with aspect ratio for a group of structurally equivalent wing configurations with and without boundary-layer control. These show that boundary-layer control increases both the optimum aspect ratio and the value of the maximum lift-drag ratio.

# MAXIMUM LIFT OF WINGS

Landing and take-off characteristics of typical thin and swept high-speed wings remain a source of concern because of the low maximum lift coefficients and associated loss of longitudinal stability and reduction of aileron effectiveness near maximum lift. Such landing aids as the split flap, while appreciably reducing the angle of attack for a given lift coefficient, give only small increments in maximum lift coefficient and do not improve the flow near the tips. They also cause large reductions in the lift-drag ratios which already are so small that power-off landings are extremely hazardous.

Prevention of separation at the outboard leading edge, by boundary-layer control or leading-edge flaps or slats, generally provides satisfactory longitudinal stability at the stall, but this can be maintained only within definite ranges of leading- and trailing-edge-flap spans. Tests on a highly sweptback wing show: An outboard leading-edge flap gave adequate stability; a partial-span double slotted flap provided a considerable increase in maximum lift coefficient without causing instability, but with a full-span double slotted flap no leading-edge flap could be found to provide adequate stability.



EFFECTIVENESS OF HIGH LIFT DEVICES ON SWEPT WINGS

# PILOTLESS AIRCRAFT RESEARCH

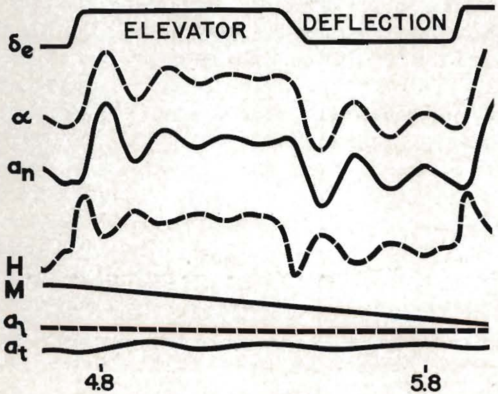
One important means employed by NACA to study flight characteristics of airplanes and missiles in the transonic and supersonic speed ranges involves use of rocket-propelled models in free flight. Techniques have been developed to provide continuous data from high subsonic speeds through the transonic range to well into the supersonic range under free-flight conditions at nearly full-scale Reynolds numbers. Some of the problems of high-speed flight for which data have been obtained by the rocket techniques are lateral-control effectiveness, damping in roll, autostabilization, static stability, dynamic stability, flying qualities, nose jettisoning for pilot escape, and drag of wings and bodies.

Models with straight, swept, and delta wings were found to be controllable and maneuverable through the transonic range, thus indicating that for these types there are no insurmountable barriers to stability and control in transonic flight. Because these results are the measured characteristics of models in free flight at approximately full-scale Reynolds number, they represent the integrated effect of all factors affecting the motion of the airplane with controls fixed.

The problem of jettisoning the nose of an airplane for pilot escape has been investigated in free flight. Some means of increasing the drag of the aft portion after separation appears to be necessary. Stabilization of the nose section after separation is essential to prevent tumbling and to cause this section to remain in a relatively low-drag attitude.

Automatic stabilization at supersonic speeds is essential to the satisfactory operation of guided missiles, and experimental research has shown that adequate roll stabilization may be secured with a variety of systems although preliminary attempts failed due to loss of aileron effectiveness. Lateral-control data obtained from other rocket techniques has shown how to improve control effectiveness which in turn will make possible supersonic roll stabilization.

In order to study the stability, controllability, and flying qualities of an airplane by this free-flight technique, the model is equipped with elevators which are caused to deflect alternately up and down according to some predetermined program. The various accelerations of the model in response to elevator motion, angle of attack, elevator angle, hinge moments, and




TYPICAL RECORD FROM MODEL WITH CONTROLLED ELEVATOR

total head are telemetered to ground receiving stations. Continuous time histories of these quantities are recorded. Such data permit determination, for the entire speed range covered in a given flight, of basic design data as follows: elevator effectiveness, elevator hinge-moment coefficients as affected by angle of attack and deflection, neutral-point position, longitudinal damping coefficient, relation between lift and drag, and relation between lift and angle of attack.

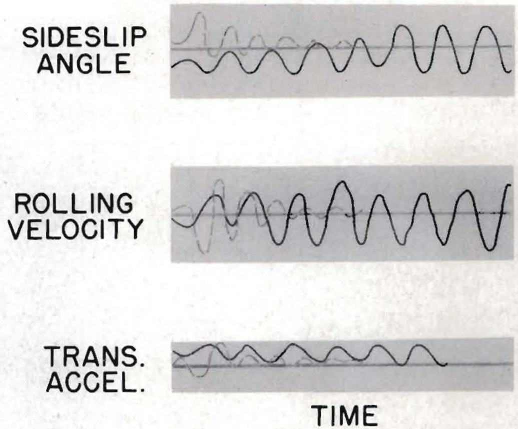
# 6 SPINNING

The problem of airplane spinning always remains important from the safety standpoint. In the past, spin research has kept pace with changing load distribution in the airplane as affected by its design and load carried, and a large amount of data has been accumulated from which design criteria could be established. Recently designed jet and rocket-propelled airplanes have greatly extended the range of mass distribution usually considered. Because of its unusual design, the tunnel can also be used for such investigations as nose jettisoning and pilot escape, tumbling, and measurement of normal accelerations in a spin.


