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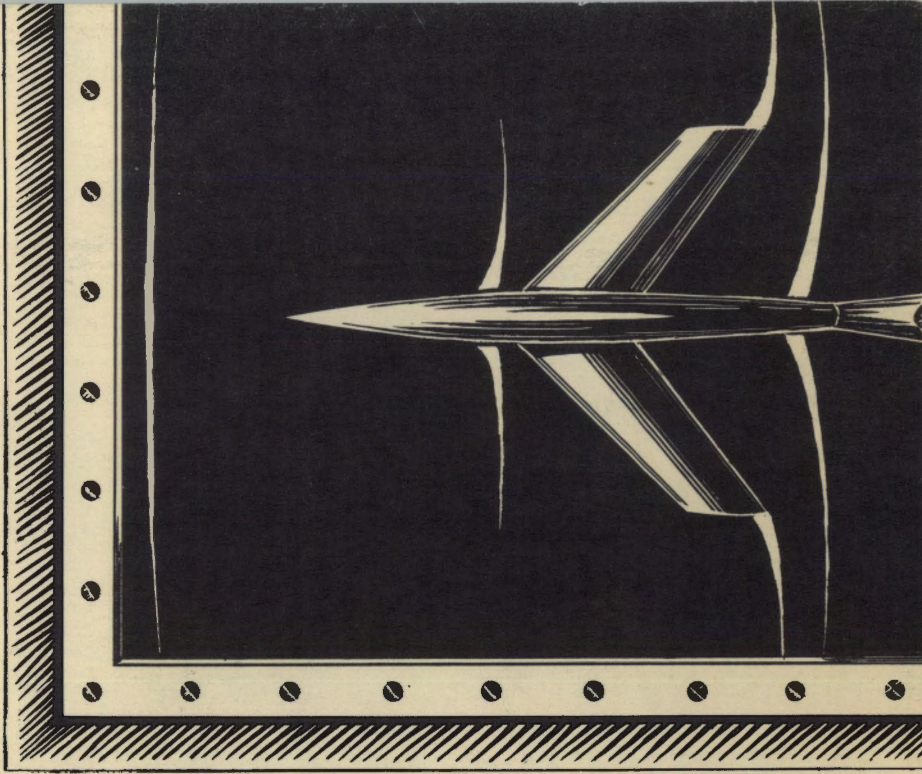


NACA

1951 INSPECTION

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WELCOME

On behalf of the National Advisory Committee for Aeronautics and its supporting staff, it is my privilege to welcome you to the Langley Aeronautical Laboratory and its 1951 Inspection.

This year, when civilization lives in the shadow of a continuing crisis, the hope that our way of life may survive depends increasingly upon the strength and quality of American air power. In the international race for technological superiority, it is essential that our new military aircraft exploit extreme frontiers of human knowledge. These frontiers are not fixed; they are constantly expanded by the pressure of discoveries and scientific developments throughout the world.

It is the purpose of this Inspection to note trends and new techniques in aeronautical research in the United States. May your stay with us be both profitable and enjoyable.

J C Hunsaker

Chairman

National Advisory Committee for Aeronautics

Transonic information
.... for tomorrow's airplanes

Aircraft engines powerful enough to enable faster-than-sound flight by tactical military airplanes have been successfully developed, and now are being put into production. As a result, the need has become immediate for a mass of detail information covering aerodynamic characteristics in both the transonic and low supersonic ranges for use in the design of tomorrow's airplanes.

Substantial progress has been made in the exploration of air flow behavior in the transonic and low supersonic speed ranges. What the aeronautical research scientists have accomplished already brings into sharper focus the great amount of work yet to be done. Tomorrow's airplanes will be supersonic, it is conceded. They will also be transonic, because during every flight to faster-than-sound speeds, the airplane must pass twice through the transonic region, where air flow is a mixture, part slower than the speed of sound, part faster.

This need for the mass of aerodynamic information about the transonic area that can be used for design of tomorrow's airplanes and missiles is, of course, only one of the many demands being made upon the talents and resources of the aeronautical researcher. It is, however, a requirement which may be overriding in its urgency.

The problems presented by transonic flight were first anticipated in the late thirties, when fighter airplanes in dives occasionally approached speeds where the laws of subsonic flow were valid no longer. Even earlier, the vexing problem of "compressibility" had been encountered when propeller tip speeds approached the velocity of sound, and had been circumvented by slowing the propellers.

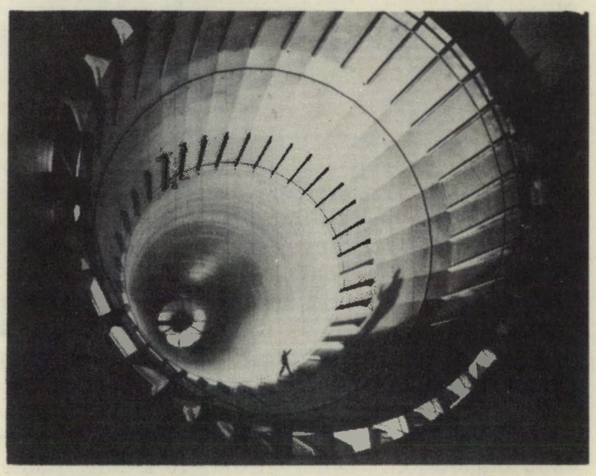
Two conditions retarded research exploration into the transonic area. Development of theory covering compressible flow at such speeds was, and continues to be, slow and difficult. In addition, the aeronautical researcher's principal tool, the wind tunnel, was found to have crippling limitations in the transonic area, especially near the speed of sound.

In World War II the insatiable demand for greater speed gave new impetus to the search for information about compressible flow in the high subsonic and transonic speed areas. In 1940, a first step was taken to develop alternate research techniques with which to explore the problem. NACA pilots dove a Navy fighter to supercritical speeds to establish the character of air flow under such free-flight conditions. This information was valuable also in studying the choking phenomena experienced in wind tunnels at supercritical speeds.

