1949 INSPECTION

H. A. Soulé

Mr. Stack has just discussed phases of an over-all program initiated during the war years for the development of means for obtaining aerodynamics in the transonic speed range where wind tunnels were not giving accurate information. It is not generally appreciated that the research airplane program was started early in 1944 as a part of that master program. Airplanes were flying in the low transonic speed range - that was the source of trouble we were trying to eliminate. If a properly instrumented airplane could be flown safely in this speed range, it could bring data as to exactly what was happening under full-scale conditions.

The matter of safety was, of course, of prime consideration. Previously transonic speeds were obtained only in dives where the force of gravity provided most of the propelling force. Under these conditions when compressibility effects were encountered the airplane could not be decelerated without leveling off. Unfortunately one of the first changes resulting from compressibility effects was a large increase in the elevator control force which was generally coupled with a nose-down trim change that made leveling off difficult.

One of the first requirements of a high-speed research airplane is that it should have sufficient power for its size and weight, to attain level or climbing flight in the speed range for which it was designed. Deceleration, in case of trouble, can then be accomplished by simply cutting the throttle. The next important requirement is that some alternate means of longitudinal control should be provided in case the elevator forces become too great for the pilot in the transonic speed range. The power-driven adjustable stabilizer is one means of providing this control. High strength and rugged construction are also desirable.

When these features had been decided upon, consideration was given to the practicability of the construction of a research airplane at the time. This entailed the study of possible layouts and the development of general specifications for the first types of research airplanes. When this work was completed and the practicability shown, a formal proposal for construction was made to the military services.

The research airplane program since the start has been a cooperative effort among the Air Force, Navy, several airplane manufacturers, and the NACA. The first airplanes were the X-1 and D-558-1. The X-1 was built by the Bell Aircraft Corporation under Air Force sponsorship and the D-558-1 was built by the Douglas Aircraft Company under Navy sponsorship. The X-1 was first flown without power in the spring of 1946 and with power in December of the same year. The D-558-1 was first in the spring of 1947. The D-558-1 held the official world's speed record for a time of 1947 and the X-1 exceeded the speed of sound in level flight at high altitude in October 1947.

The airplanes were solely research vehicles and have no tactical application. The D-558-1 was powered with the most powerful turbo jet engine available at the time and the X-1 with a rocket engine. The power-size ratio was further improved by making the airplanes as small as practical. The fuselages were tailored to just fit around the pilot, engine, fuel, and the 500-pound load of research instrumentation. Both have adjustable stabilizers. The design strengths are over 50 percent greater than for fighters. Other important features of the airplanes were the thin wing sections, relatively low aspect ratios, and pressure cabins. The thin wing sections and the low aspect ratios were used because of their known effects in reducing the severity of the changes in aerodynamic characteristics occurring at critical speeds. The pressure cabins permit operations at high altitude. With low density the dynamic pressures and consequently the loads are reduced for a given Mach number. The airplanes were not intended to be efficient supersonic airplanes.

The tests of these airplanes are continuing at the Muroc Air Force Base which has been shown to be ideal for flight test purposes. Research data have been obtained from practically every flight. You will appreciate that, for security reasons, the data and their significance cannot be discussed at this meeting. The results are being disseminated to the military services and the industry by means of appropriately classified reports and conferences. One interesting by-product of the work has been the dispelling of fear of unknown and unanticipated phenomena in the transonic-speed range.

The research airplane program has been expanded beyond the original conception and now compromises more than a half-dozen airplane types. The sweptback X-2, X-4, and D-558-2 airplanes and the X-3 airplanes have been announced.

The extension of the program was a direct result of the introduction of the sweepback principle. Shortly after work on the initial airplanes was started, Robert T. Jones, now of the Ames Aeronautical Laboratory and formerly here at Langley, conceived the idea of delaying the onset of serious compressibility effects through the use of wing sweep. The Germans, it was found later, had arrived at a similar conclusion. The benefit given by sweep varies with the amount. The variation is somewhat as is shown on the slide which gives approximately the speeds at which serious compressibility effects may be expected as a function of sweept angle. You will note that there are no significant gains to be obtained by sweep angles of less than 30° and that for speeds above about M = 1.5 extreme sweep angles may be required.

