LANDING

presented by

40- by 80-Foot Wind-Tunnel Section

Among the serious problems faced by today's aircraft designer is that of maintaining a reasonable landing speed while obtaining higher and higher top speeds. In the discussion here, we will briefly outline the landing-speed problem and examine in detail a promising solution which theoretical and wind-tunnel research have made nearly ready for flight evaluation.

This chart shows how landing speeds have been increased by the general trends in airplane design which have resulted in higher top speeds. Typical of such trends, in addition to steadily increasing gross weights, are reductions in wing area and aspect ratio, use of moderate amounts of sweep, and use of large amounts of sweep alone or in combination with unusual plan forms. These increases in landing speed have resulted from a reduction in the landing lift coefficients of wings.

The problem, therefore, is to increase the landing lift coefficients of wings without reducing the maximum speed. Much research has been directed at finding acceptable solutions. The wing cross sections shown on this chart illustrate types of solutions. The simplest was in finding proper wing shape so that sufficient landing lift coefficient for low-speed airplanes was had by increasing angle of attack only; increasingly complicated flaps almost tripled the landing lift coefficient and thus satisfied the requirements of moderately high-speed airplanes.

The landing speeds which would result if any of these flaps were used on a typical wing design now under study can be seen by noting the location of the flap along the horizontal axis. The landing lift coefficient of the wing required to give landing speeds comparable to those of current experience is shown here. It is evident that to prevent an increase in landing speed, it will be necessary to increase the landing lift coefficient above anything yet achieved, and by an increment greater than any yet realized.

The maximum lift of a particular wing or flap design depends on the maintenance of smooth flow over the upper surface of wing or flap as the angle of either or both is increased to increase lift. Research has traced the cause of the breakdown of smooth flow to the boundary-layer air next to the wing surface which moves slowly relative to the wing surface.

Research has shown that two ways exist to delay the breakdown of flow and thus increase the landing lift coefficient; the slow-moving air can be speeded up or it can be removed. However, it has been repeatedly concluded that the increases in landing lift coefficient realized in the case of the lower-speed airplane were not worthwhile in view of the mechanical complications introduced, and the research was not carried through to the point of studying the details of application. The transonic or supersonic airplane has changed this conclusion and research effort is now being directed at the details of applying boundary-layer control.

On this chart are shown three of the most promising ways of applying the boundary-layer control to obtain high lift. The boundary-layer air can be drawn away along the wing and flap leading edges through slots or porous areas or speeded up by ejecting high-velocity air along the wing and flap surface from slots at the wing and flap leading edges. Each of these methods could produce landing lift coefficients well in excess of those in current use. Research is yet required to define in detail how each form of boundary-layer control must be applied in order to achieve the desired increase in landing lift coefficient for a particular wing design. In addition, information is required so that the best of these forms of boundary-layer control in terms of installed weight, power requirements, and complications can be chosen for a particular wing design. These questions are now in the process of being answered in the research laboratories; for instance, the Langley Laboratory has examined in detail the effectiveness of a suction slot along the leading edge of a 45° swept-back wing and Ames has examined in detail the effectiveness of porous area suction along the leading edge of a 63° swept-back wing. These researches and others are continuing. Today we will demonstrate the action of boundary-layer control in a specific case which has been brought to such a point of refinement with regard to increasing lift, power requirements and installation details that flight tests are to be made.

If you would now please turn to the rail behind you, Mr. __________ will proceed with the demonstration.

You are now looking into the test section of the 40- by 80-foot wind tunnel. At the usual air speeds of testing we must close the doors you see to your left and right but at the airspeed for this demonstration we may safely leave them open. The air is flowing from the large end of the tunnel you can see beyond the test section, through the test section below us, then to the driving fans.

