7- BY 10-FOOT WIND TUNNEL

INTRODUCTORY

George McCullough or
Edward J. Hopkins

Gentlemen, you are now seated in the test chamber of the Ames 7- by 10-foot wind tunnel No. 1. The second wind tunnel operated by this research group is immediately adjacent to this one, and is identical in general arrangement. A simplified plan-view is shown on this chart (fig. 3(a)). You are seated here facing the test section in which the models under investigation are mounted. The air is driven by this fan, and circulates around the tunnel in this direction. This is an air exchanger for cooling the tunnel. These four sets of vertical turning vanes which extend entirely across the tunnel passages assist the air to turn the four right-angled corners.

Each tunnel has a maximum speed of 300 miles per hour. Although this is lower than the top speed of many existing airplanes, these wind tunnels are nonetheless of great value in the investigation of numerous unsolved problems in the field of subsonic flow. The advent of the supersonic airplane will pose a new set of problems concerned with the aerodynamic characteristics of these aircraft in the range of relatively low speeds required for take-off and landing.

The size of these wind tunnels is such as to make them ideally suited for the determination of the flying or handling qualities of airplanes by testing small models. This is shown by the fact that two tunnels are employed to keep pace with the demand for such

information. Many complete models of various airplanes have been investigated, and, from the information obtained, predictions were made of the handling qualities of the full-sized airplanes. In cases where deficiencies in these characteristics were indicated, steps were taken to remedy the defects in cooperation with the manufacturer concerned. A little later we will demonstrate the pitching characteristics of a model airplane.

Many types of fundamental problems have been investigated by this group. Such diverse problems as the effect of heat on airfoil drag; the effectiveness of various flap arrangements, and the development of adequate aerodynamic brakes have been undertaken. Considerable research has been devoted to the design of low-drag nacelle-body shapes and internal ducting systems for the jet engines of airplanes flying at high subsonic speeds.

Mr. Mossman (or Mr. Allison) will now tell you of an investigation of the design of efficient air-entry shapes for use in connection with jet engines. Mr. Mossman (or Mr. Allison)- - - -

NACA SUBMERGED AIR INLETS

Emmett A. Mossman or
George E. Allison

The efficient induction of air into the propulsion system of an aircraft has always been an important problem in aerodynamic design. Research on this problem dates back to the early years of the National Advisory Committee for Aeronautics and the development of the NACA cowling. Since that time new types of air inlets have been investigated in the various laboratories of the NACA. These inlets are now being used on the latest high-speed airplanes. In the last few years the use of the jet-propulsion engine has greatly intensified the research effort on air-induction problems, because all of the air to which energy is imparted to provide thrust passes through the working cycle of the engine. It may readily be seen that even small losses in an internal-flow system handling the large quantities of air involved, will cause serious decreases in the thrust of the engine and appreciable increases in the fuel consumption. The efficient operation of a jet-propulsion engine is a direct function of the efficiency with which the air is conducted through the inlet to the engine.

NACA research on the problems of air inlets for these engines has shown that the fuselage nose inlet possesses excellent characteristics. However, for jet-engine installations in the aft portion of the fuselage of an airplane, the long duct from the nose inlet complicates the design of the airplane in that a considerable portion of the interior space of the fuselage is not

available for other uses. External scoops on the sides of the fuselage have the advantage of eliminating much of this internal ducting. But the aerodynamic characteristics of these inlets, including excessive external drag, are undesirable. Wing leading-edge inlets have been found to be satisfactory, in many cases, especially for airplanes with rather thick wings. However, the use of thin wings on high-speed airplanes precludes the use of entries of this type.

Recognizing the need for a new type of inlet which would combine the characteristics of the nose inlet with the short internal ducting of the external scoop, the NACA began research on what is known as a "submerged air inlet." One of these inlets is shown on the model on your right. Notice that the entrance itself is completely submerged below the contour of the fuselage. The air flows down an inclined surface, which we have termed the "ramp."

One measurement of the excellence of a duct is its ability to recover the pressure energy generated by the velocity of the airplane. It was known from previous research, on external scoops, that considerable difficulty might be experienced in obtaining recovery of this pressure with submerged air inlets. The relatively thick layer of low-velocity air, known as the boundary layer, which exists on the fuselage, tends to cause the air flow to separate from the surface. It was expected that this tendency toward separation might be alleviated by various changes in the shape of the air inlet.

