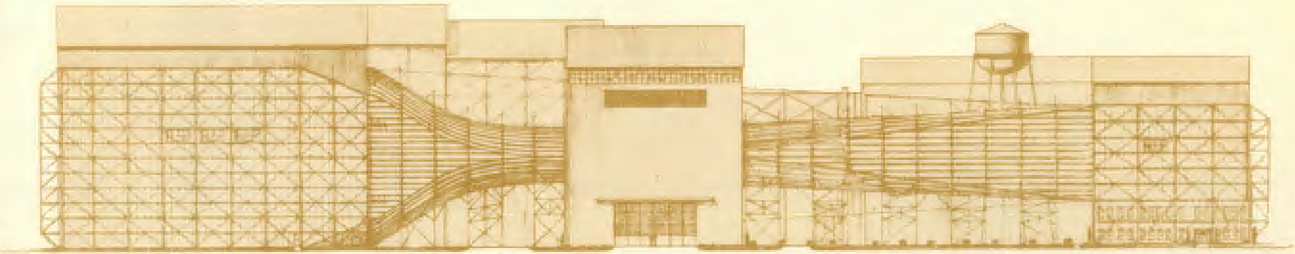
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS



AMES AERONAUTICAL LABORATORY....1950 INSPECTION

NACA

Welcome

Welcome to the Ames Aeronautical Laboratory and its 1950 Inspection.

Since 1915, the National Advisory Committee for Aeronautics has engaged in the scientific study of the problems of flight. From this research has come a steady flow of data designed to assist the aircraft industry and the military services. As you know, the problems of aircraft design, construction and operation have been greatly heightened by the reality of flight at supersonic speeds. It is the purpose of these inspections, held at the NACA's three major research centers, to summarize for you the progress that has been made in acquiring knowledge which will help in solving such problems.

It is always a privilege to greet you on such occasions...old friends who are familiar with our laboratories, new friends who are visiting us for the first time. We sincerely hope you will find that the time you spend with us has been both profitable and enjoyable.

JC Hunsaker
Chairman

National Advisory Committee for Aeronautics

Contents

PROBLEMS AND PROGRESS

Significant accomplishments have marked the past year in the progress of man-made flight. Today, while still coping with the admittedly difficult problems of transonic flight, aeronautical research is simultaneously exploring far beyond that region. A new label - "hypersonic" - has come into use to describe speeds more than five times the speed of sound, and facilities are becoming available that permit detailed studies to be made of some of the problems encountered at such speeds.

In the realm of actual flight, research airplanes have repeatedly flown above Mach number 1, while missiles have flown up to Mach numbers of about 5.

Where does aerodynamic research, which seeks to determine the most efficient shapes or forms of wings, tails, control surfaces, bodies, and other component parts of the airplane or missile, fit into this picture? What have been the contributions of the aerodynamicist to the general progress?

Competition, both military and commercial, dictates increased airplane performance. But it would be costly to a dangerous degree to accomplish this by increased power alone--by brute force, as it were.

The alternative is to obtain improved performance with more efficient aerodynamic forms, combined with more powerful and efficient propulsion systems and fuels. This has been done at lower speeds in the past and has been a potent factor in aviation progress.

It appears that aerodynamic progress in the transonic and supersonic speed regions is paralleling the rate of progress made in the lower speed regions. If higher speeds are obtained by improving the efficiency, the return is gratifying. Military aircraft will be less costly to operate or, alternately, will be able to travel farther, carry more military equipment, and hence be more effective. Commercial aircraft will satisfy the constant demand for more rapid service, will be able to make more frequent trips, carry more passengers, and produce more revenue over a given period.

In the light of this, what are the outstanding problems that are being studied today?

From the research viewpoint, a number of the problems are old and familiar; they have merely assumed new aspects and rearranged themselves in importance. For instance, air inlets must operate over a wider range of speed and flight conditions. They must operate with less loss and handle from 10 to 20 times more air. The allied problems of internal air ducts and jet engine exhausts have changed correspondingly. In every respect, internal aerodynamics research has assumed an entirely new order of importance. The old problem of buffeting increases in complexity and seriousness near sonic speeds. The solutions are no less elusive and the problem threatens, in some cases, to limit airplane performance. Propellers, in new forms, are promising high-speed performance with wide ranges of efficiencies and problems long associated with them remain to be solved.

Despite the radical changes in wings that have occurred in recent years, much remains to be learned to arrive at the most efficient forms for the wide ranges of speeds required of new airplanes. Demanding even more intensive research, however, are control surfaces. The problem of making them effective at all flight speeds, and of making their force and speed characteristics compatible with piloting capabilities, is one that is requiring multiple approaches and highly imaginative investigation techniques.

Especially important among the problems of high-speed research is the relation between aerodynamic loading and the elastic properties of the aircraft structure, where load changes induce structural deflections and vice versa. Aeroelasticity, as this phenomenon is called, is an important consideration in the design of swept wings and there is an urgent need for basic information on the subject.

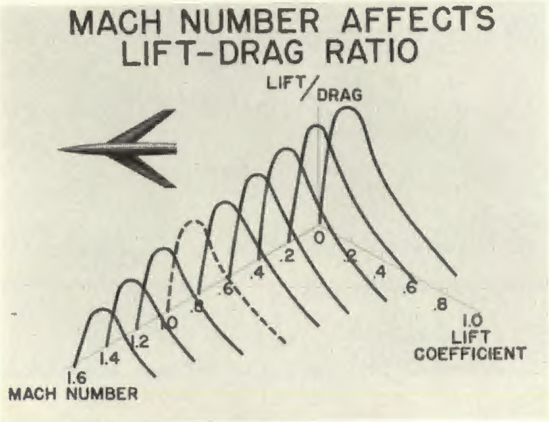
Problems of heating at high speeds, of skin friction at very high speeds, and of the effect of shape at high Mach numbers, are receiving attention because they will become of practical importance in the future.