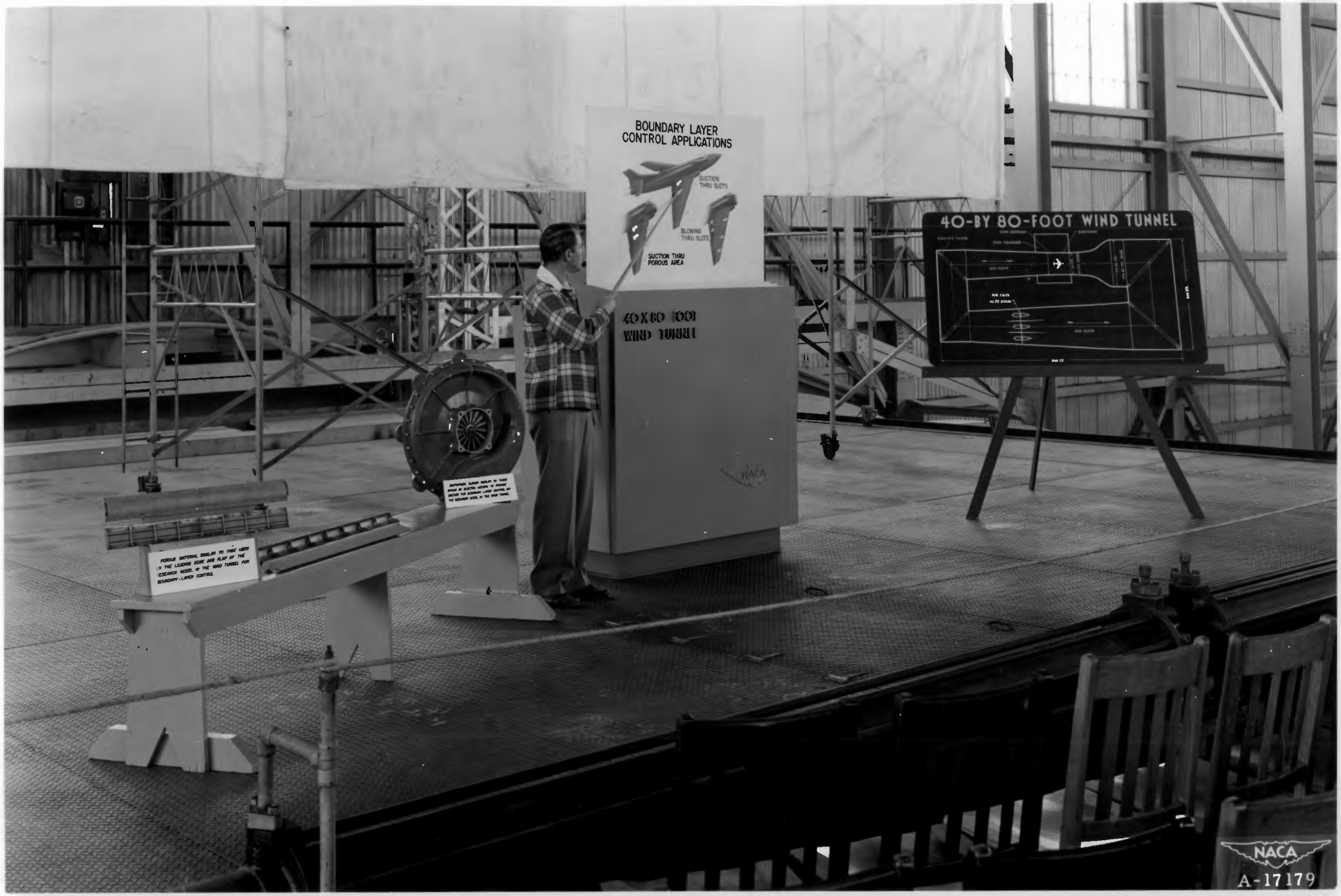
The object of the research we are doing here is to develop porous area boundary-layer control to such a degree of refinement for a particular airplane that it can be flight-tested for practical experience. With the cooperation of the U. S. Air Force, we have chosen the F-86 airplane as the flight-test vehicle and hence the model here has F-86 wings. For this research study, boundary-layer control by means of drawing boundary-layer air through porous material has been applied at the front portions of the flaps and also along the wing leading edges. During your tour today, you will be able to examine samples of the screen used for the porous surfaces.

For purposes of this demonstration, we will apply boundary-layer control to the left wing and flap leading edges but not to the right. The areas where the boundary-layer air is drawn through the porous material are outlined in red. As the angle of attack, as shown by the pointer on the model nose, is increased to increase lift, the differences in action of the tufts on the two wings will show that the wing with boundary-layer control will have smooth flow to higher angles of attack and hence greater lifts.

Note at this low angle of attack, that on the flap of the right wing which has no boundary-layer control, the tufts are waving erratically, indicating that the flow has already separated from the flap and lift is being lost, although the rest of the wing still has smooth flow. Thus this flap delfection is already too high. Our research has shown that about one-half this flap deflection is all that is usable without boundary-layer control. Note that the flap on the left wing with boundary-layer control has smooth flow over it, although near the flap trailing edge the air is flowing toward the wing tip. As we increase the angle of attack, the flow remains smooth over the surface of the left wing and flap while, above 14° angle of attack, areas of rough, separated flow will begin to appear near the tip of the right wing. The stalled area will spread slowly inboard from the tip of the right wing so that, as 18° angle of attack is reached, almost the entire right wing will be stalled. Force tests show that the maximum lift coefficient has been passed. The left wing still has smooth flow and the angle of attack could be increased further before stall would appear. However, rather than showing this, we will now turn off the boundary-layer control to illustrate its effectiveness. As the suction pumps slow down, stalled areas will appear and spread until this wing too is completely stalled. Now we will again apply the boundary-layer control and demonstrate its ability to eliminate the wing stall. As the pumps again come up to speed the stalled areas will disappear and the flow will be smooth over the entire wing and flap surface.