SPIN RECOVERY PARACHUTES

Military airplanes must be equipped with an emergency spin-recovery device during their demonstration spins. From tests in the 20-foot free-spinning tunnel on numerous specific designs, an empirical criterion has been established for determining the size parachute required. It was indicated that airplanes with tails designed so as to be effective in damping the spin rotation, such as those with the horizontal tail high on the vertical tail, required the smallest parachutes. However, because of inherent instability of ordinary parachutes, difficulties have been encountered in checking these parachutes in level flight. An investigation revealed that increasing the fabric porosity of the parachute led to stable parachutes which were equally effective for spin recovery.

# 7 DYNAMIC STABILITY




TYPICAL LATERAL OSCILLATIONS

Obtaining good dynamic lateral stability has become increasingly difficult with use of extreme sweepback and low aspect ratio, and increase in airspeeds. An objectionable lateral snaking oscillation has been encountered on several airplanes in cruising and high-speed flight. This is a lightly damped short-period oscillation of relatively small amplitude. Although much more research is needed, there are indications that some factors involved might be inherently low damping of the Dutch-roll oscillation, rudder hinge-moment characteristics, low tail effectiveness at very small yaw angles, or a negative damping effect produced by out-of-phase yawing moments on the oscillating fuselage.

At low and moderate speeds some difficulties have also been experienced with the more familiar and predictable Dutch-roll oscillation. In some cases it has been found that the customary geometric modifications to the wing dihedral and vertical tail are insufficient to provide good stability. Reducing the wing incidence to change the inclination of the principal axis of inertia is usually beneficial, but often it cannot be reduced enough. Where geometric changes are insufficient, a rate gyro automatic pilot which deflects the rudder in proportion to yawing velocity has been found to provide satisfactory damping in some cases.

# 8 TRANSONIC STABILITY AND CONTROL

When conventional airplanes are flown at supercritical Mach numbers in the transonic region, significant changes occur in the stability and control behavior of the aircraft. These result from separated flow conditions induced by shock-wave formations and may be manifested as abrupt nose-down or nose-up trim changes accompanied by severe losses in control effectiveness and large increases in the stick force necessary to deflect the controls.

It is known that thin sweptback wings delay the onset of these difficulties to higher speeds and may lessen the severity of the subsequent changes when finally encountered. The wing most suitable for a particular application, however, depends on the airfoil section, the sweep angle, the aspect ratio, the taper ratio, and the Mach number range under consideration. The wide range of variables involved, therefore, points to the need for systematic investigations that will permit the isolation and study of these interrelated factors.

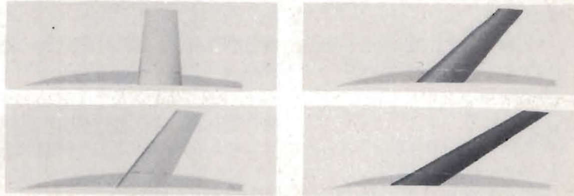
As a result the NACA has undertaken a correlated research program, involving the facilities of both the Ames and Langley Laboratories, to provide the needed basic data. One part of this program is being carried out in the Langley high-speed 7- by 10-foot tunnel.

In order to facilitate studies in the transonic region, suitably shaped bumps have been installed on the walls of high-speed subsonic wind tunnels. This testing technique is now being used both at the Ames and Langley Laboratories.

As one phase of the over-all program, a systematic investigation is being conducted relative to the effect of sweep angle on the transonic characteristics of a wing of fixed aspect ratio, taper ratio, and airfoil section. The scope of the investigation includes determination of wing-alone and wing-fuselage characteristics, downwash and dynamic-pressure surveys at various horizontal-tail positions, and determinations of the effectiveness of ailerons of varying spans.

Information of this type can be utilized by a designer in arriving at a configuration that will minimize stability and control difficulties in the

ASPECT RATIO 4 TAPER RATIO .6



SEMI - SPAN MODELS STUDIED AT TRANSONIC SPEEDS

transonic speed range. These studies have demonstrated that scrupulous attention must be given to small-detail changes which could alter drastically the over-all result. One illustration of this fact is to be found in an application where the control-position stability of the configuration depended on the particular stabilizer angle employed.

Similar studies for lateral-control applications are required because of the dependence of control effectiveness on the particular Mach number and angle-of-attack range under consideration.

