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RESEARCH MEMORANDUM

HIGH-SPEED WIND-TUNNEL INVESTIGATION OF A SWEPTBACK WING WITH AN ADDED TRIANGULAR AREA AT THE CENTER

By

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RESEARCH MEMORANDUM

HIGH-SPEED WIND-TUNNEL INVESTIGATION OF A SWEPTBACK WING WITH AN ADDED TRIANGULAR AREA AT THE CENTER

By Beverly Z. Henry, Jr.

SUMMARY

Results are presented of an investigation in the Langley 8-foot high-speed tunnel of two sweptback wings of different plan form. The purpose of the investigation was to determine the effects of the addition of a triangular area to the inboard section of a conventional sweptback wing in such a way as to produce a wing employing two stages of sweepback. Lift, drag, and pitching-moment characteristics are presented to illustrate these effects for a Mach number range of 0.40 through 0.935.

Results of the investigation indicate that the effects of the addition of the triangular area to the sweptback wing on lift and drag characteristics are small throughout the Mach number range tested. Although the changes in lift and drag characteristics are small when considered separately, a combination of the two in the lift-drag ratio results in an appreciable increase in this ratio. If a change in center-of-gravity location is assumed to accompany the addition of the triangular area, there is essentially no change in the static margin of the sweptback wing.

INTRODUCTION

A program was begun in the Langley 8-foot high-speed tunnel to determine the effects of various wing and tail configurations on the force characteristics of the D-558 airplane (reference 1). The D-558 is a research airplane used for the investigation of the aerodynamic phenomena within the transonic region.

In a continuation of this program, an investigation has been made at high subsonic speeds of wing-alone characteristics to determine the effects of adding a triangular area to the center of the sweptback wing of reference 1 to increase the angle of sweep of the inboard section of the wing and to form, in effect, a wing employing two stages of sweep. Throughout this report, the biswept wing will be referred to as the sweptback wing with glove.

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The gloved wing was designed to obtain the increase in critical speed of the sweptback wing without encountering the adverse low-speed tip characteristics normally accompanying large degrees of sweep. In addition to increasing the sweep of the inboard sections, the addition of the glove to the sweptback wing provides a lower thickness ratio at the root sections than would be obtained with a mono-swept wing for the same wing thicknesses. This decrease in thickness ratio occurs since the addition of the glove involves no change in wing thickness.

APPARATUS

Model.- For the purpose of this investigation, the sweptback wing of reference 1 was fitted with a triangular section over the inboard section of the leading edge to form, in effect, a wing with two stages of sweepback. Details of the resulting wing are shown in figure 1. Dimensions for the sweptback wing and for the sweptback wing with glove are shown in table I, and wing ordinates for the sweptback wing with glove are given in table II. These wing ordinates are for sections laid out parallel to the plane of symmetry.

The D-558-1, for which some comparative data appear, utilizes a wing which employs no sweep, an NACA 65-110 section, and an aspect ratio of 4.2.

The maximum uncorrected Mach number for this investigation was approximately 0.935. The Reynolds number for the tests of the sweptback wing with glove varied from approximately 1.5×10^6 to 2.2×10^6. Computations of Reynolds number were based on the mean aerodynamic chord of the sweptback wing with glove.

Model support and balance.- For this investigation, a sting-strut support system was used. In order to utilize an existing strain-gage balance, the wing to be tested was mounted on the D-558-1 fuselage of reference 2. Details of the model support system are shown in figure 2, and a complete description of the system is given in reference 2.

With the model aerodynamically loaded, there was a small deflection of the support sting. This deflection changes the angle of attack of the model slightly and necessitates an angle-of-attack measurement at each test point. These measurements were obtained by means of a cathetometer mounted on the side of the tunnel.

CORRECTIONS

The effect of temperature on the strain gages was determined from static-load and temperature calibration tests. The temperature was measured at each test point and the corrections determined in static tests were applied.

The data are presented for uncorrected Mach numbers up to about 0.935, where choking occurred at the support strut. The data are believed to be unaffected by choke phenomena as the strut is well to the rear of the model, and pressure measurements indicated no irregularities in the velocity field in the model region at this Mach number.

The expressions available for the effects of tunnel-wall interference are inadequate for the accurate determination of such effects for swept wings. Therefore, no corrections for these effects have been applied to the results of this investigation. From reference 2 an indication of the order of magnitude of the correction to be applied to dynamic pressure and Mach number is shown for a Mach number of 0.93 to be approximately 1 percent for a straight-wing configuration. The corrections will probably be much less for the swept configuration.

