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CHARACTERISTICS OF A TRIANGULAR-WINGED AIRCRAFT

I – PERFORMANCE DATA

By Donald J. Graham

Ames Aeronautical Laboratory

Approximately a year ago a research program was formulated at the Ames Aeronautical Laboratory aimed at investigating the possibilities of employing a wing of low aspect ratio and triangular plan form on a transonic or moderately supersonic aircraft. A wing was selected to be investigated concurrently in the subsonic, transonic, and supersonic wind-tunnel facilities of the laboratory and, in addition, at transonic speeds by means of the NACA wing-flow method. It was planned to determine thereby the effects of wide variations in both Reynolds number and Mach number upon the characteristics of the subject configuration.

The choice of wing was made on the basis of the best existing predictions of the pressure-drag characteristics of triangular airfoils in the moderately supersonic-speed region. The wing was of 5-percent-chord-thick symmetrical double-wedge section with maximum thickness at 20 percent of the airfoil chord and had an aspect ratio of 2 with a vertex angle of 53°. The sweep of the leading edge thus amounted to approximately 63°.

In figure 1 is pictured the model, which was tested in the Ames 1- by $3\frac{1}{2}$-foot tunnel and the 1- by 3-foot supersonic tunnel, and the smallest scale model tested. The wing was mounted on a slender cylindrical body which was sting supported from the rear.

Figure 2 is a photograph of the model in the Ames 12-foot low-turbulence pressure tunnel and shows the semispan configuration mounted on a turntable in the tunnel floor.

Aerodynamic characteristics of this wing were determined for Mach numbers from 0.1 to 1.5 and for Reynolds numbers from 0.7×10^6 to 27×10^6. The Reynolds number variation was confined to the subsonic tests, all of the supersonic tests having been made for Reynolds numbers of the order of 1×10^6.

A considerable portion of the results of this investigation will be published shortly. The object of the present paper is to summarize the principal results which are involved in a prediction of the performance and the stability and control characteristics of a low-aspect-ratio triangular-wing aircraft.

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The variation of the minimum drag coefficient with Mach number for the triangular wing is shown in figure 3. It will be noted that the results from the Ames 1- by $3\frac{1}{2}$-foot tunnel (unpublished data) presented for Mach numbers from 0.5 to 1.5, indicated by the solid line, appear to reasonably bridge the gap between the low-speed value from the Ames 7- by 10-foot tunnel (reference 1) and the value for a Mach number of 1.5 from the Ames 1- by 3-foot supersonic tunnel (reference 2). The higher Reynolds number data from the Ames 12-foot low-turbulence pressure tunnel (reference 3) are not in such close agreement with the high subsonic Mach number data from the Ames 1- by $3\frac{1}{2}$-foot tunnel as could be desired despite allowance for the difference in scale. It should be emphasized, however, that the respective test conditions were dissimilar. The wing in the Ames 1- by $3\frac{1}{2}$-foot tunnel was mounted on a thin body, the drag of which could not readily be separated from that of the combination; whereas, the data from the Ames 12-foot low-turbulence pressure tunnel shown are for the wing alone. The effect of adding a fuselage to the model wing in the Ames 12-foot low-turbulence pressure tunnel was to displace the curve of minimum drag coefficient above that of the wing in the Ames 1- by $3\frac{1}{2}$-foot tunnel. No satisfactory explanation has yet been forthcoming for the seemingly early rise in the drag coefficient with Mach number evidenced by the results from the Ames 12-foot low-turbulence pressure tunnel.

Also shown for comparison in figure 3 are minimum drag coefficients for a 6-percent-chord-thick symmetrical double-wedge airfoil section from two-dimensional tests in the Ames 1- by $3\frac{1}{2}$-foot tunnel. The favorable effects of sweep and aspect-ratio reduction are apparent here.