9

# 4- BY 4- FOOT SUPERSONIC PRESSURE TUNNEL

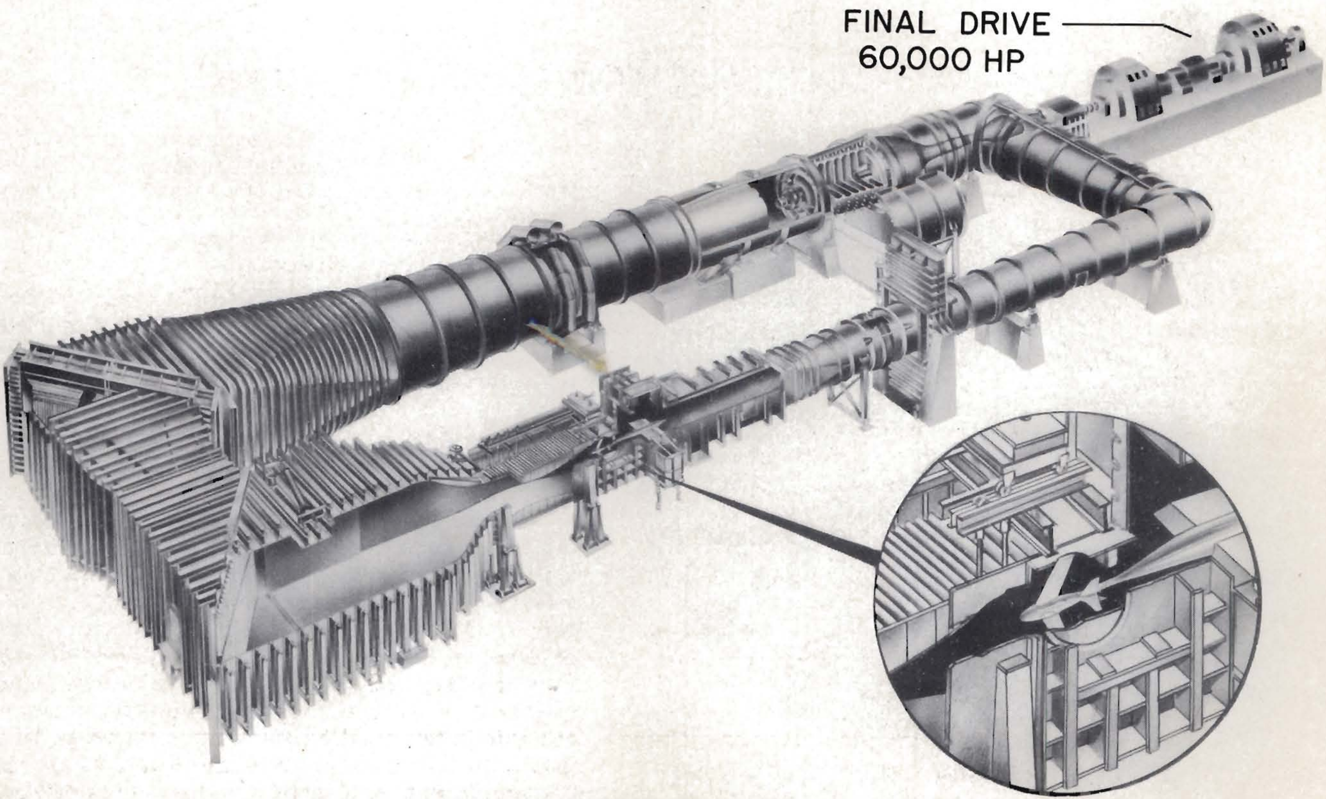
The 4- by 4-foot supersonic pressure tunnel, one of NACA's trinity of the world's largest faster-than-sound wind tunnels, has been in operation for approximately one year. During this period it has been temporarily operated by a 6,000-hp motor pending completion of the installation of the two motors capable of delivering 45,000 hp for continuous operation and 60,000 hp for 30-minute periods.

A seven-stage, 11-foot-diameter, 1137-blade axial compressor produces a pressure ratio of 2.0 and generates a flow up to 870,000 cubic feet of air per minute. With the new power arrangement, stagnation pressures can be increased to over 2 atmospheres, to attain a Reynolds number of approximately $10 \times 10^6$ per foot of chord of the test wing.

The tunnel may be completely sealed to facilitate operation at pressures from 0.25 to 2.5 times atmospheric pressure, thus providing for a wide range of Reynolds numbers. Gates make possible isolation of the test section so that model changes can be made without the necessity of returning the entire tunnel to atmospheric pressure. Drying and cooling equipment in the tunnel enables reducing moisture content of air to as low as 1 part of water in 10,000 parts of air and reducing stagnation temperature from 250° F to about 110° F.

Stainless steel is used in the walls of the test section. Two of these 25-foot-long walls are flexible and actuated by a series of jacks which enable maintaining accuracy of the nozzle contour to 0.005 inch. Speeds ranging from 1.2 to 2.2 times the speed of sound are attained.

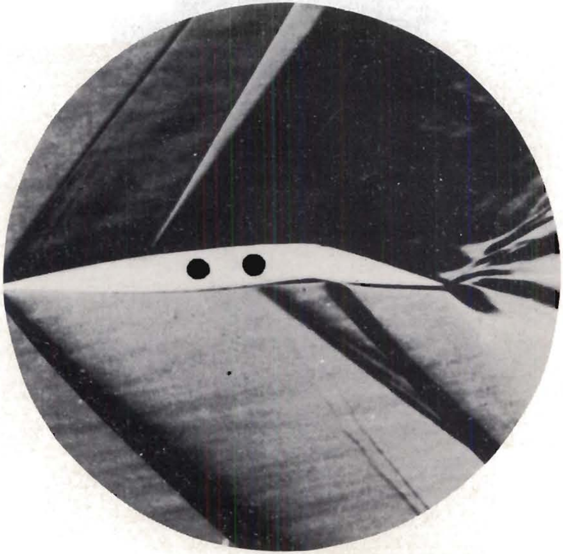
With this new facility, it is possible to employ test models large enough to permit installation of extensive instrumentation. During the past year, a 32-inch-span model of a complete supersonic airplane has been under investigation. This model is fitted with movable controls and more than 300 pressure orifices. The results obtained provide detailed information on viscous and interference effects unobtainable in the smaller supersonic tunnels. Also under way is an investigation of the details of the phenomenon of shock-wave detachment at the leading edge of supersonic wings.