RESULTS AND DISCUSSION

For the purpose of presenting data for the wings only, data of tests of fuselage alone have been subtracted from the data of the wing-fuselage combination; therefore, all wing data presented herein contain fuselage-interference effects. Comparisons have been made to illustrate the effects of the addition of the glove to the sweptback wing. Limited comparisons have also been made to the unswept wing as used with the D-558-1 airplane of reference 2. All data are presented for a Mach number range of 0.400 to 0.935.

The variations of lift coefficient with angle of attack for various Mach numbers for the sweptback wing and the sweptback wing with glove are shown in figure 3. In figure 4 are shown the variations of lift coefficient with Mach number for various angles of attack for the two wings. Figure 5 shows the variations of the slopes of the lift curves with Mach number for the two wings at two altitude conditions. A comparison of the variation of lift coefficient with Mach number for angles of attack corresponding to a lift coefficient of about 0.1 at a Mach number of 0.6 is shown in figure 6. These preceding data indicate that the addition of the glove to the sweptback wing has a very small effect on the lift characteristics of the wing.

The variations of drag coefficient with lift coefficient for various Mach numbers are shown in figure 7 for the sweptback wing and the sweptback wing with glove. The variations of drag coefficient with Mach number for various angles of attack for the two wings are shown in figure 8. These data indicate that the effects of the addition of the glove on drag characteristics are negligible up to a Mach number of 0.90 with a reduction in drag above this point.

In figure 9 the lift-drag ratios for the wings are plotted against lift coefficient for two Mach numbers. These data indicate that, although the changes in lift and drag characteristics due to the addition of the glove are small when considered separately, a combination of the two in the lift-drag ratio results in an appreciable increase in this ratio. In the low Mach number region, it is indicated that the maximum lift-drag ratio of the sweptback wing with glove is about 26 percent greater than that for the sweptback wing. In the high Mach number range, the ratio for the sweptback wing with glove is about 37 percent higher than that for the sweptback wing.

In figure 10 are shown the variations of pitching-moment coefficient with lift coefficient for various Mach numbers for the two wings. The variations of pitching-moment coefficient with Mach number for various angles of attack are shown in figure 11. For the purpose of these plots the pitching moments were computed about the 25-percent point of the mean aerodynamic chord for the sweptback wing, and about the 48-percent point of the mean aerodynamic chord for the sweptback wing with glove. This point on the sweptback wing with glove has been computed to give the same static margin as the sweptback wing at a Mach number of 0.6 under sea-level conditions. These data indicate a stable condition for the two wings through the Mach number range tested.

The foregoing data indicate that there is no appreciable change in force-break characteristics due to the addition of the glove to the sweptback wing.

Unpublished data obtained in the Langley 8-foot high-speed tunnel have indicated that the changes in force characteristics defining the force break first appear at the outboard section of a sweptback wing. These data indicate that these changes can be attributed to the shock-wave configuration of the sweptback wing which places the shock wave at the root sections well to the rear. The addition of a triangular area ahead of these sections probably has only a secondary effect on the shock-wave configuration and a correspondingly small effect on the force characteristics.

In order to illustrate more clearly the small effects of the addition of the glove to the sweptback wing, incremental lift, drag, and pitching-moment coefficients as functions of Mach number for various angles of attack are presented in figure 12. For the purpose of this plot, the pitching moments for both the sweptback wing and the sweptback wing with glove are presented about the 25-percent point of the mean aerodynamic chord of the sweptback wing. These data indicate that, if the addition of the glove is considered as a modification involving no change in center-of-gravity location, the effects on pitching-moment coefficient are comparatively large. If, however, the addition is considered as a redesign, involving a change in center-of-gravity location, as shown by preceding data computed about the 48-percent point of the mean aerodynamic chord of the sweptback wing with glove, the effects on pitching-moment coefficient are small. The incremental effects of the addition of the glove on lift and drag characteristics are small. At an angle of attack of 6°, the highest test angle, the change in lift coefficient is less than 0.03 and the change in drag coefficient is less than 0.005. The change in pitching-moment coefficient for this angle of attack is about 0.035; for smaller angles of attack the changes are correspondingly smaller.

CONCLUDING REMARKS

The results of this investigation indicate that the effect of the addition of a triangular area to the inboard section of the sweptback wing on lift characteristics is small throughout the Mach number range tested. The effect on drag characteristics is small up to a Mach number of 0.90 with a reduction in drag above this point. At an angle of attack of 6° the change in lift coefficient is less than 0.03 and the change in drag coefficient is less than 0.005.

Although the changes in lift and drag characteristics due to the addition of the triangular area are small when considered separately, a combination of the two in the lift-drag ratio results in an appreciable increase in this ratio. The increase in maximum lift-drag ratio in the low Mach number range is about 26 percent and in the high Mach number range is about 37 percent.

If no change is assumed in the center-of-gravity location, the change in pitching-moment coefficient due to the addition of the triangular area is about 0.035 at an angle of attack of 6°. If a change in center-of-gravity location is assumed to accompany the addition of the triangular area, there is essentially no change in the static margin of the sweptback wing.