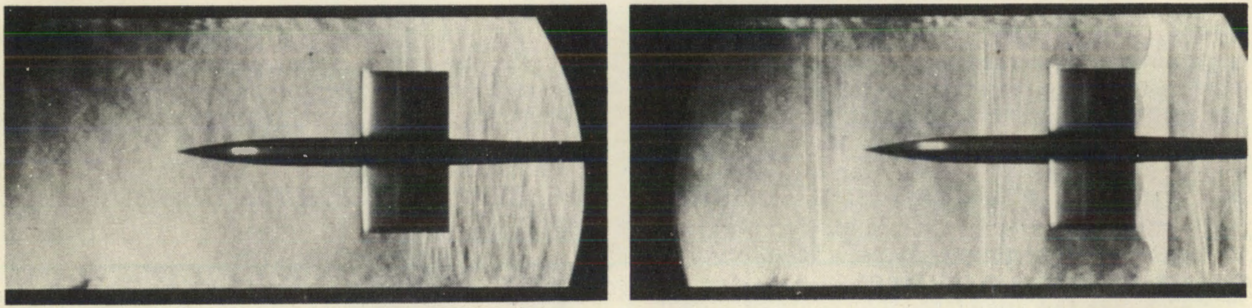
Although the speed requirements of World War II placed a premium on such aerodynamic information, the global conflict paradoxically delayed the research attack on the problem. This was because of the policy decision made at the highest level of government to fight the war with the best of the available aircraft designs, and to concentrate virtually all laboratory effort upon improvement of those types.

Even so, aerodynamic scientists continued to ponder the transonic problem, and in 1944 with victory in sight, several promising approaches were begun. One of these, first proposed earlier, involved dropping bodies from great altitudes. Radar and radio telemetering increased the effectiveness of this technique.

By placing a model, usually a wing, in the supersonic flow region that exists on an airplane wing being flown at supercritical but subsonic speeds, it was possible to study the problem from another angle. Similar in approach was the "bump" technique, in which the model



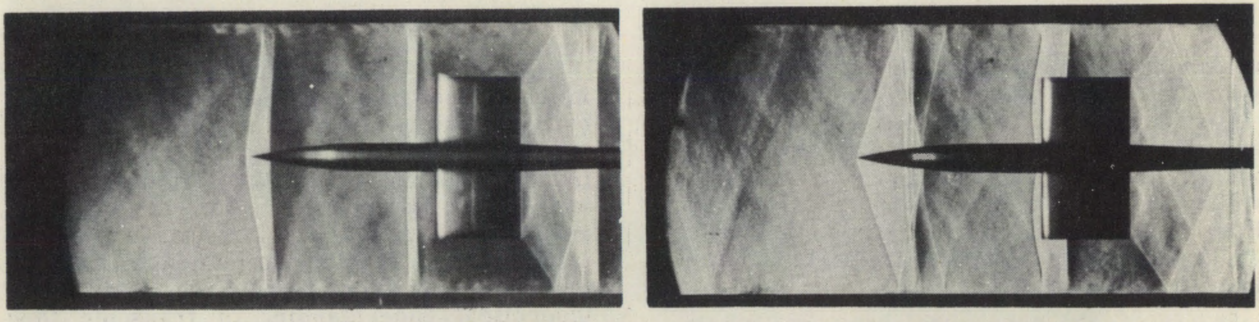
Cooling vents of 16-foot transonic tunnel



Four schlieren photos of models in transonic tunnel

to be studied is positioned in the region of accelerated flow on a bump located on a wind-tunnel floor. These methods were useful in providing trend-type information, but their value was limited by several factors, including the matter of small-scale. In 1945, an annular-type transonic tunnel was used in the study of transonic flow around airfoil models of 4-inch span. This information was valuable from an exploratory standpoint, but serious questions were raised concerning the quality of the results. This tunnel was described at the Langley 1949 Inspection. Other efforts to modify tunnel design to enable gathering of reliable information about flow in the transonic speed range suggested use of half-open and open throat tunnels, but here too, flow disturbances were found to exist.

There were two approaches to the problem which have been productive of much valuable information, and are likely to continue to be used as proven means of providing a considerable amount and variety of aerodynamic information concerning the transonic area. One uses rocket-propelled models launched from the ground. The second uses full-scale, specially-designed, high-speed airplanes. Each of these techniques is outlined in some detail elsewhere in this booklet.



Left to right, photos at Mach numbers of 0.98, 1.03, 1.06, and 1.10

Meantime, work was being continued to narrow the speed range in which the closed-throat wind tunnel was choked. By designing new-type model supports, new-type nozzles, entrance cones and throats, considerable success along this line was achieved. It became apparent, however, that even with development of closed-throat tunnel design to the ultimate, there would still remain a small but important choked-out region.