The first variable investigated was that of the angle of the ramp leading into the inlet. Results are shown on this chart (fig. 3(b)) and are for inlets with parallel sides. Here, we have plotted the percentage of the pressure generated by the forward velocity of the airplane which is recovered by the inlet, as a function of the velocity into the inlet, in percent of flight velocity. As the ramp angle is increased beyond a value of about 11°, the recovery of pressure becomes appreciably less. As the ramp angle is increased to 18°, this pressure recovery drops to 67 percent. You will note that the peak pressure recovery for the 7° ramp is only 77 percent. This value was considered to be low in comparison with the pressure recovery obtainable with nose inlets. For this reason, further tests were made to try to eliminate the influence of the boundary layer in causing incipient separation with consequent low recoveries of pressure.

At the suggestion of one of the younger engineers in this section we tried diverging the walls of the ramp as shown on this next chart (fig. 3(c)). Here you see three inlet designs; one with parallel ramp walls, which is the configuration we have just discussed on the previous chart, another with partial divergence, and a third with full divergence of the ramp walls. You will note that increasing the angle of these walls improved appreciably the pressure recovery available at the entrance to the jet engine. At first we were not sure why changing the walls should have the beneficial effect shown. It was surmised, however, that the

alteration caused much of the boundary layer on the fuselage surface to flow around the duct instead of down the ramp, thereby permitting a higher recovery of pressure and the use of lower inlet velocities. This was substantiated by measuring the air flow in the region behind the inlet. It may be noted that the pressure recovery now has a peak value of 90 percent in the important inlet-velocity range, compared with 77 percent for parallel walls. This approaches closely the best value which may be obtained with the fuselage nose inlet.

In our discussion we have been able to touch only briefly on the research that has been done on this inlet. It may be well to mention, however, that we have found that the location of the inlet on the fuselage, relative to the wing, has a large influence on the characteristics of the duct. It has been found desirable to minimize the influence of the wing on the inlet by moving the duct somewhat forward of the wing. The location shown on this model, with the entrance at the same fuselage station as the leading edge of the wing, was found to be less satisfactory than a location about 15 percent of the wing chord ahead of the leading edge of the wing.

In summary, submerged air inlets afford definite advantages over other types of air entries. Very good pressure recovery and high-speed characteristics may be obtained by careful design. The elimination of extensive internal ducting allows more freedom of internal design, provides more space for equipment in the fuselage, and permits a reduction in fuselage frontal area. Some

manufacturers are using these inlets in their new jet-propelled aircraft designs. Much research remains to be done, however, especially at very high speeds.

Mr. McCullough (or Hopkins) will now conduct a demonstration of the stability characteristics of the model in the wind tunnel. Mr. McCullough (or Hopkins).

STABILITY DEMONSTRATION

George B. McCullough
or Edward J. Hopkins

This demonstration is designed to illustrate the effect of power and landing-flap deflection on the pitching characteristics of a fighter-type airplane. The model in the wind tunnel is not a model of any particular airplane, but is intended to be representative of a general type, and is used for obtaining design information. The model may be made to pitch about a fixed point in the wind tunnel. (Pitching the model is demonstrated.) The two dials are connected to the wind-tunnel balance system so that this dial gives a measure of the lift of the model, and this dial gives a measure of the pitching moment of the model.

Now, as you know, the pitching moment of an airplane is a measure of the tendency of the airplane to nose up or nose down. A nose-up tendency is positive, and a nose-down tendency is negative.

A stable airplane is one which will of itself maintain a fixed attitude without movement of the control surfaces. In terms of the quantities we are now going to measure, lift and pitching moment, stability in pitch means that as the lift increases the airplane must experience an increasing tendency to nose down. Assume that a gust causes the nose of an airplane to rise; the angle of attack and consequently the lift will increase. To correct this effect a stable airplane possesses an inherent tendency to nose down. If this condition does not exist, the airplane would depart from the intended flight path with increasing

divergence unless corrected by the pilot.

The wind-tunnel measurements determining the stability of an airplane model are plotted on a graph similar to this (fig. 3(d)). Here the lift is plotted along the horizontal scale, and the pitching moment along the vertical scale. Positive pitching moments are plotted above the axis, and negative pitching moment below the axis. The pitching-moment curve of a stable airplane slopes downward to the right. The steeper the curve, the greater the degree of stability.

We will now start the wind tunnel and plot the readings of the lift and moment dials for three different test conditions of the model. The first test will be made with the flaps up and propeller idling. We will make the three runs as rapidly as possible, then discuss the results after the tunnel stops.

(The tunnel is started and the speaker steps to one side and speaks into a public-address system. A young lady plots the test points as the readings of the dials are called out. During the period the tunnel is running the speaker more or less ad-libs to fill in the pauses between the reading of the test points. Attention is called to a green light which glows when conditions in the tunnel are steady, indicating that the dials may be read. A similar red light indicates that power is being supplied to the model propeller.