These and many other problems are being attacked in the Laboratories of the National Advisory Committee for Aeronautics, a Government agency which conducts scientific investigation of the problems of flight, with a view to their practical solution. To this end, the NACA uses all of the tools of research--wind tunnels, aircraft (including the very latest research airplanes now being flown at Edwards Air Force Base at Muroc, Calif.) engines, rocket-propelled models, etc. Its principal product consists of technical reports of various types. Once a problem is attacked, the job is not finished until the results are analyzed, a satisfactory explanation is obtained for the controlling factors, conclusions drawn, and the whole accurately reported. Thus, ideas, design data, and all available advances in the knowledge of a problem are made available to the armed forces and the aircraft industry in the form of technical reports, which act as guide posts in the creation of the airplanes and missiles of tomorrow.

RESEARCH FOR TOMORROW'S AIRPLANES

WINGS FOR HIGH SPEED

Jet propulsion has given us enough thrust to fly at transonic and supersonic speeds. The record has proven this, and aerodynamic knowledge today is sufficient to make a reality of controlled flight at such speeds. Research now seeks to learn the shapes of wings best suited to the various types of aircraft designed to fly at transonic and supersonic speeds. In addition to acquiring this knowledge, information must be provided about the low-speed behavior of these shapes, because airplanes must land and take off at reasonable speeds.



Such research is pursued through this speed range using both theory and experiment. It was theory which first suggested swept-back wings for high-speed flight. Experiment has been used in the solution of numerous flight problems. Many tools are used in this work, the most valuable of which has been the wind tunnel. Over the years, the number and kind of wind tunnels required have increased as new problems were attacked. Even now new tunnels are coming into use to permit extension of research to still higher speeds.

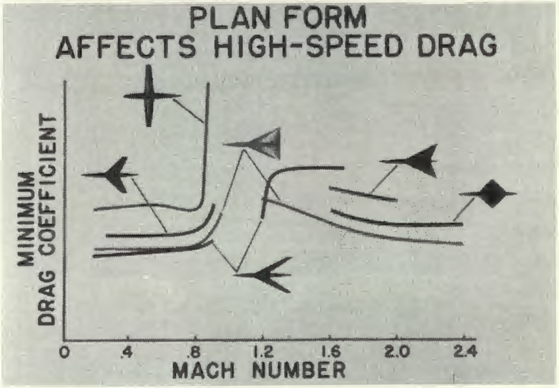
high-speed research

For an airplane to be fast, its drag obviously should be as small as possible. Making the wings extremely thin is effective in reducing drag at transonic and supersonic speeds, and research is being conducted on wings only 3 percent thick. Although such thin wings show little drag reduction at low speeds, the drag improvement at transonic and supersonic speeds may be tremendous.

Another principal choice the designer has is selection of the best wing plan form to keep the drag small. The primary device now used is sweeping the leading edge of the wing back; the optimum angle of sweepback increases with Mach number. At really high speeds, the aerodynamically ideal sweep probably will be so great as to exceed practical limits. Sweepback and wing thinness are the two main considerations; there are many important details, all of which are being studied intensively.

For an airplane to fly efficiently, for it to carry large useful loads over long distances, its wing must be able to carry heavy loads compared to the drag. The aerodynamicist says the lift-drag ratio must be large. The same shape variables, wing thinness and wing plan form, are available to help accomplish this. Again, sweeping the wing and making it thin are helpful. But to carry such loads efficiently the sections of the wing must be curved, or cambered, properly. For the whole wing, this camber may have to be varied along the span and twist may be required to give the wing the best efficiency.

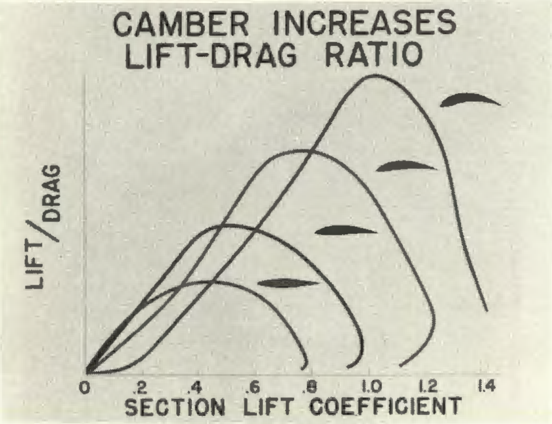
Research findings indicate that proper camber will increase the lift-drag ratio by important amounts. To date, however, the gains realized by cambering complete swept-back wings have been less than half as large as tests of the wing sections indicate might be possible. Methods to realize a greater pro-



portion of the potential gains are the subject of current research.

low-speed research

Many of the design features which improve wings for high-speed flight tend also to increase the take-off and landing speeds and to introduce undesirable flight characteristics at these low speeds. Sweepback reduces drag at transonic and supersonic speeds because it reduces the component of air speed across the wing at right angles to the leading edge. Unfortunately, a corresponding reduction of effective air speed remains at low speed and reduces the lift available. In a representative case, the combined effects of sweepback and thinness, compared to the older-style straight, thicker wings reduce the lift available at landing and takeoff speed by 60 percent.



Considerable research is in progress to learn how to make wings which are of the best-known design for high-speed flight capable of landing and taking off at safe speeds with heavy loads. Small models do not generally behave the same as full-scale wings in this respect, so much of this research is conducted in large wind tunnels such as that at Ames with a 40- by 80-foot test section, and in the large pressure tunnels at Langley and Ames.