4-BY 4-FOOT SUPERSONIC PRESSURE TUNNEL

# HIGH SPEED TUNNEL STUDIES

$M = 1.6 \qquad R = 1 \times 10^6$



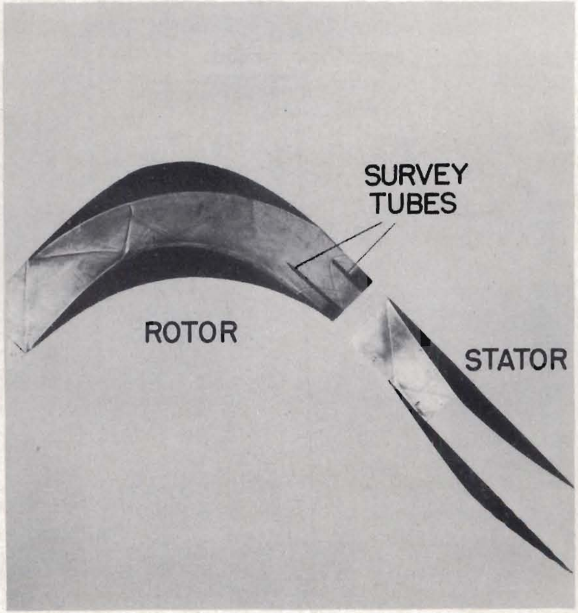
A SCHLIEREN PHOTOGRAPH OF FLAPPED AIRFOIL

In the accomplishment of practical supersonic flight, a major problem is that of providing the airplane with effective control for operation over a large range of Reynolds and Mach numbers. High-speed-tunnel studies of supersonic airfoils with trailing-edge flaps were extended to higher Reynolds and Mach numbers to provide data needed in certain missile applications. Results obtained at $R = 5 \times 10^6$ and $M = 4.0$ indicated that the large viscous effects found in previous small-scale tests were not representative of large-scale conditions.

At a low Reynolds number, deflection of the flap produced separation of the flow for an appreciable distance forward of the flap. This effect is evident from the presence of the forked shock. At high Reynolds and Mach number conditions, however, the flap had no effect on the flow ahead of the hinge line. In the large-scale case, close agreement is obtained between theory and experiment. It is considered improbable that further increases in scale would cause appreciable changes in the performance of flaps of this type.

# CASCADE RESEARCH

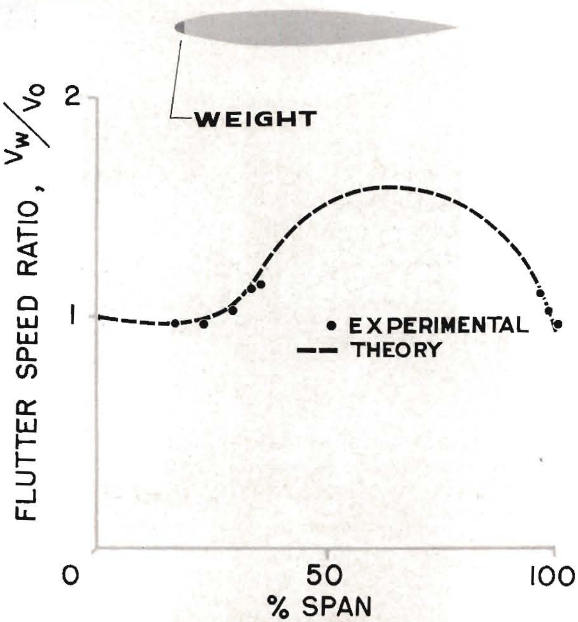
Many important advances in gas turbines have had their origin in aerodynamic research utilizing stationary cascades representing the blade rows of the compressor or turbine element of the engine. Supersonic cascade investigations made possible design of the first successful supersonic compressor. Recent cascade research indicates the feasibility of a new "impulse" type of supersonic compressor in which the rotor increases the speed of the air but does not produce any pressure rise. All of the pressure rise occurs in a supersonic stator which decelerates the air, partly by means of a normal shock, to subsonic velocity. The possibility of obtaining the potentially high performance of this design in practice is contingent upon efficient turning of the air in the rotor through a large angle and efficient diffusion in the supersonic stator. In making detailed studies of the flow in a diffuser, it is helpful to visualize the flow. One method used successfully in cascade research utilizes the shadowgraph. From such photographs it is possible to detect shock-wave patterns and certain boundary-layer characteristics.