The three test conditions are:

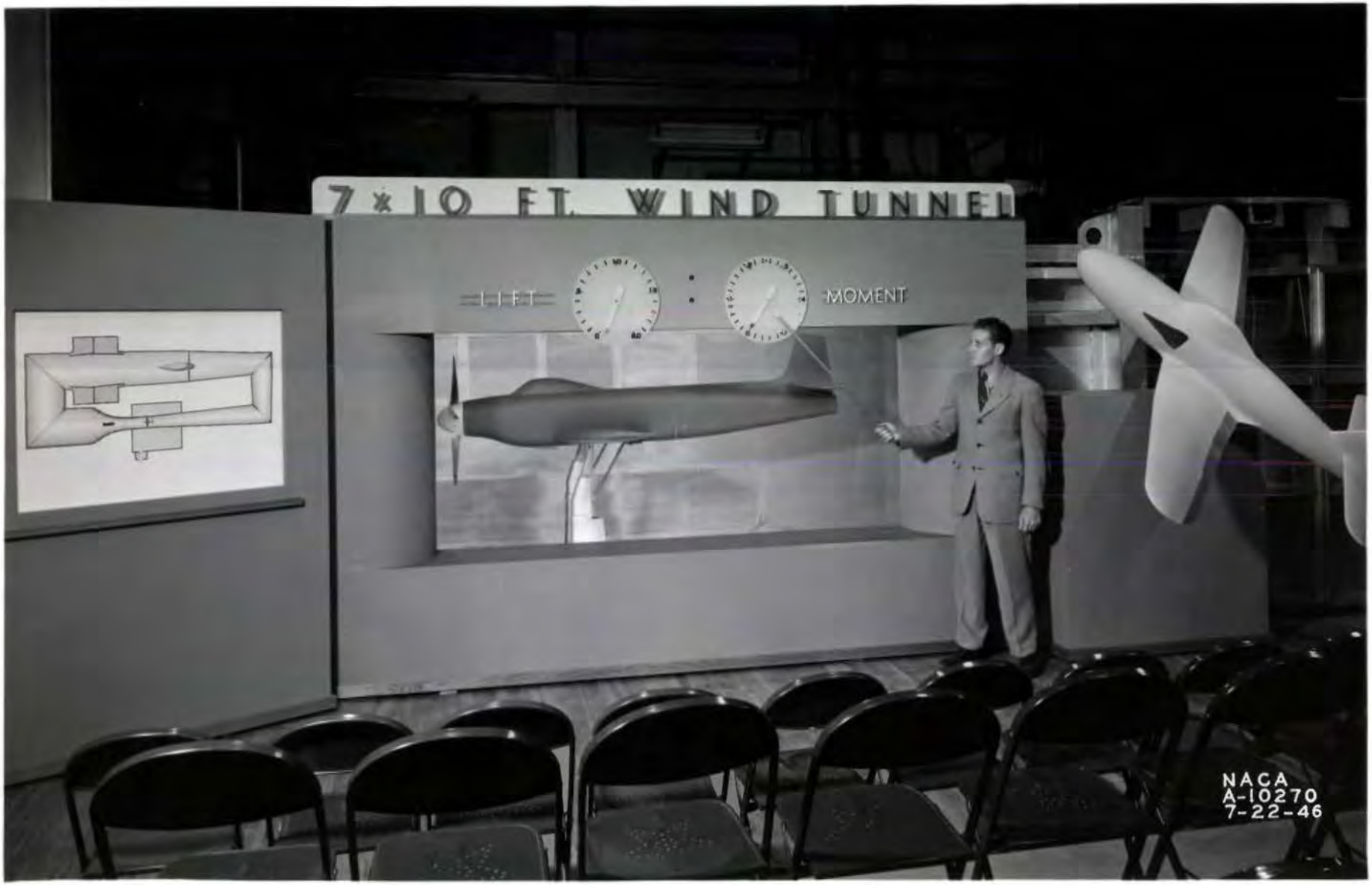
1. Propeller idling and landing flaps up.
2. Propeller idling and landing flaps deflected.
3. Propeller delivering power and landing flaps deflected.)

(The speaker enumerates the various test conditions as the runs are made and explains their correspondence to the similar conditions of actual flight, that is, gliding with power off, the landing approach, and the wave-off or balked landing. Attention is called to the increase of lift and change of pitching moment with increasing angle of attack of the model; to the landing flaps as they are deflected, and to the application of power for the third test condition. Four test points are plotted for each run. When the last point is plotted and the curves faired the speaker steps to the front and discusses the curves.)