It was inferred at the beginning of the paper that the present wing was selected because, from theoretical considerations, it had the lowest pressure drag for the practicable thickness distributions of the given triangular plan form at moderately supersonic speeds. Subsequent tests, however, in the Ames 1- by 3-foot supersonic tunnel and the Ames 1-by $3\frac{1}{2}$-foot tunnel showed lower actual minimum drag coefficients at a Mach number of 1.5 for a wing of the same plan form with the maximum thickness at 50 percent of the airfoil chord, an effect traced to the differences in the friction drag of the two surfaces. Hence, if any useful function such as structural convenience were to be served by locating the maximum thickness in the vicinity of the midchord, there would apparently be no associated penalty in minimum drag.

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In figure 4 the variation of maximum lift-drag ratio with Mach number is presented. The differences in the subsonic-speed characteristics as determined in the various facilities appear to be consistent with the corresponding differences in the Reynolds numbers of the respective tests. The subsonic-speed lift-drag ratios, although seemingly low, might reasonably be expected to improve somewhat with increasing Reynolds numbers, as was observed in the case of the subsonic speed characteristics.

Furthermore, for these tests, the wing had sharp leading edges and, hence, did not realize an appreciable amount of the possible leading-edge suction which would further boost the maximum lift-drag ratios in the speed range under consideration.

Previously reported tests (reference 4) in the Ames 1- by 3-foot supersonic tunnel at a Mach number of 1.5 with the leading edges of this wing rounded have indicated the attainment of a significant but by no means major portion of the theoretical leading-edge suction. Figure 5, the material for which was presented at the NACA Conference on Supersonic Aerodynamics at the Langley Laboratory, June 19-20, 1947, illustrates the variation of lift-drag ratio with lift coefficient at a Mach number of 1.5 for the wing with sharp leading edge and with the leading edge rounded to approximate the nose radius of a 5-percent-chord-thick NACA 65-series airfoil. Rounding the leading edge, while raising the maximum lift-drag ratio by decreasing the drag due to lift, did not affect the minimum drag. These results should not be taken as evidence of the maximum gain to be expected from leading-edge shape modification because the subject wing section was not selected with this objective in mind. It appears likely that at full-scale Reynolds numbers the use of airfoil sections with rounded nose contours of the subsonic type on wings with highly swept leading edges would, by realizing a greater part of the possible leading-edge suction, afford considerably higher maximum lift-drag ratios at low supersonic Mach numbers than those indicated in figures 4 and 5.

An additional fact of interest is that the lift coefficients corresponding to the maximum lift-drag ratios were found to be sensibly independent of Mach number, having varied but inappreciably from a value of about 0.2 over the range of the tests.

The slope of the lift curve of the triangular wing as a function of Mach number is shown in figure 6. Satisfactory agreement is evident both between the results of the various wind-tunnel tests and the calculated subsonic and supersonic values. The variation with Mach number is regular and apparently free from abrupt discontinuities at transonic speeds.

From the standpoint of performance at transonic Mach numbers the results of research to date indicate the low-aspect-ratio triangular wing to be a practicable lifting surface for a short-range interceptor aircraft. Were a wing section to be selected at this date for an aircraft designed to fly at transonic or moderately supersonic Mach numbers with the type of wing plan form under discussion, a profile having the general shape of the NACA 64-series or 65-series airfoil sections would be recommended because of the higher maximum lift-drag ratios afforded.

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3. Edwards, George G., and Stephenson, Jack D.: Tests of a Triangular Wing of Aspect Ratio 2 in the Ames 12-Foot Pressure Wind Tunnel. I - Effect of Reynolds Number and Mach Number on the Aerodynamic Characteristics of the Wing with Undeflected Flap. NACA RM No. A7K05, 1947.