In general, devices which increase the lifting ability of old-style wings are helpful with high-speed wings, but the requirements are more severe and the details must be different. The main differences arise because the thinner wings stall differently and also because, when sweep is used, there is a strong tendency for some of the air near the wing surface to flow along the span. Lift-increasing devices which show some promise for use on high-speed wings include: Flaps, not only on the trailing edge but also on the leading edge; slots; boundary-layer control, and, as at high speeds, twist and camber. All these devices are being investigated to determine the optimum design for each and to learn which type is best for each purpose.

Throughout this discussion of high-speed wings mention has been made only of research centered upon load-carrying ability and drag. Many other problems arise with each new wing design and must be considered. Some of these on which research progress is being made include: Provision for optimum handling qualities through good lateral, longitudinal and directional stability and control; avoidance of adverse effects of elastic distortion of the slender wing panels; flutter; buffeting; and many structural problems.

SWEPT-BACK WING IN
40-BY-80 FOOT WIND TUNNEL

AIRFOIL - BODY COMBINATIONS

The development of faster aircraft and the growing importance of missiles have increased the significance of interference, which can be defined as the mutual interaction between wings, bodies, and tails which affect the aerodynamic characteristics of the combinations.

In the past, research has been concerned primarily with airplanes which were composed of a wing of rather high aspect ratio on a relatively small body and with a relatively small tail to provide the required stability. For such an airplane, the major interference problems are (1) the interference of the body on the wing and (2) the interference of the wing on the tail. Since, in this case, the body is small relative to the wing span, interference of the body on the wing is almost negligible. In general, also, since the body contributes only a small portion of the total lift and stability, even the interference of the wing on the body is not a major consideration. Therefore, the interference problem, as it affects stability, is reduced practically to one of the effect of the wing on the tail, which was solved by a combined theoretical and experimental attack some years ago.

On the other hand, in order to fly at high subsonic or supersonic speeds, we must utilize wings which are very thin to provide a minimum of interference to the air stream. The use of thin wings requires that the span of the wing be reduced to avoid excessive bending stresses at the wing root. The net result is that for airplanes flying in the speed ranges mentioned, the diameter of the fuselage is much larger, relative to the wing span, than on aircraft designed for lower speeds. It is evident that here the mutual interference of wing and body becomes very important. Furthermore, the reduction in the aspect ratio of the wing causes the air flow field in the wake of the wing to become highly distorted, so that interference between the wing and tail becomes of even greater significance.

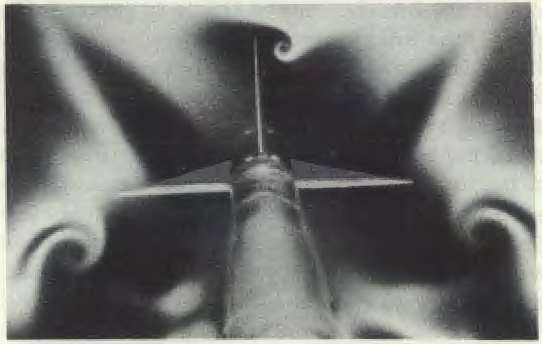
In the case of supersonic missiles, wing spans are reduced even further, since the wings must be very thin and since the missile must develop very high accelerations in order to turn in tight circles when pursuing its target. Because the body must be large to house the electrical guidance system, rocket motor, and war head, the wing span for a typical missile may be only twice the body diameter.

The interference problem associated with missile design is further complicated by the fact that on many missiles cruciform, or cross-shaped, wings are necessary. For such missiles, the further problem of interference between the vertical and horizontal wings is present.

One example of the use of the cruciform wing is on an air-to-air missile which is fired from one airplane at another. Because the missile must maneuver very rapidly, it does not have sufficient time to bank and turn, but must accelerate laterally without banking, dictating the use of a vertical as well as a horizontal lifting surface.

A great deal of research is now being devoted to these interference problems in the Laboratories of the NACA. One of the most interesting problems on which the Ames Laboratory is working is concerned with the downwash flow field behind cruciform wings. In this research, it has been found that the flow behind such wings can be studied visually by introducing water vapor into the wind tunnel to cause formation of fog particles in the air stream. If the fog particles are illuminated by a plane of light passing through the test section, the vortices appear in this plane as dark spirals.

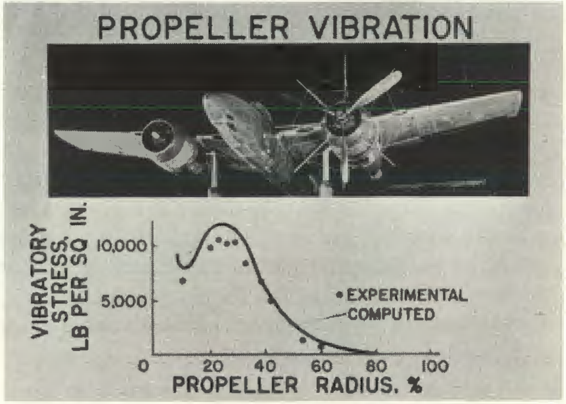
FLOW BEHIND A CRUCIFORM WING



PROPELLERS

Research during the past two years has shown how propeller efficiencies can be increased as much as 30 percent for flight at Mach numbers between 0.7 and 0.92. This discovery has created a resurgence of interest in propellers for flight at speeds faster than 500 mph, and there is reason to believe that further raising of the practicable upper limits for turbo-prop airplanes may yet be accomplished.