....and now, transonic tunnels

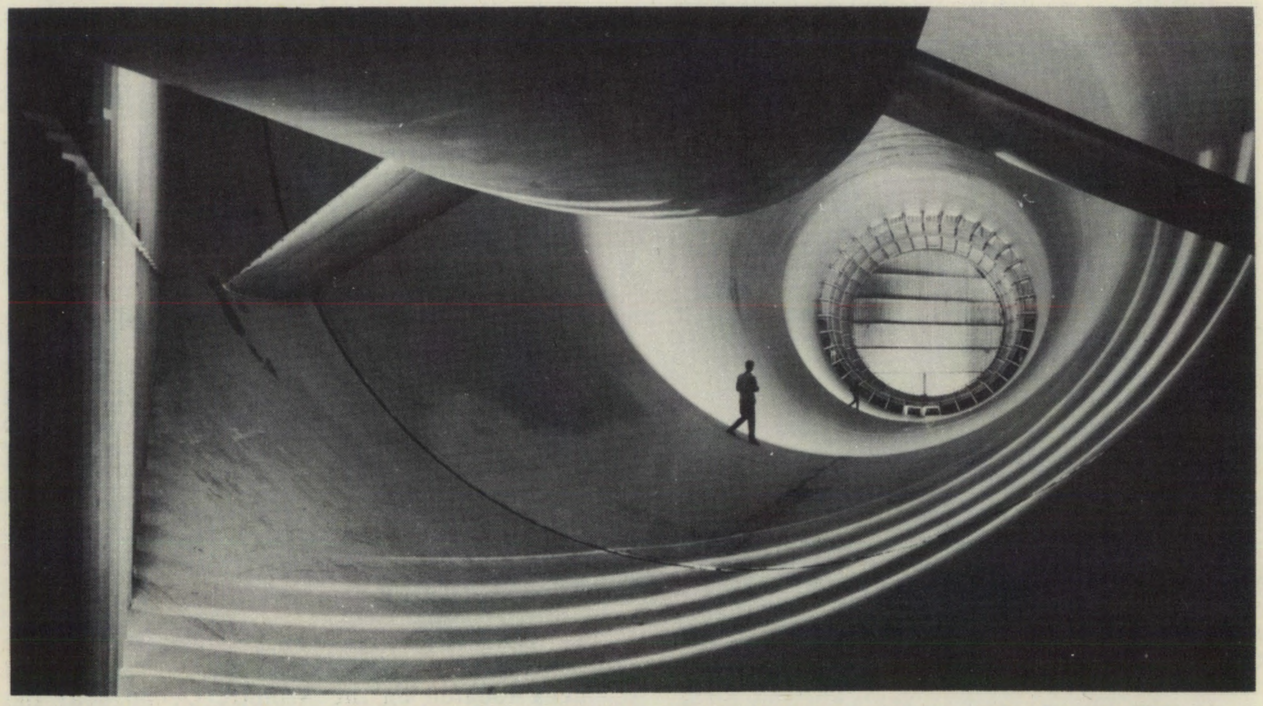
The importance of a reliable laboratory method for transonic experimentation was not decreased by the progress made in developing alternate techniques; rather, it was increased as information from these other methods focused attention more sharply on fundamental problems of fluid mechanics. In order to complete theoretical and mathematical calculation of transonic air flow, there was still needed the opportunity to experiment with standardized equipment, using nonexpendable models under conditions so closely controlled as to permit detailed measurements of local pressures as well as the application of optical means for visualization and measurement of the flows.

To this end very great effort was placed upon development of a new concept of wind tunnel, which would permit gathering such precise information under laboratory conditions. The effort has been successful. Already, the NACA has placed in operation two large tunnels, as well as smaller ones, which are capable of providing accurate aerodynamic information about flow conditions in the full transonic range. Transonic test sections now are being installed in other large tunnels.

Because of world conditions, security requirements do not permit discussion of the "how" of this new tunnel concept. Consideration may be given, however, to what uses the aeronautical scientists are putting these new tunnels. The largest of the transonic wind tunnels currently completed is the 16-foot tunnel at the Langley Laboratory. The 8-foot transonic tunnel at the Langley Laboratory was the first of these new, large research tools to be completed and placed in operation. Throughout the entire transonic speed range, air flow through the test section is as accurate as can be maintained in modern tunnels designed for use on aerodynamic problems in other speed ranges. Tunnel airspeed can be held precisely or varied smoothly through a Mach number of 1.

One of the models which has been installed in the 16-foot transonic tunnel for correlation purposes has been a quarter-scale X-1, so instrumented that as many as 200 pressure distribution readings from the loading over the wing can be recorded simultaneously. Using models of this size, it may be possible to gather sufficient experimental information for analysis to permit development of mathematical and theoretical understanding of transonic flow phenomena.

The drive for the 16-foot transonic tunnel consists of two 30,000-hp motors connected by 60-foot shafts to the fans. These counter-rotating fans have an aerodynamic efficiency of 95 percent. Rigid connection between the drive end and the remainder of the tunnel was avoided by using rubber seals, thus preventing vibrations generated in the drive end from being transmitted to other parts of the tunnel. At both the inlet and exhaust openings of the air-exchange tower acoustical baffles were installed. Noise level surveys show that the tunnel with its 60,000-hp today is more quiet than when it was powered with 16,000 hp.



View inside 16-foot transonic tunnel, facing turning vanes and air vents for cooling

Rocket-powered delta-wing model

In addition to aerodynamic study of airplane and missile models in the transonic speed range, the tunnel will be used in the investigation of high-speed propeller characteristics. A 6000-hp propeller dynamometer can be installed in the test section of the tunnel, permitting testing of high-speed and supersonic-type propellers at large scale up to low supersonic speeds. Both aerodynamic and vibration characteristics of such propellers will be surveyed.

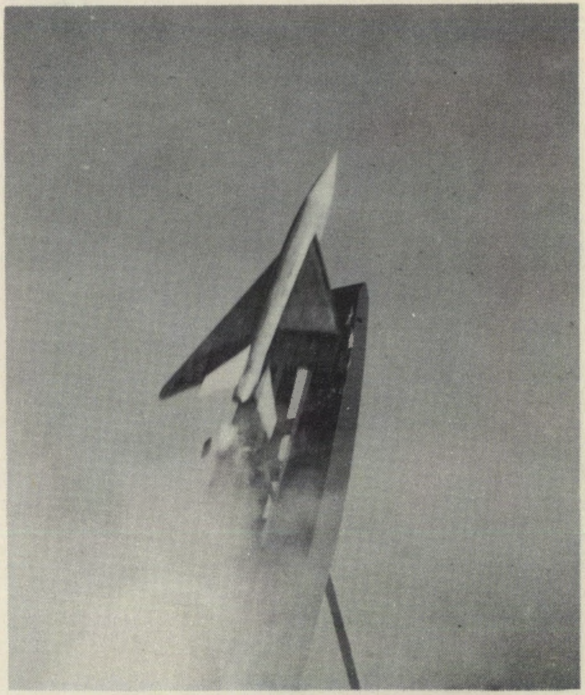
Rocket models supply data....