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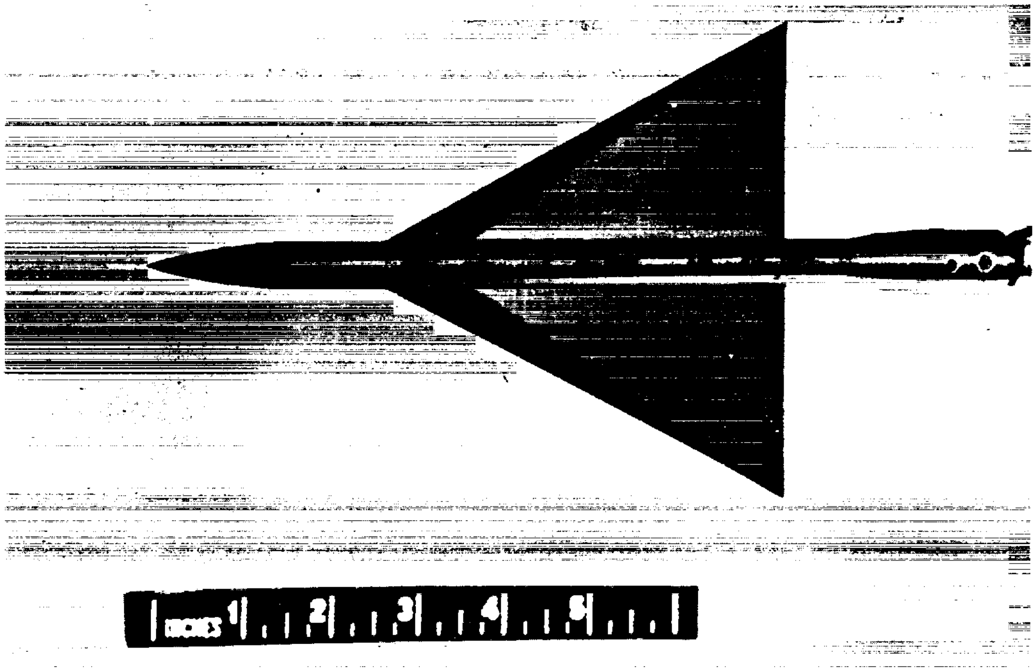

Figure 1.- Model tested in the Ames 1- by $3\frac{1}{2}$-foot tunnel.