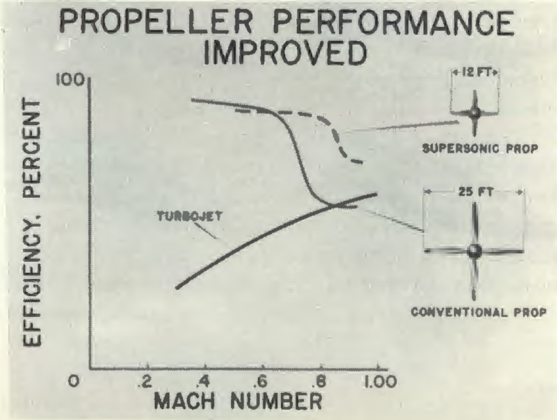
This great improvement has resulted from abandonment of efforts to keep subsonic the speed of propeller blades through the air. Even in the 1920's loss of propeller efficiency from compressibility effects at the blade tips had been observed. To lessen these losses, engines were geared to rotate the propellers more slowly. This required increasing the propeller diameter to absorb the engine power, and this in turn necessitated even greater reduction in the rotational speed of the propeller. There was a further limitation; blade angles became so large that too much power was wasted pushing the air around with the propeller instead of propelling the airplane forward by pushing back on the air. These limitations were such that propeller efficiencies dropped sharply at flight speeds above a Mach number of 0.7. So great was this drop-off of efficiency that propellers could not compete with turbo-jet engines at speeds much above a Mach number of 0.8.


PROPELLER VIBRATION

The "supersonic propeller" -- the entire blade of which may travel at speeds faster than sound even when the airplane is flying at subsonic speeds -- offers an escape from this vicious circle of propeller problems, and represents a complete change in design. The improved efficiency comes about because the lessened efficiency resulting from supersonic blade speeds is much more than offset by gains from the use of smaller blade angles and blade sections which are very thin.

Other advantages result. Because of its higher rotational speed, the supersonic propeller need have only half the diameter of a subsonic propeller for the same power, and this permits an important saving in propeller weight and in the complexity and weight of the drive gearing; it permits also use of a shorter and hence lighter landing gear.

One phase of current propeller research is study of the air forces on the thin sections of the supersonic propeller blades. The extreme thinness of the new-type blades intensifies flutter and vibration problems, problems which have been limiting factors even with the thicker subsonic blades. Flutter research has shown that proper selection of blade width can help to prevent flutter at the higher Mach numbers. Vibration research has shown how blade vibrations through one cycle per revolution can be calculated once the speed and angles of the air flowing into the propeller are known. Efforts are being made to devise ways of calculating the flow in front of wing-body combinations. From such work, it is hoped to provide better tools for the engineer to use in analyzing his propeller designs to avoid flutter and vibration.

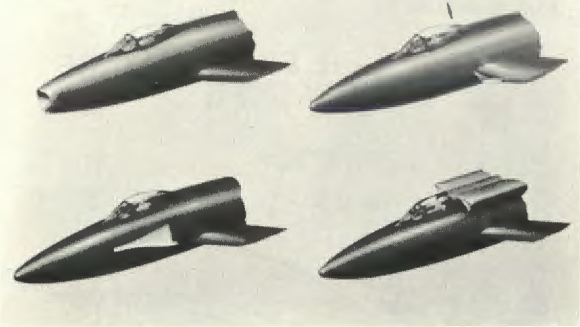


AIR INLETS

During the past year the Laboratories of the NACA have intensified their studies of the varied problems associated with air inlets for engines, and progress can be reported in both the subsonic and supersonic fields.

The importance of research on air inlets has been growing steadily with increases in flight speeds. As these speeds increase larger engines that require more air are necessary and the efficiency of the air induction system becomes a greater factor in the over-all efficiency of the aircraft.

TYPES OF SUBSONIC AIR INLETS



For subsonic air inlets, systematic design information is being provided for all possible flight conditions and for the maximum speeds at which each of several types of subsonic inlets is practical. These include the nose inlet, the inlet at the wing fillet, the submerged inlet on the fuselage, and the scoop inlet on the fuselage a considerable distance behind the nose. The advantage of the nose inlet is that it eliminates boundary-layer troubles at the inlet entrance, but at the cost of loss of space for armament and radar. The other types provide ample stowage space in the nose, but generally require some method of boundary-layer control.

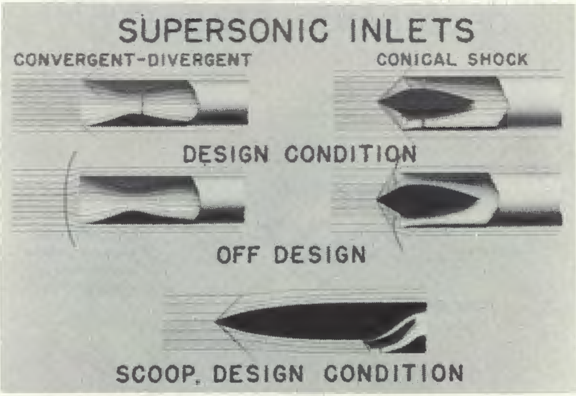
In the supersonic field, a major problem which is under laboratory attack continues to be that of discovering the most efficient way of slowing the air to low subsonic speeds by the time it reaches the engine's compressor (or in the case of the ramjet, the burner) regardless of the supersonic speed of the airplane. The higher the speed the more difficult becomes the problem of using efficiently the energy due to flight to force a maximum quantity of air into the engine.

Research has provided the designer with considerable basic information on the performance of supersonic inlets. Measurements have been made of drag, pressure recovery and flow rate on the convergent-divergent, conical-shock and scoop types.

Design elements that affect these characteristics are being studied in order that the designer can have all the information required in planning air inlets for any condition. Among these factors affecting the design are combustion, type of engine, altitude and inlet shape and location.

One important problem which has been encountered is that of flow fluctuations. This has been the subject of both theoretical and experimental activity; but much more knowledge of the basic phenomena governing such conditions remains to be acquired. The importance of the problem lies in the fact that these flow fluctuations cause a decrease in engine thrust and an increase in airplane drag.

The fluctuations also cause severe structural problems, particularly in the compressor blades of the engine, and make it extremely difficult to feed the fuel at the proper rate to the burners of a ram jet engine.