FLOW IN SUPERSONIC CASCADE

12

## FLUTTER RESEARCH




EFFECT OF CONCENTRATED WEIGHT ON WING FLUTTER SPEED

The flutter field continues to increase in importance and significance in airplane design. There is an increasing need for understanding the interaction of free-body stability modes and the flutter modes involving structural distortions. Theoretical and experimental flutter research has been extended into the supersonic speed range. The experimental flutter program for near-sonic speeds has been pursued with the combined use of the flutter tunnel and with the aid of rocket vehicles and freely falling bodies, requiring telemetering techniques. Special studies have been made of sweptback wings and of effects of concentrated weights.

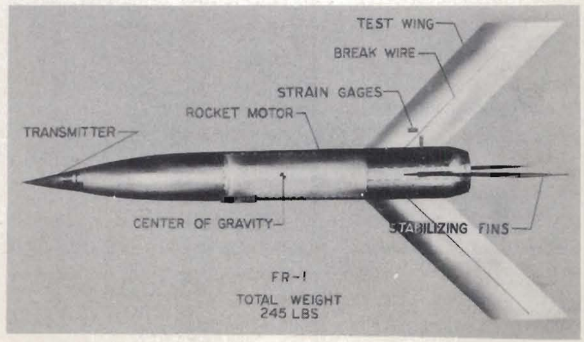
By means of these techniques experimental wing-flutter results have been obtained through the transonic range up to a Mach number of 1.3 for both swept and unswept wings. Of special interest are the results of a combined experimental and analytical study of the destructive oscillations of a wing missile in combined missile-pitching and wing-bending.

Methods of analysis for the determination of the flutter characteristics of unswept-wing aircraft are not directly applicable to aircraft with swept wings. An analysis has therefore been developed which includes aerodynamic effect of sweep, and a series of experimental investigations on cantilever wings of moderate length-to-chord ratios has confirmed the analysis.

In order to determine effects on flutter of such items as wing-tip tanks and engine nacelles, a broad program has been undertaken in the flutter tunnel to study the effects of location of concentrated weights in conjunction with the effects of sweep. Moments of inertia, chordwise and spanwise positions, as well as aerodynamic shape of these weights, have been varied.

In order to appraise and test the commonly employed methods of flutter calculations using selected modes, a comparison has been made between experiment and various theoretical methods for a wing carrying a concentrated weight. A wing-weight combination was chosen for which there was available an exact solution of the differential equation describing the flutter of the wing as a continuous structure. This exact solution has been compared with experiment and with the calculations by the use of a chosen number of modes of vibration.

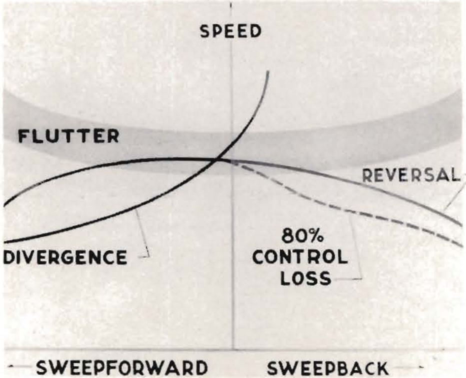
Information also is being sought on flutter wherein separated flow conditions may prevail, leading to hysteresis effect, as in types of control surface flutter at high speeds and in propeller stall flutter. Among experimental techniques useful for this work is the development of pressure cells for conveniently measuring instantaneous pressures on an oscillating surface.




ROCKET POWERED FLUTTER TEST VEHICLE

# 13 AERODYNAMIC LOADS

Aircraft loads problems have tended to multiply with the great advances in flight speeds. Some of the new problems have arisen because of the entrance into the unexplored transonic and supersonic ranges of flight. Others have arisen because of the increased importance of structural elasticity. High-speed aircraft are subjected to extremely high aerodynamic forces and at the same time require the use of thin wings or thin swept wings. Thus, there has arisen the need for considering the interaction of aerodynamic and elastic forces or aeroelastic effects as a primary factor.



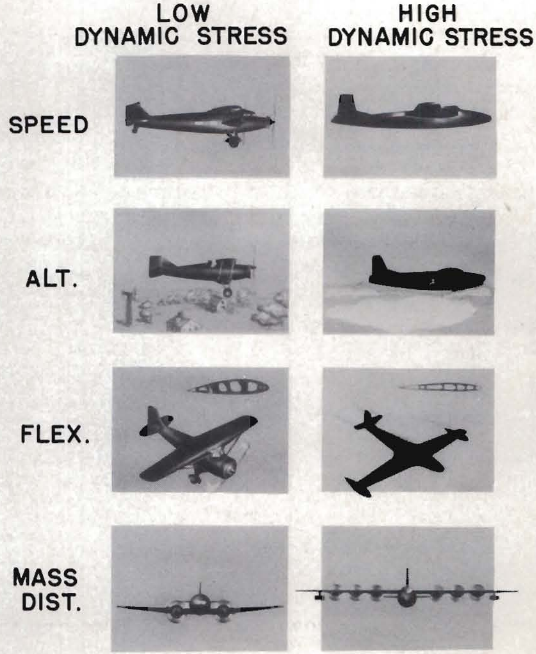

AEROELASTIC EFFECTS OF SWEEP

Progress has been made in defining the $C_{L_{max}}$ and the buffeting boundaries as affected by Mach number and rate of variation of angle of attack. The results now available furnish a useful guide for determination of maximum loads that may be imposed on high-speed aircraft.