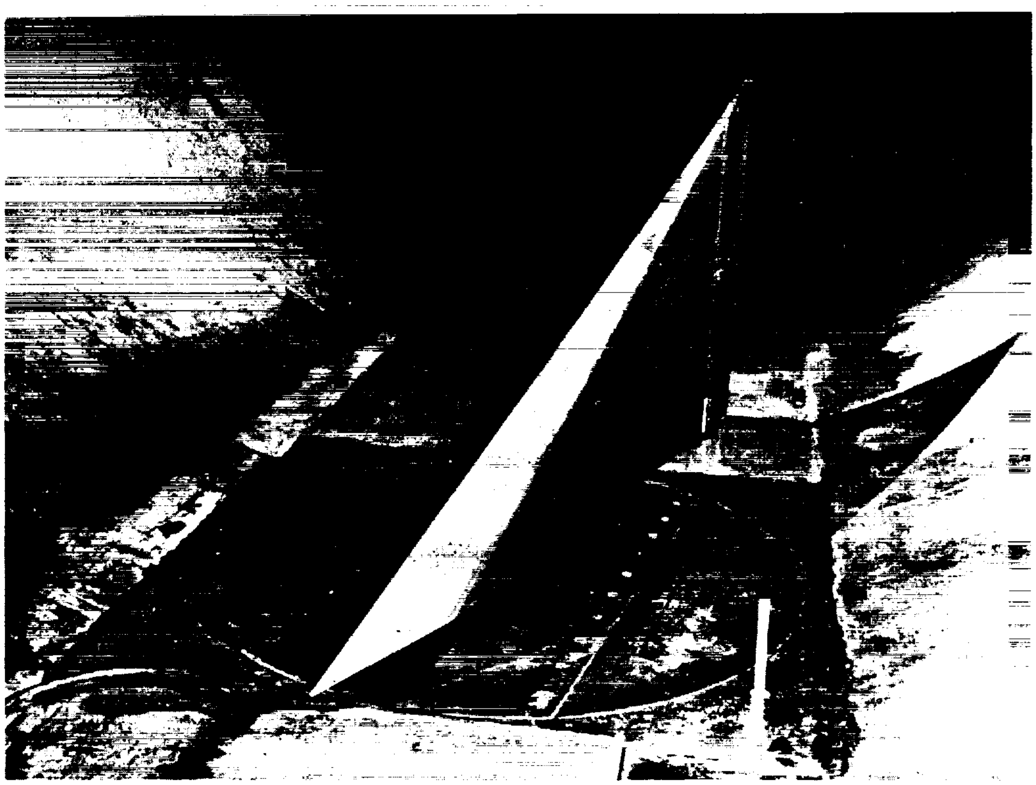

Figure 2.- Model tested in the Ames 12-foot low-turbulence pressure tunnel.

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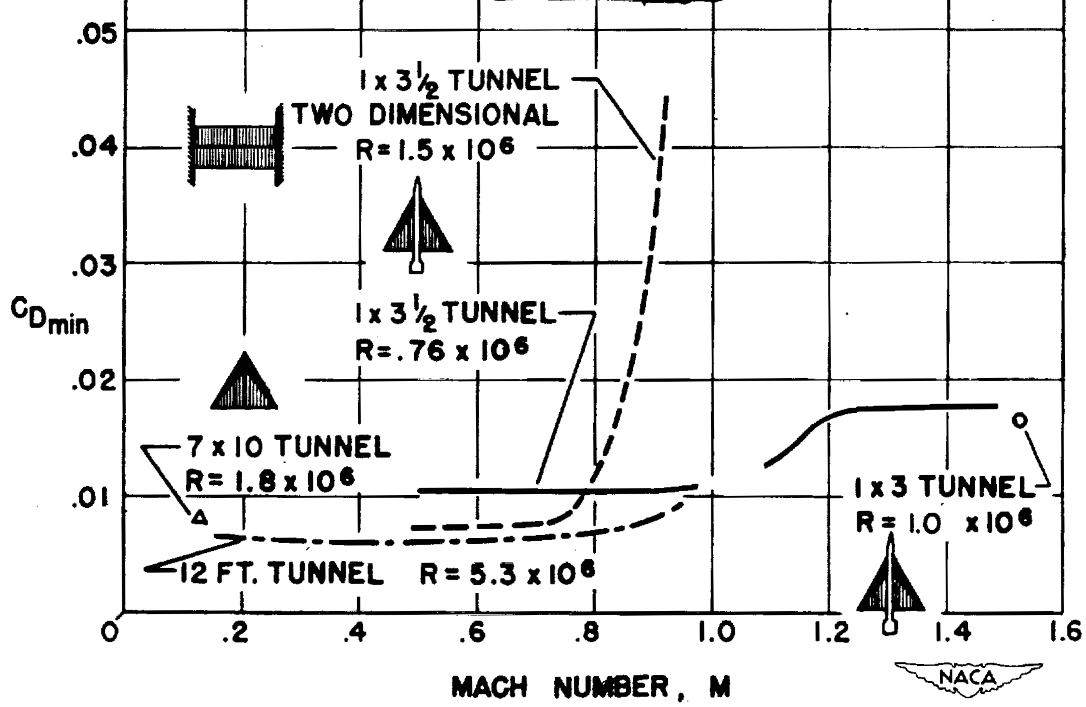

Figure 3.- The variation with Mach number of minimum drag coefficient for triangular wing.