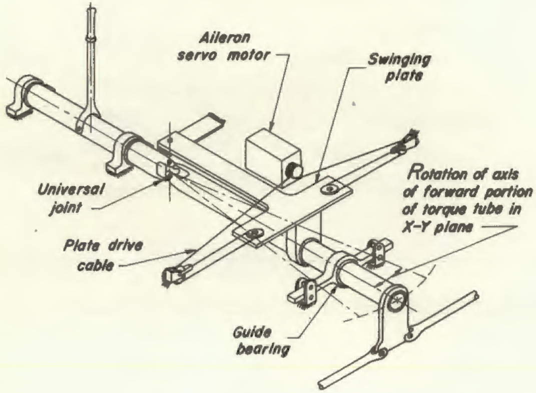


NACA-Langley - 7-3-50 - 3500

DYNAMIC STABILITY

The manner in which an airplane returns to steady flight after being disturbed, as when flying through rough air, is determined by its dynamic stability. In passenger airplanes, good dynamic stability is important for comfort. Combat airplanes must have good dynamic stability to provide steady aiming platforms for the armament. Missiles must have good dynamic stability to permit their being guided accurately to their targets.

CONTROL SYSTEM FOR STUDY OF DYNAMIC STABILITY



Present and future airplanes which will attain the high speeds contemplated are assuming new shapes and proportions. These new shapes and proportions introduce new stability problems. Also, the heavier wing loadings and higher operating altitudes have marked effects upon dynamic stability characteristics. To provide the information needed to assure good dynamic stability, research effort on the problem has been intensified.

The motions or oscillations of an aircraft about its intended flight path depend not only on the characteristics of the airplane itself but also upon the actions of its pilot. Consequently, the research effort on the subject includes evaluation of the human pilot's ability to control various motions as their frequency, their natural rate of increase or decrease, and the control effectiveness are altered. Special research tools have been devised to facilitate this evaluation.

Questions also arise about the degree of stability which is optimum for the pilot. This matter is being explored with an airplane that has been equipped with special automatic controls which give it the dynamic stability characteristics of a number of quite different hypothetical airplanes. The results from this unusual research technique are expected to tell the designer what stability characteristics he should seek to incorporate into his airplane.

Another goal of this broad research program is to provide the designer with basic information concerning the forces present on a wide variety of airplane wings, tails, fuselages, and these components in combination, while they undergo all types of oscillations. This information is being gathered both from theoretical studies and experiments.

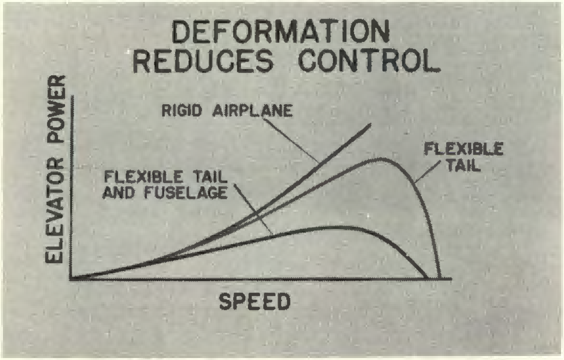
Theoretical research has shown that the disposition of the weight of an airplane has important effects upon its oscillatory motions. For example, it has been learned that if a swept-back wing has a higher angle of attack than the fuselage, serious "Dutch-roll" oscillations may occur during landing or takeoff.

Dynamic stability is a complex subject involving all the aerodynamic, weight, elastic, and control characteristics of the airplane. As speeds and altitudes increase, the problems of dynamic stability become more and more serious, demanding increased effort to find adequate solutions.

AIRPLANE USED IN DYNAMIC STABILITY STUDIES

AEROELASTICITY AND LOADS

With the trend toward higher aircraft speeds, particularly for military airplanes, the effects of structural deflection on the aerodynamic characteristics of the airplane are assuming new significance to the designer. These deflections are especially important factors in the design of certain missiles which have much higher operating speeds than airplanes.



The problems created by what is known as "aeroelastic effects," and the need of considering them in the design stage, are more readily realized through an examination of the troubles which can result.

For example, the twisting and bending resulting from the combination of the forces of the air and the forces due to the weight of the various parts of the airplane have been found to have a pronounced effect upon longitudinal stability and longitudinal and lateral control. These aeroelastic effects can thus cause instability, complete loss of control of the airplane, and even structural failure in flight.

In the case of missiles, structural deflection complicates the already difficult problems associated with control and guidance.

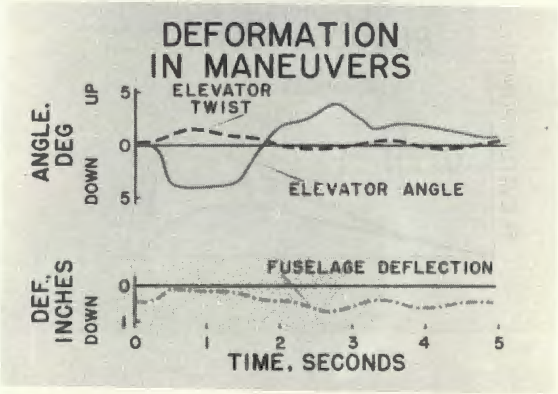
The problems arising from structural deflection are, of course, present for all aircraft. But at the lower maximum speeds attained in the past they have been relatively small. However, with the introduction of swept-back wings for transonic and supersonic flight, the need for intensified research has increased, because of the significant effect which wing bending has on the aerodynamic properties of swept wings.

With the straight wings commonly used in the past, bending of the wings does not alter the angles of attack of the different portions of the wing along the span. On the other hand, when a swept-back wing is bent upward, for example, the angles of attack of the wing sections are decreased more and more toward the tip.

An immediate problem is that of providing adequate lateral control through the speed range involved. And the problem of adequate longitudinal stability and control will become more serious as flight speeds increase and larger aircraft take to the air.