For the past 6 years extensive use of rocket-propelled free-flight models launched from the ground has enabled the research scientist to gather quickly large amounts of varied information about aerodynamic behavior in the transonic and supersonic ranges. For some time these rocket model techniques have been a principal source of large-scale transonic and supersonic information.

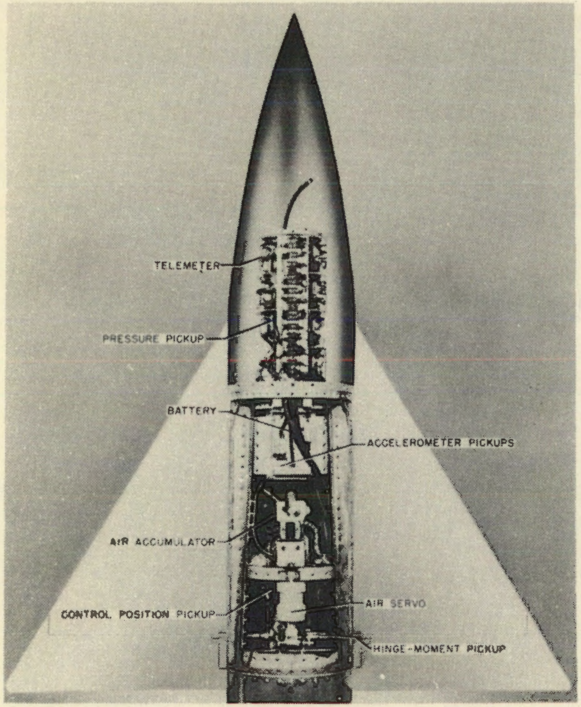
The firing of these rocket-propelled models is done at Wallops Island, a sparsely settled area located on the Atlantic Ocean near the Maryland-Virginia state line. The models to be tested are instrumented in the Langley Laboratory and then taken to the Wallops Island firing area where both radar tracking and telemeter recording are used to gather information during flight.

The models themselves must be light and strong in order to attain high speeds with the rocket power available and to withstand the high aerodynamic loads and accelerations experienced in the relatively dense air in which they are flown. The instruments installed in these models must be compact in order to fit in the limited space available and must be capable of high precision and highly reliable even when subjected to large acceleration.

Solid propellant-type rockets are used to obtain the speeds required. The models usually contain an internal rocket which is ignited after a booster rocket has brought the model part way up to speed. The largest rocket in current use produces about 6000 pounds of thrust and can accelerate a 130-pound model to a Mach number of 1.5 in 3 seconds. The booster rocket must be designed to separate from the model under tests after it is fired without disturbing the model.



Model at moment of launching



Cutaway drawing of research model

The research models vary in complexity depending on the type of test being made. Where only drag or control effectiveness are being studied, simple models can be used with little or no instrumentation. For drag studies, the basic information is obtained from the ground-based radar equipment alone and with no instrumentation in the model. For studies of control effectiveness, the controls are preset and a small radio transmits the rate of roll of the model to the ground. The rate of roll is, of course, a measure of control effectiveness.

In the more complicated studies, the model is equipped with a transmitter, various instrument pick-ups, and a mechanism for deflecting the elevator in a programmed pattern of flight. Such a model is accelerated to supersonic speeds by a booster rocket and following the separation of the booster rocket the elevator movements cause the model to perform various maneuvers throughout the angle-of-attack range at various Mach numbers. The recorded reactions of such a model are analyzed to obtain data on lift, drag, static and dynamic stability, control forces, and control effectiveness. The variation of these quantities with angle of attack and control setting is determined over the entire speed range in a single flight.

The design of tactical and research airplanes and guided missiles, now in use, reflects aerodynamic data obtained through the use of these models. For some time the rocket model techniques have been principal sources of large-scale transonic data. As the transonic wind tunnels come into full operation, it will be possible to relieve the rocket model technique of much detail work in the transonic range and permit greater concentration of effort on dynamic stability, measurements on flutter research, and on tests at higher Mach numbers where information at large scale is greatly needed.

Special airplanes aid research

Despite continued development of the accuracy and versatility of laboratory techniques, ultimate verification of information gained from the use of such research tools can be obtained only by actual flight-proving of the data in full-scale airplanes. In addition, there are problems related to loads, dynamics, and operation, which can best be attacked by flight tests with


Ram-jet preflight test setup

full-scale airplanes. Some of these problems can be isolated for study in flight.

In the study of transonic problems, specially designed and instrumented airplanes provide valuable information. The research airplane program, in which the Air Force, the Navy, the aviation industry, and the NACA are participating, continues to be productive of good results. This year it may be accelerated with the availability of additional research airplanes.

To assure maximum success of the program it was necessary to remove all possible limitations on the use of the airplanes for the purposes required. One important step in this direction was development by the military services and the industry of the technique of air launching the heavily loaded research airplane from a mother ship flying at high altitude over the virtually unlimited landing area at Muroc Dry Lake, Cal. In this manner, some of the limitations associated with take-off, climb, and landing were removed. This technique, together with use of rocket engines, which suffer no decrease of thrust at high altitude, makes it possible to reach transonic or supersonic speeds in level or climbing flight at high altitude, and to slow down to safe speeds if dangerous control characteristics develop.

Another advantage of such high altitude flight is that it eliminates the danger of overloading the structure in case the research airplane gets out of control. Likewise, the difficulty of large control forces is avoided. One need which this flight work has demonstrated is for all-moving horizontal-tail surfaces to cope with marked trim changes experienced during flight at transonic speed.

Satisfactory operation of an all-moving tail during transonic flight requires a system capable of positioning precisely the control surfaces. Usually a power boost system for the controls is needed because of the very high aerodynamic forces involved, and the NACA is investigating the general design requirements of such booster systems, especially with respect to the handling qualities of airplanes. An airplane, equipped with a control boost and simulated feel system, is being used in flight studies of the several difficult problems involved. Already, this work has shown the need for reducing friction existing in the slide valves of power boost systems.