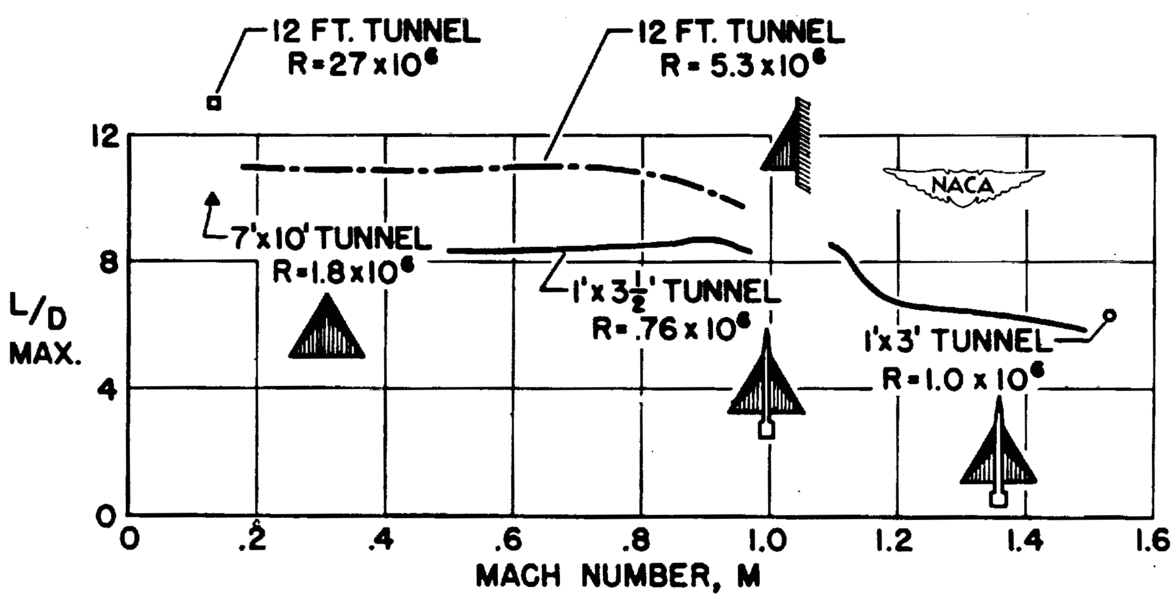

Figure 4.- The variation of Mach number with maximum lift-drag ratio for the triangular wing.

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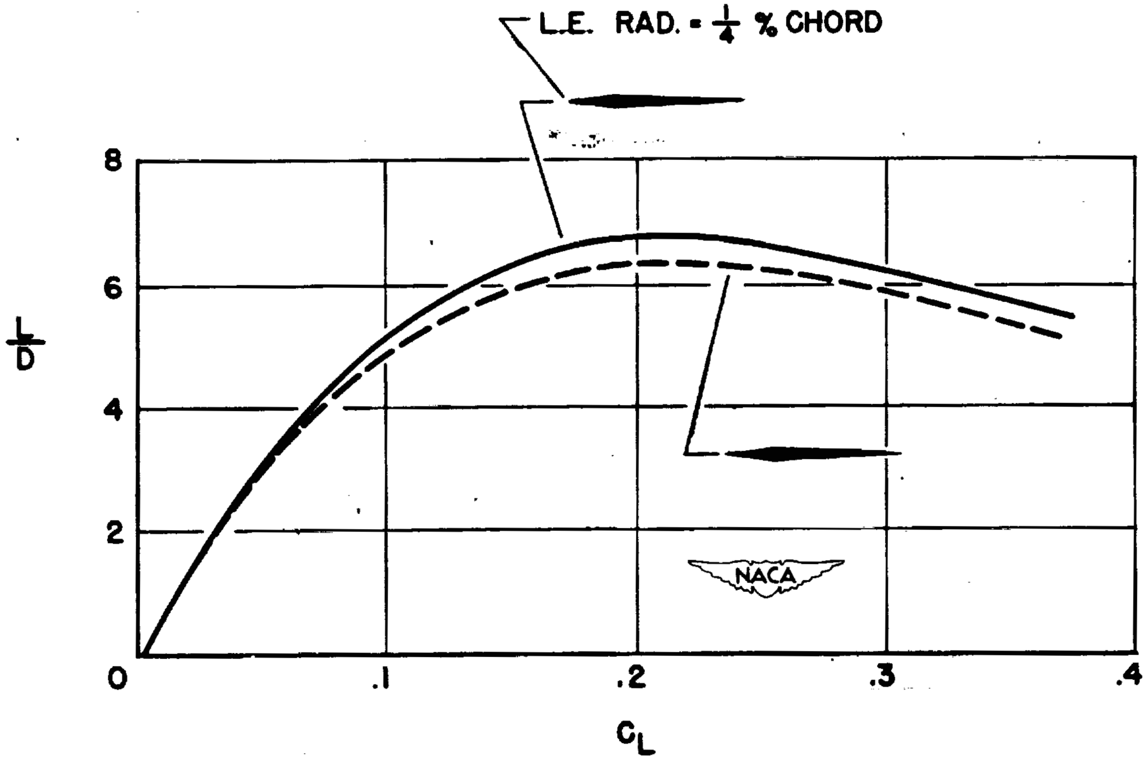