The NACA has fundamental research in progress to provide a better understanding of aeroelastic problems, to provide information on the distribution of air loads which cause the troublesome bending and twisting, to provide improved methods of structural design and to discover types of controls which do not lose too much effectiveness through distortion of the airplane.

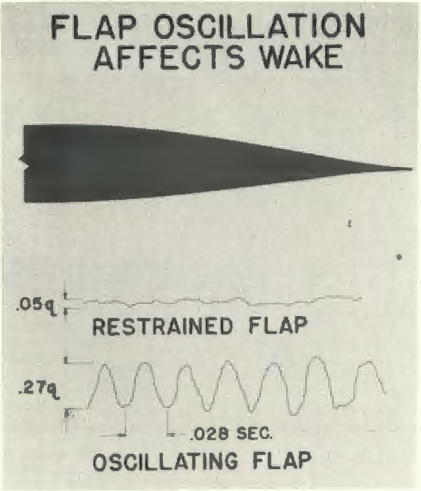
From the results of such research, designers should be able to assess the relative merits of the various controls and choose those most appropriate to their particular installation.



NACA-Langley - 7-3-50 - 3500

BUFFETING

When critical speeds or angles are exceeded the flow over airplane surfaces becomes rough. This rough flow buffets the surface where it originates, and may buffet other parts of the airplane. Under some circumstances buffeting shakes the airplane severely.



In the past, buffeting was generally considered to be a low-speed problem. However, at the high speeds where compressibility occurs, the buffeting may become so severe as to limit maneuverability and safe speed. With flight at transonic speeds almost commonplace, research on buffeting in this range has been intensified, both in flight and in wind tunnels.

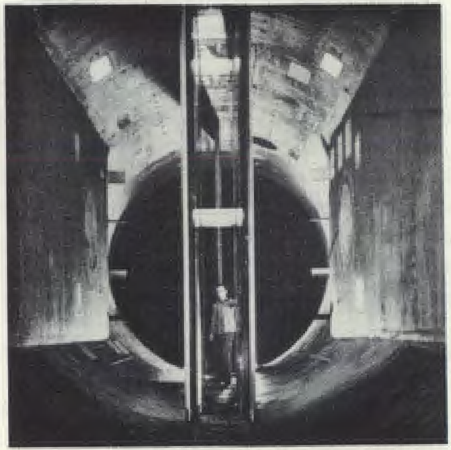
Flight experience with a number of airplanes indicates buffeting becomes perceptible soon after the flow over the wing begins to break down. From this point, buffeting intensity increases rapidly with increases either in speed or lift. In some of the research flights, the shaking was severe enough to throw the pilot back and forth against the seat and safety belt with a force of four and a half times his own weight.

It was found that sweep had the effect of alleviating buffeting intensity. In flight investigations with two swept wing aircraft, the increase in buffeting with increases in speed or lift was less severe than with conventional straight wing aircraft and the maneuverability of these airplanes was not severely limited by buffeting.

One important phase of wind-tunnel research on buffeting is measurement of the fluctuating pressures on the surfaces of wings and in their wakes, employing special pressure pick-ups and associated electronic equipment developed at the Ames Laboratory. Much work remains to be done, but it has been found that the pressure fluctuations in the wake behind a wing are about as large as the dynamic pressure in the undisturbed air stream, and that sizable fluctuations extended beyond the limits of the average wake. The frequencies of the pressure fluctuations appear to be largely random but are being studied further. It is evident that an airplane tail in the fluctuating region would be buffeted severely, and that major design changes would be required to move the tail completely from this fluctuation region.

From this continuing effort will come, it is hoped, knowledge of how airplanes can be designed so that buffeting will no longer limit their usefulness.