We note now that the first curve obtained with landing flaps up and propeller idling has the greatest slope downward to the right, indicating that the model in this condition has the greatest stability. The second curve obtained with the landing flaps deflected has a somewhat lesser slope. The effect of deflecting the landing flaps in this case is to reduce stability. The third curve, obtained with the landing flaps deflected and propeller delivering power also indicates a loss of stability caused by the application of power. In all three test conditions the model exhibits a satisfactory degree of stability, and the airplane would probably possess acceptable handling qualities. It is not unusual, however, for the application of power to cause the pitching-moment curve to turn up like this. (An unstable curve is drawn on the board.) In this case the airplane would be unstable.

These effects of power and flap deflection on stability may, in some cases, be so severe as to result in unacceptably poor

flying qualities of the airplane. However, by proper design it is usually possible to confine these adverse stability changes within limits which are acceptable. Improvements in the stability characteristics of airplanes before they were placed in production have been effected by such means as changing the plan form or location of the horizontal tail, changing the flap design, or tilting the axis of the propeller so as to obtain a stabilizing moment from the propeller thrust. Part of our effort has been to furnish manufacturers the basic design data they need to design airplanes possessing satisfactory stability and control characteristics.



(a) General view.

Figure 3.- Seven- by ten-foot wind tunnel exhibit.

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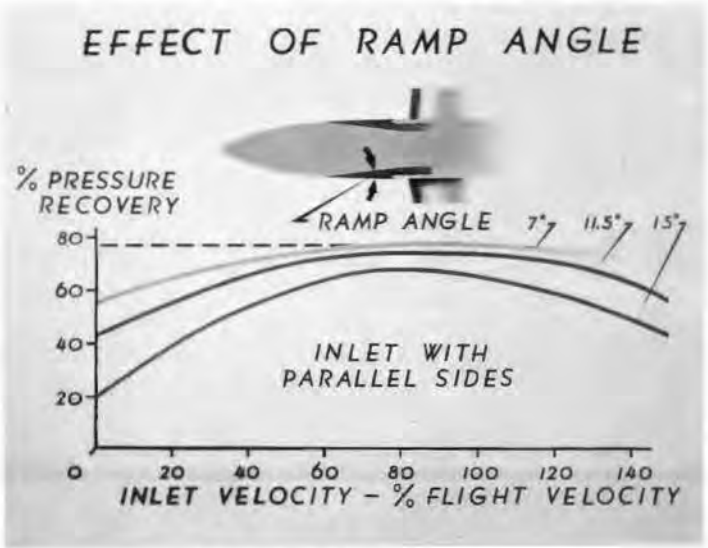
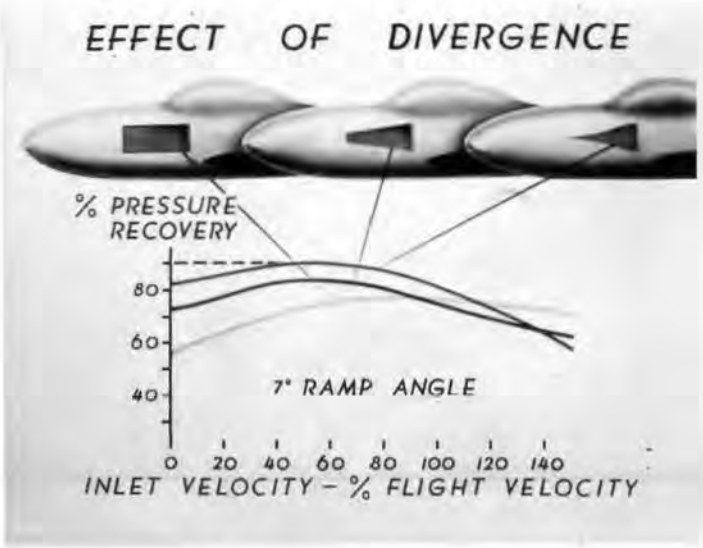
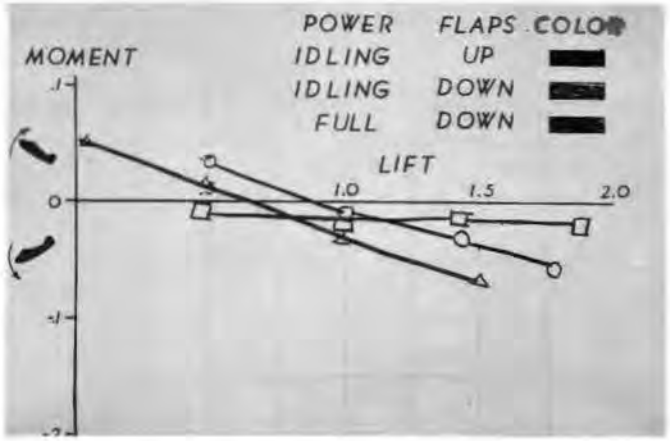


(b) First Chart.



(c) Second chart.



(d) Third Chart.

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Figure 3.- Concluded.

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