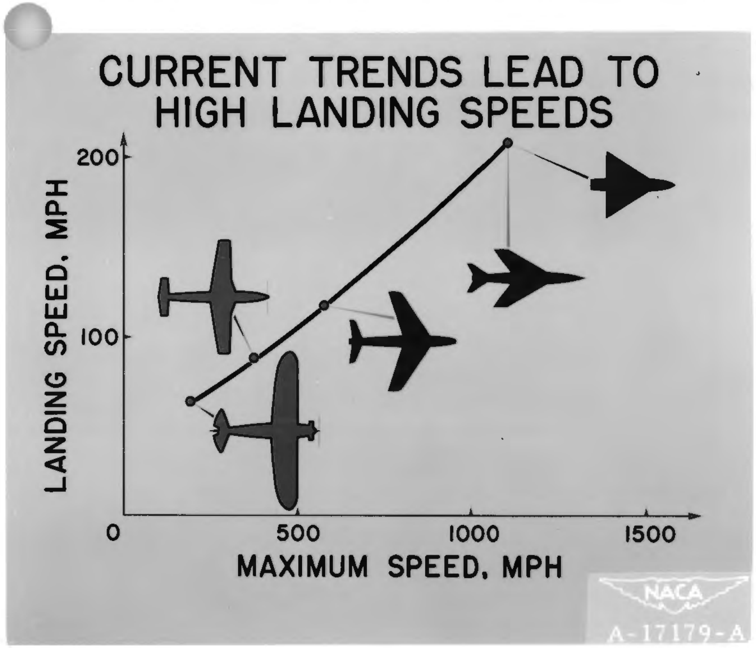
We have demonstrated here that boundary-layer control by suction through porous areas is a powerful means of increasing the landing lift coefficients of swept-wing airplanes. Study of the results shows that improvements in drag, stability, and control are also realized and that the cost in power is low. We know that further gains can be made and so the research is continuing. This concludes your visit to the 40- by 80-foot wind tunnel.

I now turn you back to your group leader.

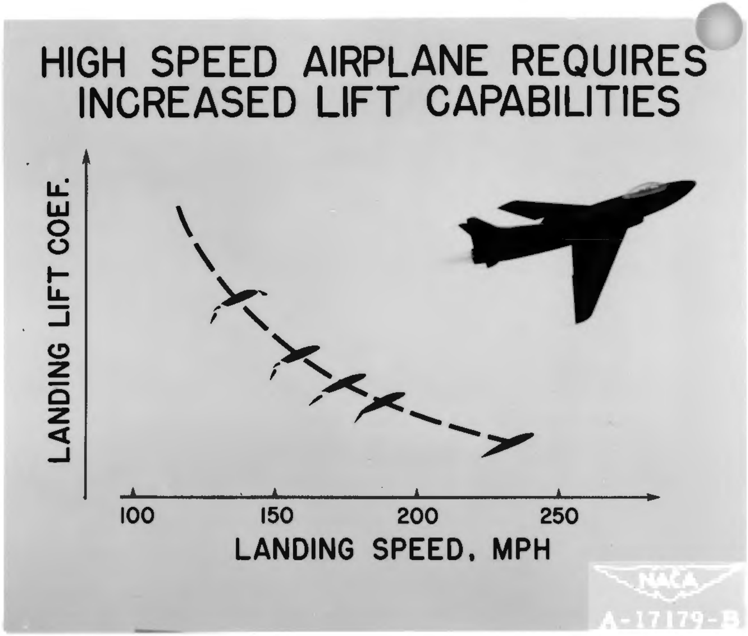


(a) Main display, 5th Floor

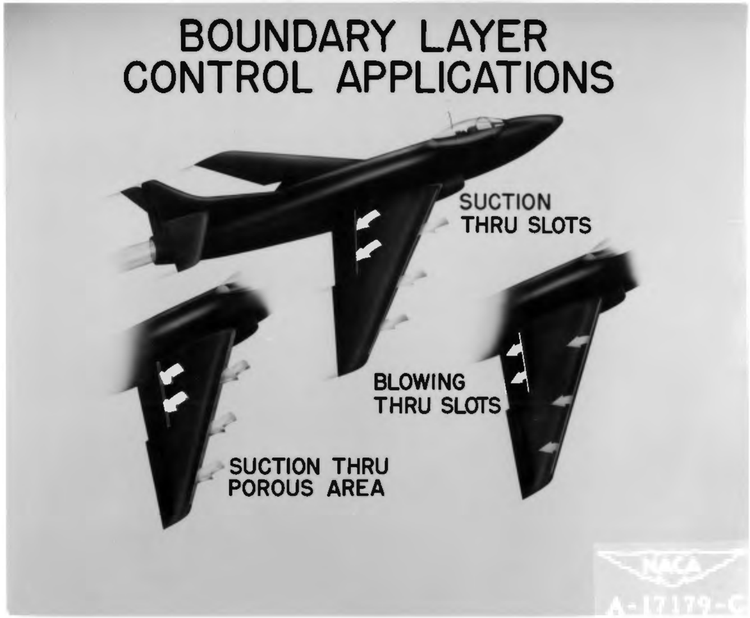
Display for presentation of "Landing"