WING IN TUNNEL
FOR BUFFETING STUDY



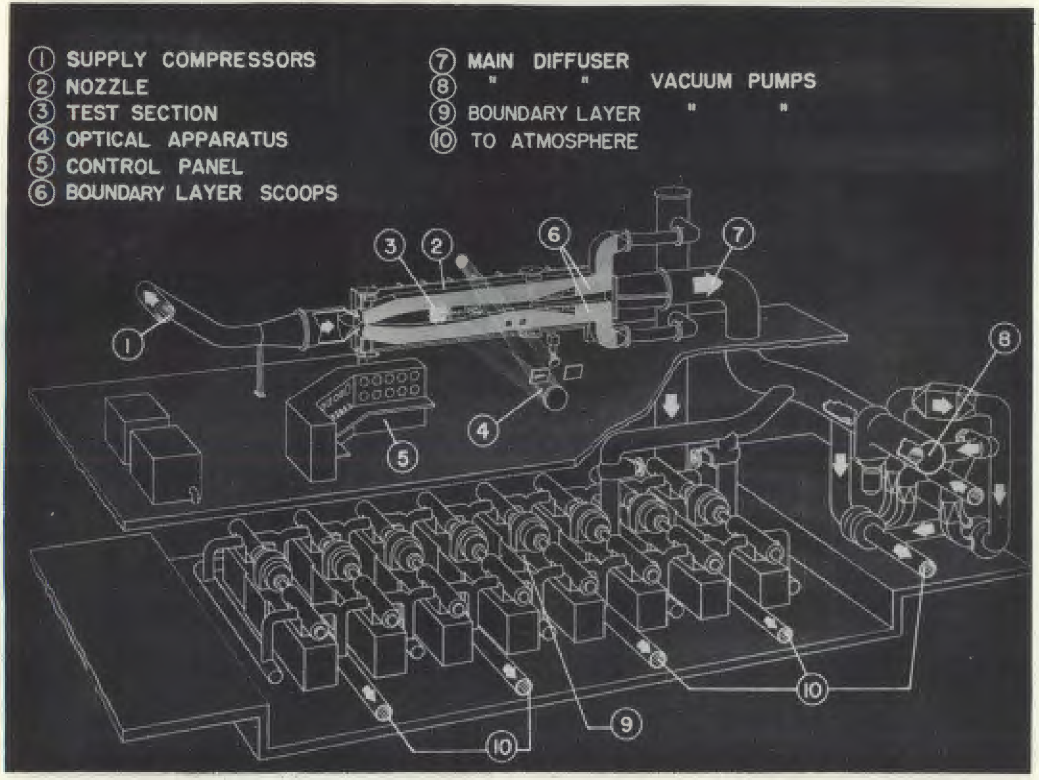
FASTER . . . AND STILL FASTER

A few years ago, with airplanes still flying at subsonic speeds, aeronautical research was already acquiring the basic knowledge which cleared the way for the present reality of flight faster than sound. Much of this knowledge was concerned with the fundamental properties of air flow and the flow changes that occur in the transition from subsonic to transonic and low supersonic speeds.

There have been spectacular advances in actual and potential flight speeds. Today there is a growing need for data at high and still higher supersonic speeds - - at Mach numbers of 5 and upwards - - in order that the designer may have the knowledge to guide him in creating the missiles of today and the airplanes of tomorrow.

Not only is it necessary to continue to acquire knowledge of flow changes about a body going from subsonic incompressible flow to transonic speeds--involving the alterations in streamline patterns, increases in boundary-layer thicknesses and the onset of shock and oscillating wake with increasing Mach number. Today the aerodynamicist is pressing forward into the high supersonic (hypersonic) ranges, studying such phenomena as the tendency of the bow shock and the succeeding flow field to merge along the surface of a body, and the manner in which viscous effects influence a larger portion of the flow field at higher Mach numbers. One major conclusion is that viscosity--always difficult to handle theoretically--will have a more pronounced influence on the efficiency of flight in the high supersonic range than at low supersonic speeds.

To accomplish this study of air flow at Mach numbers of 5 and above, the NACA, at its Ames, Langley and Lewis Laboratories, and other research groups have had to develop special equipment. Two new wind tunnels at the Ames Laboratory are designed for such research. They are described on succeeding pages.



THE 10-BY 14-INCH SUPERSONIC WIND TUNNEL

10 - BY 14 - INCH SUPERSONIC WIND TUNNEL

One of the new research tools developed for use in intensified study of aerodynamic problems at Mach numbers of 5 and above is the 10- by 14-inch supersonic wind tunnel at the Ames Laboratory. It is of closed-throat, nonreturn, continuous-flow design, and is capable of producing the wide range of air-stream Mach numbers from 2.75 to more than 7. This is roughly equivalent to sea level air speeds from 2000 to 5000 mph.

Similar research equipment to facilitate the study of air flow at hypersonic velocities has been developed at the Langley and Lewis Laboratories and at other research organizations. Perhaps the greatest obstacles to the progress of hypersonic research are the difficulties encountered in providing the high compression ratios required for generation of high Mach numbers, and in providing instrumentation to cover the broad ranges of temperature, pressure, density, etc., encountered in hypersonic flow.

To use a conventional Laval nozzle followed by a conventional expanding diffuser would have required compression ratios as high as 200:1 to obtain flows at a Mach number of 7. With such a nozzle arrangement, use of the available supply pressure of only 6 atmospheres, as was contemplated, would have required exit pressures of less than 0.03 atmosphere. This low a pressure would have required very bulky and expensive vacuum equipment.

Most of the pressure required is used to overcome the loss in slowing down the air downstream of the test section. The solution was to use a diffuser which first contracts and then expands. By this method the flow velocity is smoothly reduced. This reduces the required compression ratio. At the same time, the allowable exit pressure is increased.

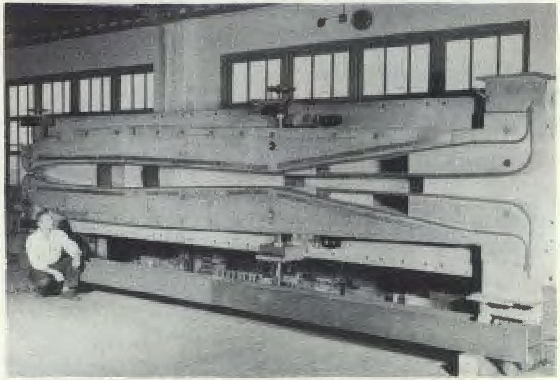
Jacks are used to position the nozzle blocks and thus control the tunnel air speed. Boundary-layer scoops located just downstream of the diffuser throat stabilize the flow out of the diffuser and consequently improve its efficiency. With this design, the compression ratio required for flow at Mach number 7 is only about 30:1 compared to the estimated 200:1 for a tunnel incorporating a conventional diffuser.

High-pressure air for the tunnel is supplied by centrifugal compressors connected to coolers and a silica-gel dryer. Air at the nozzle entrance has a maximum total pressure of 6 atmospheres, a temperature of about 100° F and an absolute humidity of 0.0001 pound of water per pound of air.

The model support and force measuring equipment are similar to those used in other supersonic wind tunnels. The models are supported from the rear on a sting, which in turn is supported by a strut passing through the sidewalls. The forces and moments acting on the model are measured by a conventional strain-gage balance system.

At a Mach number of 7, the test-section pressure falls to one-thousandth of an atmosphere. This is equivalent to that found at an altitude of 160,000 feet. Eighty special low-pressure gages are used to measure these pressures, and accuracy is held to approximately one percent. A highly sensitive optical apparatus is used to visualize changes in air flow.