Propeller research dynamometer

Because of the high speeds which tomorrow's tactical airplanes may be expected to attain, attention is being given to the problems of automatic flight controls. Such automatic systems, responsive either to the wishes of the pilot or a ground operator, can be studied effectively only by actual flight research.

Supersonic speed problems . . . .

Information about aerodynamic behavior in the supersonic range is a matter of immediate need both for missiles and high-speed airplanes, and the NACA's large, faster-than-sound tunnels are being used intensively to provide such data. The Langley 4 × 4-foot supersonic pressure tunnel, with an operating Mach number range from 1.2 to 2.2 and variable density to permit attainment of large-scale results, is particularly adapted for research on both supersonic airplane and supersonic missile shapes.

One phase of the work done in this tunnel utilizes complete missile models in the study of wing-body interference, downwash, inlet characteristics, stability factors, and other basic problems of current interest. Instrumentation, connected to outside-the-tunnel recording apparatus through the sting-type model mount, includes a six-component balance. The control surfaces of the model can be controlled electrically, and mass flow through the inlets can be varied to simulate full-scale operation under varying conditions.

A second phase of this experimental research which also is closely connected with missile work involves study of the effects of scale on the skin-friction drag characteristics. The desirability of maintaining laminar boundary layers as a means of reducing drag has long been recognized. The attainment of laminar layers at subsonic speeds has been found impracticable in the majority of cases; however, research results indicate that conditions more favorable to the maintenance of laminar flows may exist at supersonic speeds.

If means can be developed for maintaining a laminar boundary layer for the high-altitude and high-speed flight conditions of a typical missile, the skin-friction drag could be reduced to about one fourth of the values currently existing for turbulent boundary layers. The overall drag would be reduced by about one half.

Aerodynamic heating, at the high Mach numbers at which tomorrow's missiles will be flying, may become of equal or even greater importance than drag. Here again, delay of the flow transition from laminar to turbulent offers an opportunity to extend greatly both the speed and duration of flight which now are limited severely by allowable structural temperatures.

A missile initially at atmospheric temperature absorbs heat from the hot boundary layer and rises in temperature. By attaining laminar flow the amount of heat absorption would be lessened greatly. Another important factor in aerodynamic heating is atmospheric density. At 100,000 feet, for example, the atmospheric temperature is the same as at 50,000 feet, but the density is much less, which reduces greatly aerodynamic heating. If it proves feasible to combine the advantages of laminar flow and low atmospheric density, the temperature limit of ordinary materials used in missile construction would not be exceeded, even on long flights at high Mach numbers.

Probing the hypersonic range

In certain types of long-range missiles, most effective performance is obtained by operation at high altitudes and Mach numbers in the range of 5 to 10. Exploratory research at even higher Mach numbers is being conducted in small ballistic-type facilities at both the Ames and Langley Laboratories.

11-inch hypersonic tunnel

At hypersonic speeds, it has been determined, shock waves are swept back close to the model, and the boundary layer becomes thick. Whereas at moderate angles of attack at subsonic speeds lift is derived largely from the upper surface of a wing, at hypersonic speeds the largest part of the lift is derived from the lower surface. At the same time, the influence of the three-dimensional tip flows becomes smaller until at hypersonic speeds this influence is so small that use of wings with extremely low aspect ratio appears to be practical. Even though lift-drag ratios are low, they are sufficient to permit horizontal flight at high altitude at hypersonic speeds. At these speeds more of the load can be carried by the lift derived from the body, as distinguished from the lift coming from the wings.

The boundary layer grows at a much faster rate at hypersonic than at lower speeds. The thick boundary layer changes the surface, thus altering the effective wing or body shape. This problem is of considerable importance at Mach numbers of 7 on slender shapes suitable for missile use, and will assume even greater importance as the Mach number is increased still further.

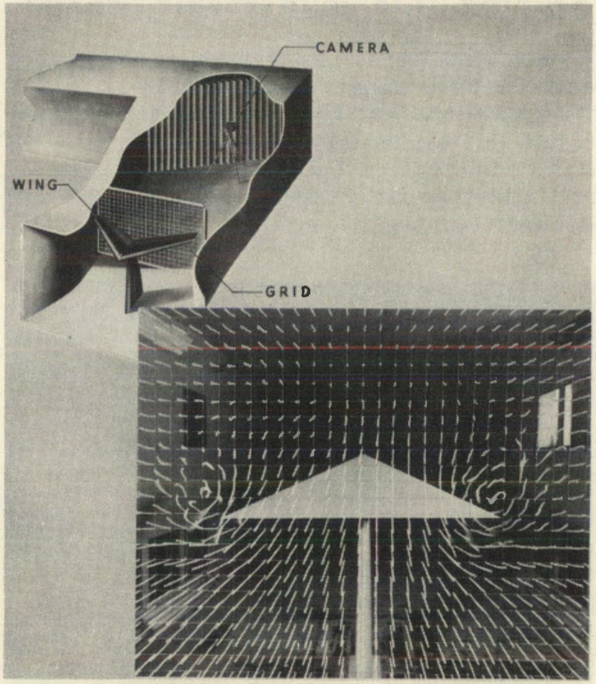
NACA-Langley - 5-17-51 - 3500

Wing-wake problems studied

The flight behavior of airplanes, particularly at high angles of attack, is complicated by the interaction of the various parts. A tail assembly located behind the wing, for example, is affected by the wing wake. For wings with high aspect ratios, the effect of the wing wake on the tail generally does not present a serious problem. When a tail assembly is used behind a low-aspect-ratio wing, however, the problem is more serious, because regions of highly disturbed air flow lie close to the tail. This condition effects not only the static stability of the airplane, but also the damping of oscillatory motion.

To aid in studying the air flow behind a wing, a tuft grid setup has been developed for use in one of the Langley 7 × 10-foot tunnels. Consisting of a steel framework on which fine wires are strung with equal spacing both vertically and horizontally, the grid has wool tufts attached to the intersections of the wires.