In gust research, data have been obtained on the effect of compressibility on the slope of the lift curve under unsteady flight conditions. The modification of the gust loads and wing stresses due to elasticity of the structure has been investigated. The frequency of occurrence of gusts in the atmosphere has been used to study the fatigue life of airplanes.

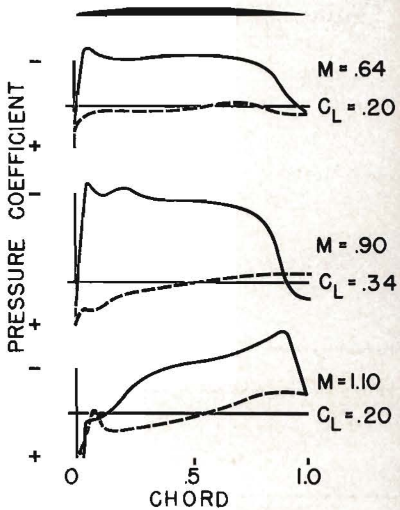
Methods for predicting aeroelastic effects have been under development. It has been found that apart from the immediate effects elasticity has on load distribution, wing divergence tends to be most important for sweptforward wings, control loss for sweptback wings, aerodynamic center shift for all highly swept wings, and flutter for unswept wings. Results are available from which it is possible to predict whether strength or stiffness is likely to be critical in a given design.

Problems of landplane impact and landing-gear design have received increased attention. The trends of aircraft design indicate heavier weights and higher landing speeds which will increase the complexity of the landing gear design problems. In studies of the effects of elasticity of the several airframe components on the impact loads, it has been found that seemingly small variations of the forcing function applied at the landing gear results in large differences in the response of the structure. Progress has been made in the development of suitable experimental techniques for providing information that will make design more rational.

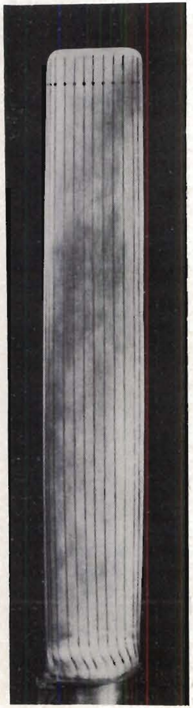



FACTORS AFFECTING DYNAMIC STRESS

# PROPELLERS



PRESSURE DISTRIBUTION ON ROTATING PROPELLERS



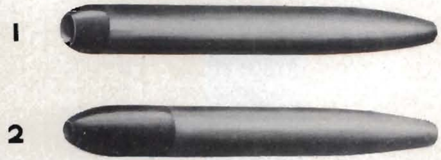
The need for further improvement of high-speed propeller performance has resulted in continuing to devote a considerable amount of research effort to the problem. A program designed to define the high-speed performance of propellers is currently being conducted in the 8-foot high-speed tunnel. Effects of blade thickness, camber, and sweep on high-speed performance of propellers, as well as dual-rotation propeller performance, are included. In addition, studies conducted in the Langley 16-foot high-speed tunnel will provide detailed information concerning such propeller performance by the delineation of propeller section characteristics from the measurement of pressures acting on rotating propeller blades. Such data will yield section lift, drag, and pitching-moment characteristics.

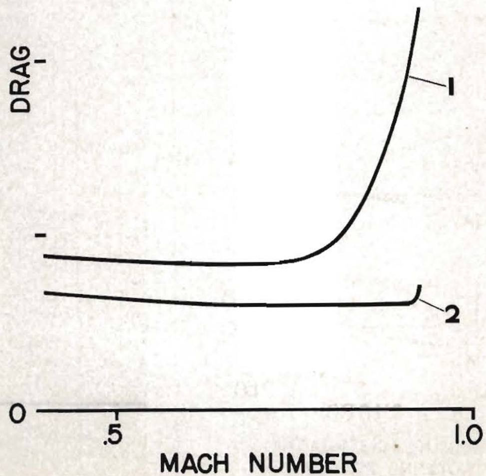
The serious problem of propeller vibration encountered on large diameter propellers absorbing large amounts of power has also led to considerable effort being devoted by the Ames and Langley Laboratories to fundamental study of the factors contributing to the high levels of propeller stress being encountered.

## AIR INLETS

NACA research on air inlets has been directed toward a study of air-inlet shapes which deliver air to the engines with minimum pressure losses, without inducing high local velocities and without associated adverse effects on airplane drag. Investigations are being conducted at both subsonic and supersonic speeds for air-inlet configurations such as open-nose, annular, wing-leading-edge, scoop, and flush-type inlets.

Considerable effort has been devoted to the determination of the high-speed drag and ram-recovery characteristics of nose inlets. Previous work had permitted accurate determination of the critical speeds but, as in the case of airfoils, a large margin between critical speed and point of drag rise was expected. The results for the shorter nose inlet confirmed this fact. This margin becomes smaller for the larger nose inlet having the higher critical speed. In addition, the effects of operating at different inlet-velocity ratios have also been determined. These results will thus serve to permit the accurate determination of the high-speed drag characteristics.