The problem of developing satisfactory man-carrying airplanes is not quite as simple as incorporating the indicated sweep for a given design speed. There has been past experience with sweep on tailless airplanes which use sweep for an entirely different reason than it is used on current research airplanes. This experience has shown that sweep has adverse effects on the stalling characteristics and the low-speed stability characteristics. These effects increase with sweep angle. Consequently the design of swept wing supersonic airplanes involved low-speed as well as high-speed problems.

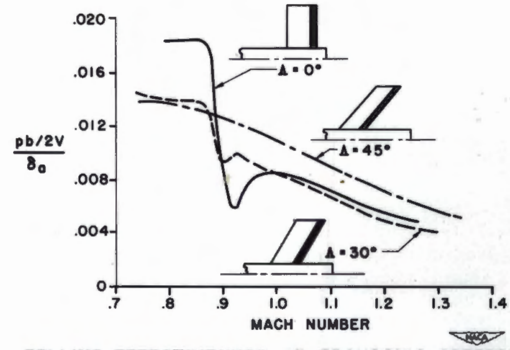
The determination of the low-speed characteristics with sweep, along with other considerations as the structural construction difficulties and efficiency, will probably impose a practical limit of the order of 60° on the amount of sweep that can be utilized on airplanes. The speed scale for airplanes can, therefore, be divided into at least three ranges. There is the older speed range below M = 0.8 where compressibility effects are small, a range between M = 0.8 and 1.5 where sweep is known to have a beneficial effect, and a range above M = 1.5 where the best configuration considering all factors has not as yet been determined. There is also probably a fourth range above M = 2 where the heat generated by speed becomes a factor. Without going into detail, it may be noted that the current research airplane series form an integrated group to permit the exploration, at least, of the problems of each speed range. The program has included a low-speed airplane, the L-39 airplane which is a P-63 airplane modified to incorporate 35° for the investigations of the probable low-speed and landing characteristics of the X-2 and D-558-2 airplanes. Data from this investigation were presented at the Ames Laboratory inspection last year.

Much credit for the success of the initial phases of the research airplane must go to the instrumentation and the men who developed it. The instrumentation is very similar in all later research airplanes. It has been devised to permit the study of flying qualities, the detailed stability and control characteristics that affect the flying qualities, the drag characteristics and the efficiency of the aerodynamic loads both over-all and detailed by means of pressure distribution, the performance of the engines and their induction systems in case of air breathers, and specialized items as skin temperatures and boundary-layer characteristics. As different measurements call for different flight plans, all instruments are not used simultaneously. The basic wiring and sensing elements, however, were installed during construction. Continuous records can be made of the items of interest from the start of the take-off or launching to the end of the landing. The instrument arrangement is such that accent can be readily shifted from one subject to another to keep knowledge of all phases coming along at about equal rates. In addition, certain of the more basic data are telemetered to the ground as insurance against loss of the airplane in the particular flight.

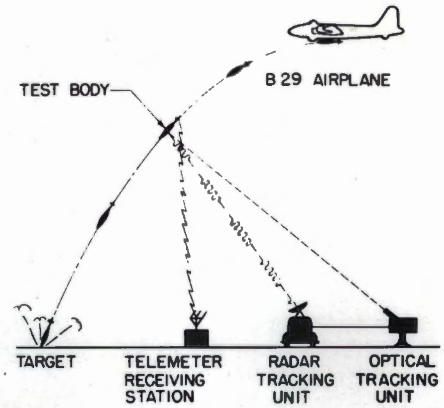
I would like to stress the cooperative nature of the program. While the NACA could supply general specifications for the airplane, the manufacturer had to supply the practical construction details. The Air Force and Navy supplied the funds and inspection and generally coordinated the plans. The extent of the cooperation may not be well appreciated; for example, the Air Force X-1 is powered with a Navy developed RM-I rocket, whereas the Navy D-558-1 is powered with an Air Force developed Allison turbojet. The Bell Company was responsible for the development of the air-launching technique which has greatly increased the duration of the supersonic flight of the X-1.

The extension of the research airplane program represents, of course, a departure from the original intention. The newer research airplanes provide a means for permitting early flight trial and evaluation of ideas developed through theoretical studies and through use of the other techniques discussed by Mr. Stack. This is an important change of procedures. In the past, the trial of devices and ideas was, for the most part, left to the airplane manufacturer. This entailed considerable financial risk on his part and consequently there was always a great time lag between the completion of the research and development on a given item and its appearance on tactical aircraft. This time lag which, because of the radical changes involved in supersonic airplane designs and greater financial risk, cannot be tolerated. Research airplanes will greatly reduce this lag and their use should be further extended.