Cameras, either still or motion, are located far downstream in the tunnel to take pictures of the tufts in a vertical plane. In regions of un-



Wing-wake problems studied

disturbed flow, the tufts show in the pictures as small dots. In regions of downwash and sidewash, the flow pattern is clearly shown by the tufts.

Results of research conducted during the past 5 years in the NACA's full-scale tunnels at the Langley and Ames Laboratories on a broad range of high-speed, sweptback wing shapes now make possible reasonable prediction of the low-speed characteristics of such wings. With regard to the flow phenomena, the stalling of such wings may be grouped in two predominant types: those with round-nose airfoils and those with sharp-nose airfoils. The type of flow has an important effect on the pitching-moment characteristics of a wing.

Airfoil nose radius and sweep angle of the wings were found to influence importantly the maximum lift coefficient. Longitudinal instability due to tip stalling is a fundamental problem for a large number of swept wings. Various methods of achieving stability by controlling flow have been studied and data gathered to aid in the selection and design of devices to obtain stability.

Inlets for supersonic airplanes

As in the design of other airplane parts for efficient operation in the transonic speed range, serious new problems are introduced respecting the air inlet of a power plant for this speed range. Most important of these for the inlet are drag and pressure recovery.

Research has shown that an open-nose inlet can be designed for high subsonic speeds which will be useful through the transonic range to low supersonic speeds. At higher speeds, however, a strong detached shock develops ahead of the relatively blunt nose of the inlet, causing excessive loss in available engine pressure as well as excessive drag.

For flight at higher speeds, air inlets clearly must be designed especially for supersonic flow, and great emphasis is being placed on inlet research covering such speed ranges, with new problems present as well as the older ones. One of the most important problems is that of matching the area of the inlet with the air required by the engine through the supersonic range. At subsonic speeds, inlet size is not critical. An inlet can be designed to operate through a wide range of air flow rates without harmful effects.

At supersonic speeds, however, because of its shock pattern, an inlet may be too small to supply the air required by the engine at speeds other than in the relatively narrow range for which it was specifically designed. Decreased thrust and increased drag at off-design speeds may be the result. If, on the other hand, the inlet is too large at off-design speeds, external shocks are produced ahead of the inlet which increase drag. In either situation, the result is a serious loss in effective engine thrust.

One solution to the problem would be the development of an inlet which could be varied in opening to provide for the proper amount of air for the desired operating speed, thereby avoiding severe penalties in drag or thrust. Under some conditions, a movable-cone inlet offers promise, and other possible solutions are being studied.

Because of the intended use for an airplane, it may be impracticable to position the air inlet in the fuselage nose, where, aerodynamically, the design problems are simplest. Such nose space may be pre-empted by armament, electronic equipment, or photographic apparatus. The problem then becomes one of designing an efficient air inlet which will be located elsewhere. Inlets located on the side of the fuselage, in the wing root, or in the wing, or attached to the fuselage as scoops, are options.

One promising solution is the side inlet, to the study of which considerable research effort has been devoted. Utilizing the rather complete information which the NACA has acquired on supersonic nose inlet design, the approach has been to split the nose inlet for mounting in the sides of the fuselage. Unless a by-pass is provided so that a sufficient quantity of boundary-layer air can be removed, the ram pressure recovery losses are great. With such a by-pass, however, ram recovery can be restored to a value nearly as high as that for the nose inlet.

New instruments for research

In the study of such problems as buffeting and flutter, instruments suitable for investigation of the phenomena under scrutiny must be developed. Until recently, the pressure recording instruments used in buffeting research have been mechanical in action. The pressure to be measured at some point, as on the wing, has been conducted through a long tube to a measuring instrument. Especially when there were rapid changes in pressure, the lag resulting from the long tube made accurate recordings impossible.

One solution has been development of a 30-cell pressure-distribution manometer, small enough to be placed in the wing of a fighter-type airplane. The manometer presents data as tiny spots of light, so arranged as to plot a conventional pressure distribution diagram which can be photographed by a motion-picture camera. This instrument has been used to obtain a visual representation of the way loads at a wing section of a fighter-type airplane were varying in flight and to determine the regions of oscillating pressures.

When buffeting is investigated using small models in a wind tunnel, the frequencies involved are very high, which requires the development of special electrical pressure gages for dynamic studies. These gages are particularly adapted to the measurement of oscillating and unsteady pressures both in flight and in wind-tunnel research. Another instrument now being used is an electrical pressure integrator which can condense as many as 40 pressures into a single data channel. Electrical pressure gages also are being used in some flutter studies, while in other investigations strain gages are mounted on the wing beams.

Recent design trends, particularly for very large aircraft, have indicated the need for flutter and vibration studies using completely scaled dynamic models. Such complex models, if properly designed, are capable of producing much useful information. They may be used to indicate good or bad effects of relatively minor changes in prototype design, a particularly desirable feature if the prototype is an unconventional type. They may indicate the significance of the various assumptions made in vibration analyses. They may be used to solve certain complex vibration problems which are difficult to formulate, let alone solve. Actually, such models are effective analog computing machines.

By the use of many techniques and by attacking such problems from many sides, it is hoped reliable experimental data can be compiled which will be useful in predicting buffeting and flutter more accurately, and in the alleviation or elimination of such troubles.

Aircraft loads investigated

Aircraft loads research is being conducted by means of theoretical investigations, wind-tunnel measurements of loads on airplane models, and flight measurement of loads on models as well as on full-scale airplanes. Still another method involves use of a machine which makes fatigue tests on full-scale aircraft structures.

In structures research on fatigue, mentioned elsewhere, the laboratory methods used have produced stresses which were uniform in size and were applied with regularity. In flight, however, stresses in the airplane's structure are imposed by gusts which are variable both in intensity and occurrence. To simulate such fatigue-inducing stresses in the laboratory, a testing machine has been developed which enables a study of full-scale aircraft structures.