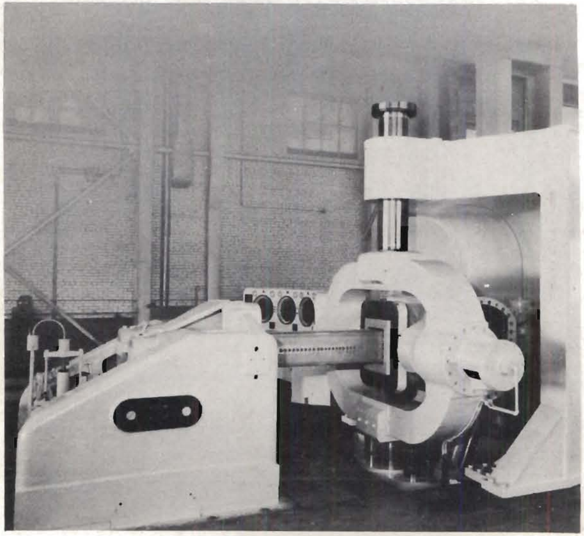



DRAG OF NOSE INLETS

# AIRCRAFT STRUCTURES RESEARCH

For the improvement of airplane structures, more efficient use of material is needed to satisfy the requirements for strength and stiffness. The trend toward higher speed aircraft with thinner wings of greater flexibility has created problems of aeroelasticity. Thick skins in such wings at high stresses, and possibly at elevated temperatures, raise problems of plate buckling in the plastic range.



COMBINED LOAD TESTING MACHINE

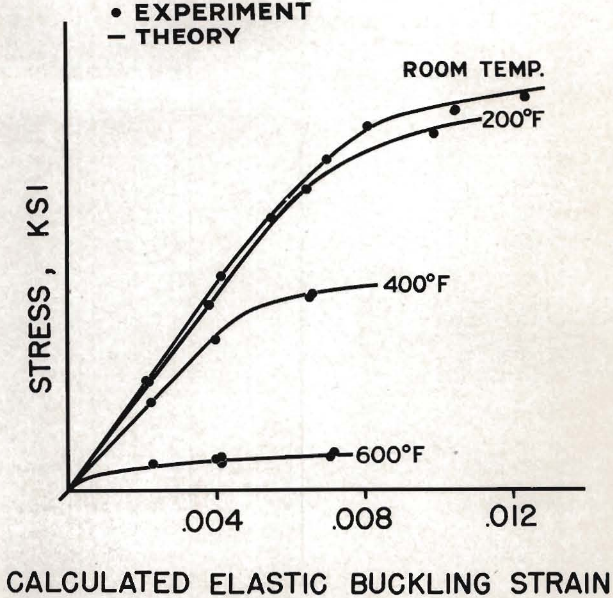
Associated with these problems is the matter of stress distribution in shell structures due to load concentrations, structural discontinuities, and elevated temperature conditions. The fact that fatigue strength of material has not kept pace with its static strength increases the need for research in fatigue.

Much of our structures research is conducted with simple load conditions, correlating the strength of the structure with the basic properties of the material at room and at elevated temperatures. The results for flat plates buckling in compression show that the strength can be calculated at both elevated and room temperatures. Most of the loading conditions that occur on the elements of the airplane structure are combinations of shear, bending, and twisting; a part of the theoretical and experimental research is devoted to these problems.

For this purpose a combined load-testing machine has been provided. One of the researches completed with this machine was concerned with buckling strength of flat plates in combined compression and shear. Another fundamental problem of great importance thus studied was the stress-strain properties of aluminum alloy in combined compression and shear beyond the elastic range.

This investigation led to development of a new plasticity theory, based on the concept of slip, which eliminates some of the fundamental objections to previous theories and gives better agreement with experiments on materials under combined stresses.

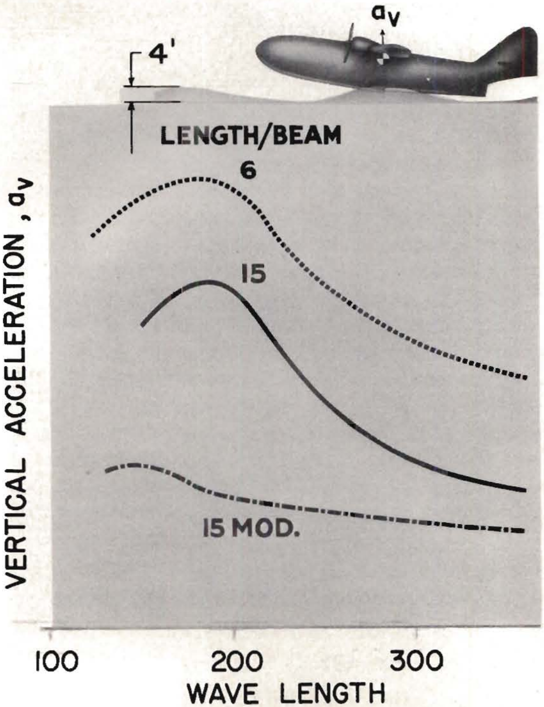
Recent structures research projects have included the development of numerical methods for such problems as the stress analysis of shell structures, the determination of the flutter speed and the associated modal shape of wings, and the calculation of the transient stresses that occur in aircraft during gusts or landing.