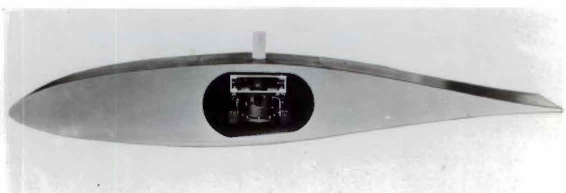
(Typed 5/17/49,vt,nbh)



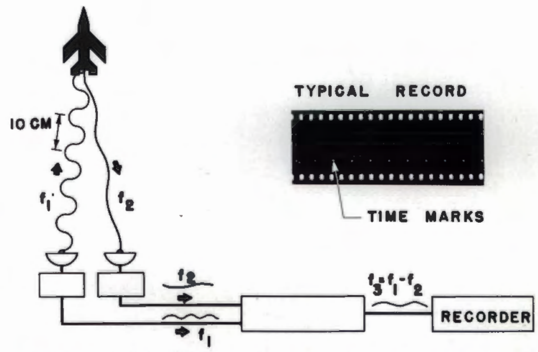
ROLLING EFFECTIVENESS AT TRANSONIC SPEEDS



SCHEMATIC SKETCH ILLUSTRATING TEST PROCEDURE

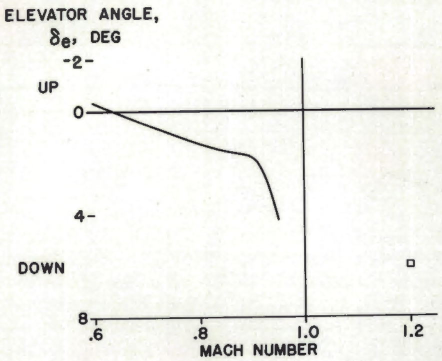


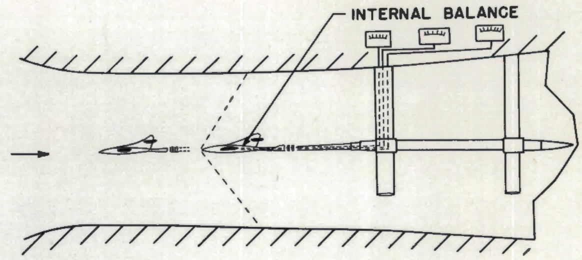
MOCK-UP OF WING FLOW APPARATUS

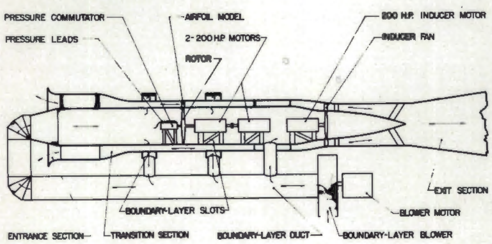


CONTINUOUS-WAVE DOPPLER RADAR TECHNIQUE

NACA
LAL 61300

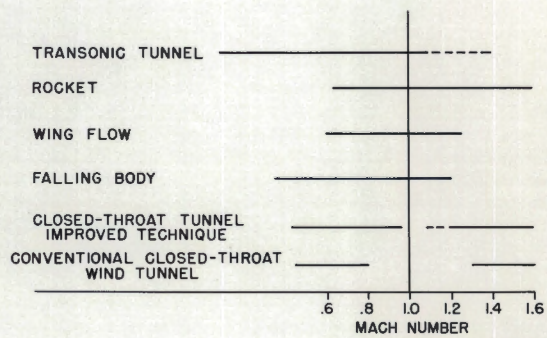


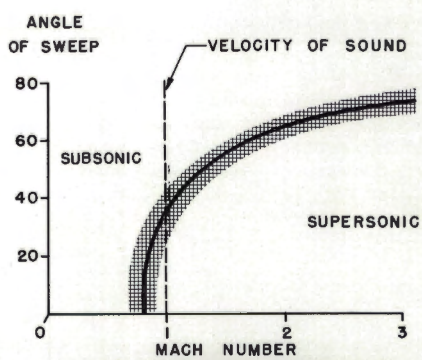




SCHEMATIC DIAGRAM OF TRANSONIC TUNNEL

RESEARCH TECHNIQUE SPEED RANGES
1949





EFFECT OF SWEEP ANGLE ON CRITICAL SPEED