First, the machine applies a steady load, corresponding to that imposed on an airplane in steady flight through smooth air. Then, oscillating loads of 16 different amplitudes are superimposed on the steady load. The sequence of the amplitudes and the number of oscillations at each amplitude are established in advance, enabling study of very complicated load patterns which can, for example, match the statistical distribution of rough air loads.

It is important that the size and distribution of the net loads experienced in flight be known to enable adequate structural design. These loads are caused by the interrelated action of aerodynamic, inertia and elastic forces which may be imposed on the airplane in steady or maneuvering flight, gusts, or in landings.

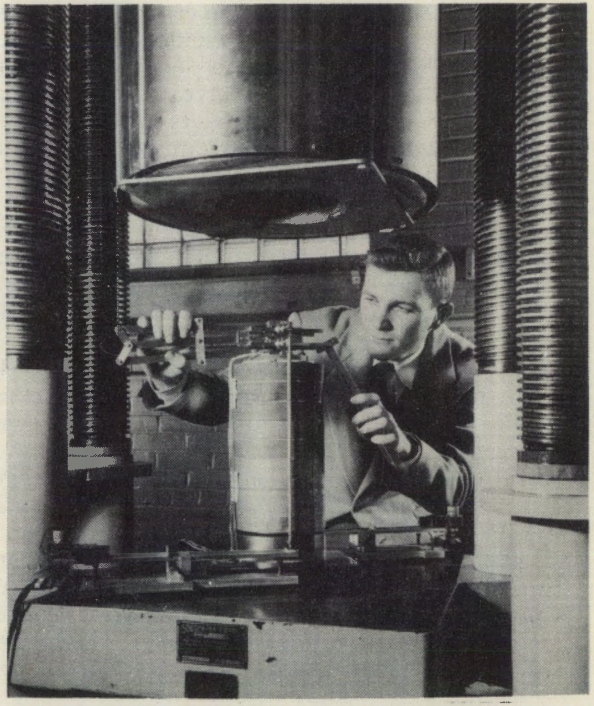
Loads may be determined by means of measurements of acceleration, pressure, and deflection. Accelerometers are useful in measuring the over-all airplane loads and inertia loads. Pressure distributions over the wing, tail, and fuselage determine not only the total load on the surface but the distribution of load over the surface. Deflection measurements by means of small electrical wire resistance strain gages help in determining the loads induced by elastic deformation.

Materials for high temperatures

Much research is being conducted on the suitability of materials for use in airplanes and missiles that will be subjected to the high temperatures associated with supersonic speeds. One criterion for such use is the ability of the material to withstand yielding, or stretching beyond permissible limits, at the higher temperatures which are experienced.

Aluminum alloys currently used in aircraft lose almost all their strength at 600° F. Titanium alloy and stainless steel seem to hold up much better at such high temperatures, and stainless steel seems to be much better than titanium, although when compared on the basis of strength per unit of weight, the differences are less pronounced. Titanium is better on a strength basis for use where intermediate temperatures will be experienced.

In the bending of a compression structure like the plate elements in the upper skin of a wing,



Titanium under test in laboratory

the full material strength often cannot be realized because the skin tends to wrinkle when the skin is thin. This wrinkling can occur long before the material itself has been stressed to its capacity. After wrinkling occurs, the plate elements still can take load but their maximum strength no longer is directly related in a simple way to strength of the material. In order to provide a basis of material selection for such cases, research has been conducted to determine the correlations between the strength of the structural elements and the yield strength of the material.

If the consideration of weight is added to the above-mentioned factors, of the materials compared stainless steel is to be preferred at temperatures above 800° F, and the titanium alloy is superior in the intermediate temperature range. At lower temperatures, any one of the three materials might be most efficient, depending upon the particular design conditions. A general conclusion is that no one material is universally superior, but that the choice of a material depends not only on the temperature consideration but also on the structural use to which it will be put.

Another field of structures research is fatigue, where repeated stressing of material may eventually cause it to fail. Why materials fail by fatigue is not yet known, but many factors affecting the fatigue life of structures are now understood. For example, fatigue failure generally starts in the vicinity of so-called stress raisers such as holes, notches, or fillets which disrupt the uniform flow of stress. Such an increase over uniform stress is called the stress concentration factor. The relation between it and fatigue life is affected by the size of the specimen, an effect which has been evaluated for steel, and now is being studied with aluminum alloys.

....Research in flight

In addition to the use of full-scale airplanes for investigation of aerodynamic problems in the transonic range, discussed elsewhere, there are many other areas in which actual flight is a most effective, and sometimes the only, method of securing needed aeronautical information. For example, measurements on airplanes in flight provide virtually the entire basis for current design requirements as to the degree of stability and control an airplane needs for safe, precision flight.

Such flight work has been performed with respect to helicopters to the end that stability and control information could be made available to designers. To check the adequacy of "maneuver requirements," established by flight trials conducted with normal, every-day visibility, flying qualities are being assessed under blind flying conditions. These blind flying trials have also directed attention to a new problem, that of directional control. During instrument flight, holding a steady course becomes a difficult task. Possible changes in stability and control characteristics to lessen this difficulty are being investigated, and work also is being done to discover a better way to present flight information, via the instrument panel, to the pilot.

Measurements on airplanes in flight are a primary source of information about loads that will be imposed on an airplane by the pilot, or by atmospheric turbulence. One such study was made of a service airplane with strain gages being used to measure loads on the wing, horizontal tail, and vertical tail. The purpose of the flight program was to establish the degree of agreement between actual loads measured and those calculated by the engineer on the basis of information available at the time of design. During the flights, a series of abrupt push-down, pull-up maneuvers were made to compare measured and calculated tail loads in abrupt maneuvers. It was found that the flexibility of the rear fuselage and tail combination affected the calculation of tail loads. For large, flexible airplanes, this factor should be included in tail load calculations.

Nearly always flight tests are required to provide a final check on conclusions reached in the laboratory, where exact duplication of all the actual conditions of use seldom is possible.