Figure 5.- The effect of leading-edge radius upon lift-drag ratio of triangular wing at a Mach number of 1.53 and a Reynolds number of 1×10^6.

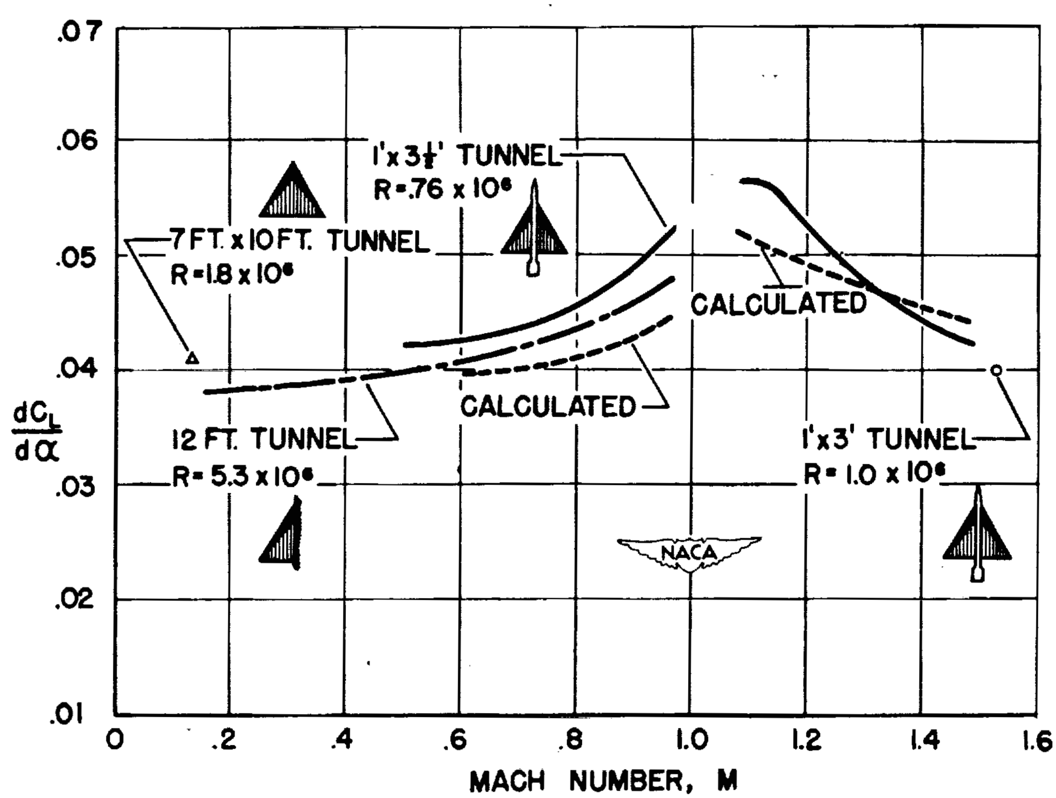

Figure 6.- The variation of Mach number with lift-curve slope of the triangular wing.