TEMPERATURE EFFECT ON BUCKLING
75S-T6 PLATES IN COMPRESSION

17

## HYDRODYNAMICS




VERTICAL ACCELERATION IN WAVES

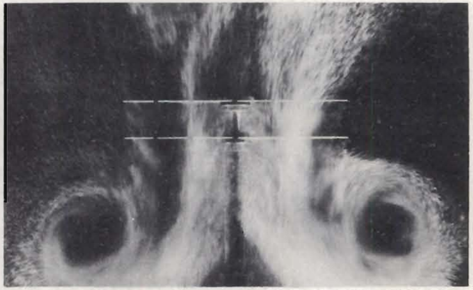
In view of requirements for increased range and speed in future flying-boat designs, investigations have been made of the aerodynamic and hydrodynamic characteristics of flying-boat hulls as affected by hull dimensions and hull shape. The principal emphasis was on reduction of aerodynamic drag without detriment to hydrodynamic performance. As part of the general investigation, a related series of hulls of varying length-beam ratio was investigated.

Wind-tunnel investigations showed large reduction in aerodynamic drag as the length-beam ratio was increased and hydrodynamic tests in smooth water indicated that hulls with high length-beam ratio have desirable characteristics. Of special concern was the behavior in rough water of hulls having high length-beam ratios. Investigations of a hull having a length-beam ratio of 15, compared with a conventional hull having a length-beam ratio of 6, indicated that substantial reduction in vertical acceleration can occur with an increase in length-beam ratio. Additional decreases in vertical acceleration can be obtained by modifying the hull.

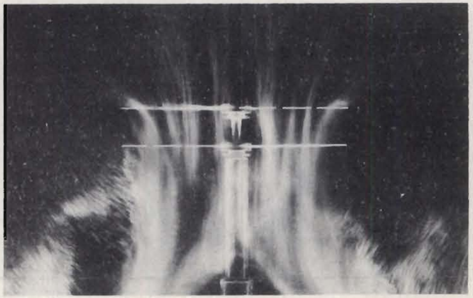
# HELICOPTERS

Fundamental factors affecting performance, stability and control, and vibration characteristics of helicopters currently are being investigated. Data are obtained from helicopters in flight, wind-tunnel tests, tests of powered models in a free-flight tunnel, and from full-scale rotors on a test tower. Extensive work has been done to check the validity of helicopter theory.

Among helicopter problems receiving most attention at present is that of stability and control, together with that of flying and handling qualities requirements. Another prime problem is to determine what characteristics the designer should strive for to make helicopters safer and easier to fly. Flight investigation of one phase of this problem indicates that, in relation to longitudinal characteristics in forward flight, the most important consideration is prevention of prolonged stick-fixed divergence. Also, that the factor appreciated by the pilot in judging further improvement is the continuous development of normal acceleration following abrupt control deflection, in contrast to a pause in the development of acceleration during the first second following displacement.



RAPID THRUST INCREASE



STEADY HOVERING FLIGHT

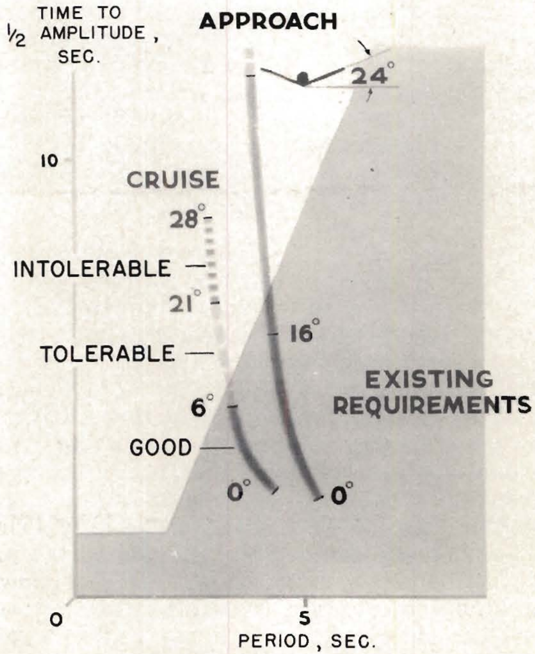
HELICOPTER AIR FLOW

19

## FLIGHT RESEARCH

Flight Research uses airplanes under actual flight conditions, thus providing a final check on results of wind-tunnel and theoretical research, and allowing evaluation of the handling characteristics of airplanes as they influence the pilot. Significant transonic and supersonic flight research is being conducted at Muroc. Often investigations are conducted under air-flow conditions not readily simulated by wind tunnels or other ground equipment. Such problems include handling qualities of airplanes, automatic controls, and wing-body interference effects.

One problem currently being investigated by means of flight research at the Langley and Ames Laboratories is poorly damped oscillations or snaking, and particularly the effect of period and damping on the pilot's ability to control such oscillations. Flight tests were made of a fighter airplane whose stability characteristics were modified by an automatic control device which changed the effective dihedral by deflecting the ailerons in proportion to the angle of sideslip. In the cruise condition, pilots felt that considerable damping was desirable, while in the approach condition the damping of the lateral oscillation appeared to be less critical.




DIHEDRAL EFFECT ON DYNAMIC STABILITY

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