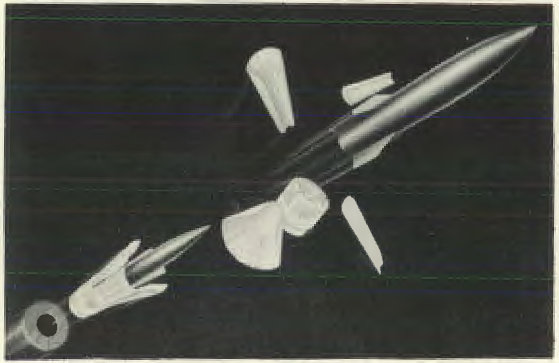
10-BY 14-INCH TUNNEL NOZZLE



SUPERSONIC FREE - FLIGHT WIND TUNNEL

Another of the new research facilities at the Ames Laboratory is the supersonic free-flight wind tunnel, in which models are fired from guns into the face of a moving air stream. Currently being used to study the characteristics of missile shapes, this wind tunnel already has been operated at 8 times the speed of sound and has a potential of 15 times sonic speed, equivalent to about 11,000 mph at sea level.

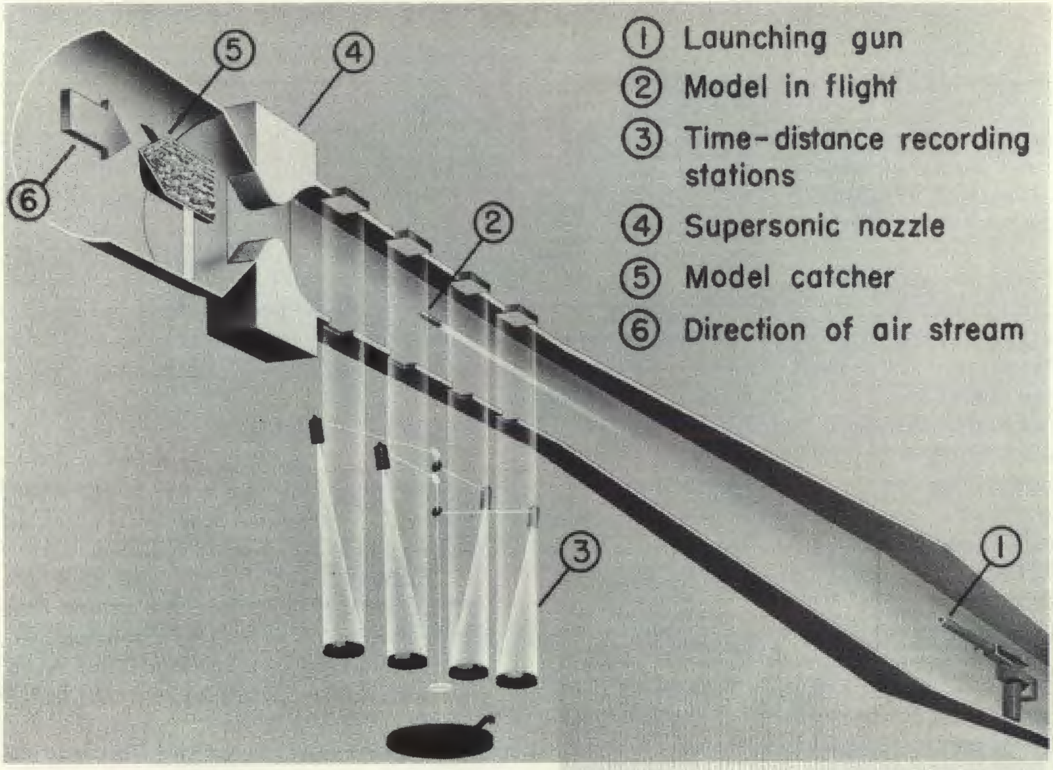
MODEL AND SABOT SEPARATION



These speeds are attained by firing the models at high velocities into an air stream moving in the opposite direction at two to three times the speed of sound. Launching velocities are changed by varying the powder charges in the guns. Test barrels of a number of different sizes are available, from .22 caliber to 3-inch.

While the models used are small, the relatively high density of the air in the test section makes it possible to obtain research results comparable to those elsewhere with much larger models. For example, a 6-inch model tested in the free-flight wind tunnel at a Mach number of 7 would provide data corresponding to the behavior of a 50-foot missile - - as large as the V-2 rocket - - flying at the same Mach number at an altitude of 100,000 feet. By contrast, to get the same results in a conventional wind tunnel would require a model over 10 feet long.

The tunnel is of the "blowdown" type, the air being supplied at a maximum pressure



THE SUPERSONIC FREE-FLIGHT WIND TUNNEL

NACA-Langley - 7-3-50 - 3500

of six atmospheres. Passing through a settling chamber, the air flows through the supersonic nozzle into the test section, which is 18 feet long, 2 feet deep, and 1 foot wide. Past the test section, the air enters the diffuser and then is released.

The launching gun is located in the diffuser, its muzzle pointing into the air stream. In the gun barrel, the model is housed in a small carrier, or "sabot," which serves as a piston and keeps the model properly alined. As the model leaves the muzzle after firing, the sabot separates and falls away, leaving the model free to fly by itself through the test section. At the upstream end of the tunnel, the model is caught in a steel cylinder filled with cotton waste, backed by wood and steel.

Techniques which parallel those used in aero-ballistic firing ranges are employed to determine the aerodynamic characteristics of models in the free-flight wind tunnel. To obtain data on drag, for example, the time-distance history of a model is made by a four-station shadowgraph and chronograph system. As the model flies through the test section, each station in turn takes a shadowgraph of the model and a distance scale, and a chronograph recording.

Extreme accuracy is required. In some cases distance measurements are within a few thousandths of an inch, and time measurements to one tenth of a micro-second. This time measurement is so brief that light travels only 100 feet in its duration.

Measurements of drag have already been obtained in the wind tunnel and work is being directed toward measurement of lift and moment, the latter data being secured by disturbing the model on launching, and observing the resulting motion in flight. This behavior can be recorded either by using the shadowgraph equipment or a high-speed motion picture camera.


NACA