CURRENT TRENDS LEAD TO HIGH LANDING SPEEDS



HIGH SPEED AIRPLANE REQUIRES INCREASED LIFT CAPABILITIES



BOUNDARY LAYER CONTROL APPLICATIONS

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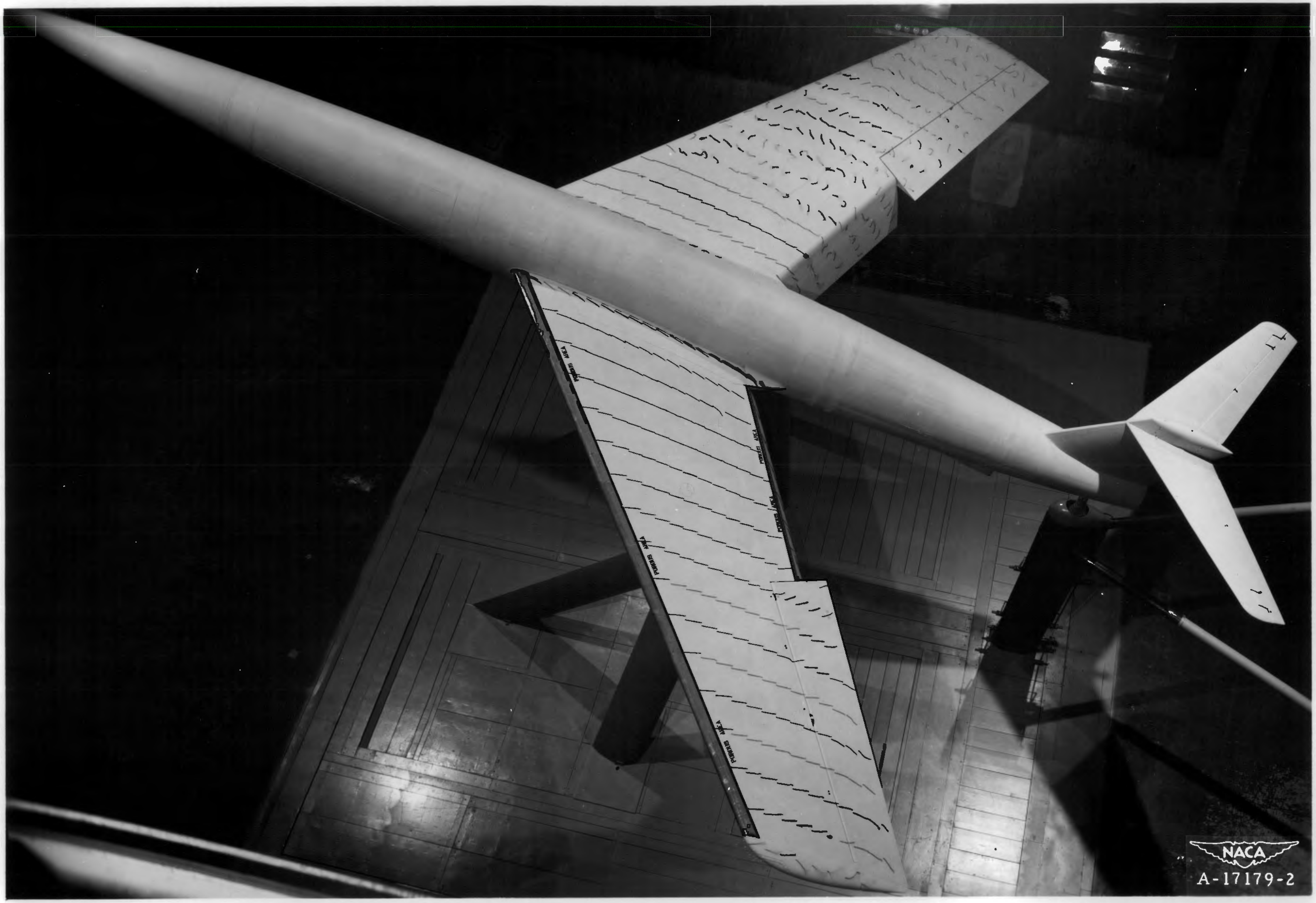
(b) Static display, 2nd Floor

(c) Static display, Ground Floor



Demonstration Model in 40- by 80-Foot Wind Tunnel

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