Operating problems under attack

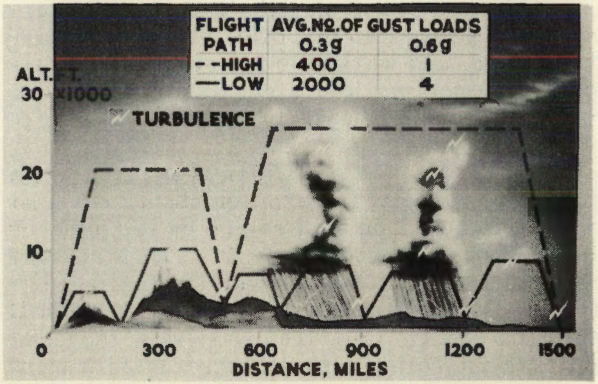
Operating problems of commercial aircraft are being studied at all three of the NACA's laboratories and include flight and wind-tunnel work, theoretical work, and the development of specialized instruments and new testing techniques. Among problems are effects of turbulence and meteorological conditions such as winds and temperatures at high altitudes. For the study of these, data from actual airplane operations are needed.

NACA-Langley - 5-17-51 - 3500

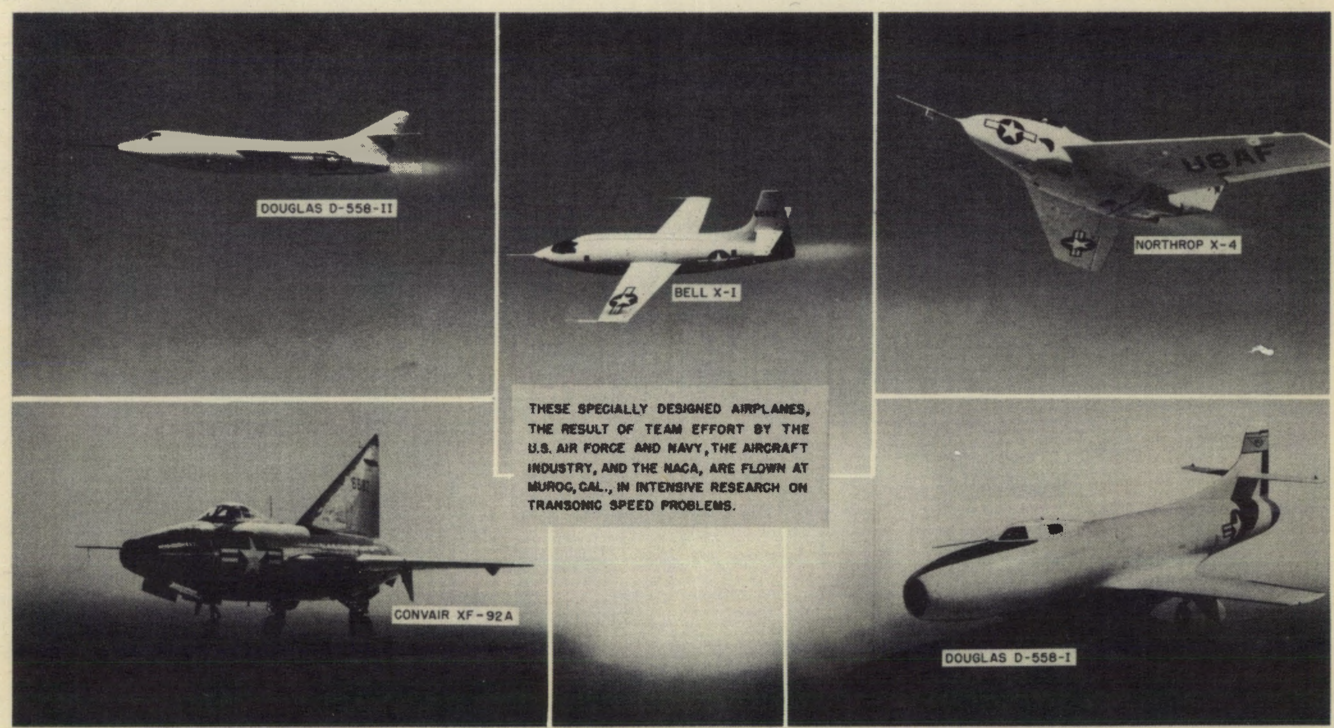
For a number of years, V-G recorders have been installed in commercial airplanes in routine operations, yielding pertinent information on maximum loads experienced, charted against airspeed. Unfortunately, these V-G recorders tell nothing about smaller loads which contribute to structural fatigue and passenger discomfort. A newer instrument being used currently is the V-G-H recorder which gives a time history of all the loads and the corresponding airspeed and altitude.

Preliminary statistical work has been done to determine the rough-air experience of airplanes operating below 10,000 feet and also at altitudes from 20,000 to 30,000 feet. Hardly 1/5 the number of accelerations corresponding to noticeable and moderate passenger discomfort were recorded in the higher altitude range, compared to low-altitude flight. The high-altitude airplane flies above many cumulus clouds, and is not subjected to as much rough air associated with mountainous terrain. Further, it has a better chance of avoiding the higher thunderstorms.

In the determination of reasonable safe speeds for airplanes, it is known that aircraft are limited by speeds and by Mach numbers which cause buffeting, adverse stability changes, and structural problems. The question becomes more serious with respect to jet airplanes, because they can be flown near their limiting speeds and Mach numbers in climbing and level flight, as well as descent. Further study is being given the problem, as well as possible methods to insure operation within safe speed and Mach number limits.



High flight avoids turbulence



THESE SPECIALLY DESIGNED AIRPLANES, THE RESULT OF TEAM EFFORT BY THE U.S. AIR FORCE AND NAVY, THE AIRCRAFT INDUSTRY, AND THE NACA, ARE FLOWN AT MUROC, CAL., IN INTENSIVE RESEARCH ON TRANSONIC SPEED PROBLEMS.