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Langley Field, Va.

REFERENCES

1. Wright, John B., and Loving, Donald L.: High-Speed Wind-Tunnel Tests of a $\frac{1}{16}$-Scale Model of the D-558 Research Airplane. Lift and Drag Characteristics of the D-558-1 and Various Wing and Tail Configurations. NACA RM No. L6J09, 1946.

2. Wright, John B.: High-Speed Wind-Tunnel Tests of a $\frac{1}{16}$-Scale Model of the D-558 Research Airplane. Basic Longitudinal Stability of the D-558-1. NACA RM No. L7K24, 1948.

TABLE I

DIMENSIONS OF SWEPTBACK WING AND SWEPTBACK WING WITH GLOVE

	Sweptback wing	Sweptback wing with glove
Wing section	65-110	(See Table II)
Aspect ratio	4.17	3.00
Taper ratio	1.85	2.59 (inboard panel)
		1.33 (outboard panel)
Dihedral, deg	4.0	4.0
Sweep angle (50-percent chord), deg	35	48.6 (inboard panel)
		35.0 (outboard panel)
Span, in.	18.76	11.4 (inboard panel)
Area, sq ft	0.587	0.799
Mean aerodynamic chord, in.	4.656	7.07
Root chord, in.	5.94	11.00 (inboard panel)
		4.25 (outboard panel)
Tip chord, in.	3.20	4.25 (inboard panel)
		3.20 (outboard panel)
Longitudinal location of 25-percent point of mean aerodynamic chord from forward point of sweptback wing with glove	9.82	7.54

TABLE II

AIRFOIL ORDINATES OF $\frac{1}{16}$-SCALE SWEPTBACK WING WITH GLOVE

[All dimensions in percent chord; sections laid out parallel to plane of symmetry]

Chord station	20 percent b/2			40 percent b/2			60 percent b/2			80 percent b/2		
	Upper	Lower	Total	Upper	Lower	Total	Upper	Lower	Total	Upper	Lower	Total
0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	.665	.582	1.247	.828	.799	1.627	1.291	.788	2.079	1.325	1.219	2.544
5	.998	.769	1.767	1.183	1.095	2.278	1.751	1.225	2.976	1.748	1.695	3.443
7.5	1.221	.936	2.163	1.420	1.272	2.692	2.188	1.532	3.720	2.172	2.066	4.238
10	1.455	1.040	2.495	1.716	1.450	3.166	2.495	1.751	4.246	2.543	2.331	4.874
15	1.830	1.247	3.077	2.012	1.746	3.758	3.282	2.188	5.470	3.020	2.808	5.828
20	2.121	1.435	3.556	2.396	2.012	4.408	3.720	2.626	6.346	3.497	3.126	6.623
25	2.308	1.663	3.971	2.663	2.219	4.882	4.158	2.845	7.003	3.762	3.444	7.206
30	2.432	1.871	4.303	2.870	2.367	5.237	4.376	3.063	7.439	4.079	3.550	7.629
35	2.578	1.975	4.553	3.047	2.604	5.651	4.464	3.414	7.878	4.291	3.603	7.894
40	2.703	2.141	4.844	3.254	2.663	5.917	4.595	3.501	8.096	4.397	3.656	8.053
45	2.765	2.266	5.031	3.343	2.811	6.154	4.639	3.501	8.140	4.291	3.603	7.894
50	2.848	2.349	5.197	3.491	2.870	6.361	4.551	3.457	8.008	4.291	3.497	7.788
55	2.890	2.412	5.302	3.432	2.870	6.302	4.376	3.326	7.702	4.132	3.338	7.470
60	2.786	2.370	5.156	3.402	2.751	6.153	4.245	3.063	7.308	3.921	3.073	6.994
65	2.703	2.266	4.969	3.254	2.604	5.858	3.807	2.757	6.564	3.497	2.702	6.199
70	2.578	2.100	4.678	2.959	2.426	5.385	3.282	2.407	5.689	3.020	2.384	5.424
75	2.349	1.871	4.220	2.574	2.130	4.704	2.713	2.013	4.726	2.596	1.960	4.556
80	1.996	1.663	3.659	2.071	1.716	3.787	2.276	1.444	3.720	2.013	1.589	3.602
85	1.601	1.351	2.952	1.568	1.183	2.751	1.751	.963	2.714	1.430	1.060	2.490
90	1.185	.915	2.100	.888	.680	1.568	1.094	.525	1.619	.901	.689	1.590
95	.707	.603	1.310	.355	.296	.651	.438	.263	.701	.530	.371	.901
100	.187	.416	.603	0	0	0	0	0	0	0	0	0

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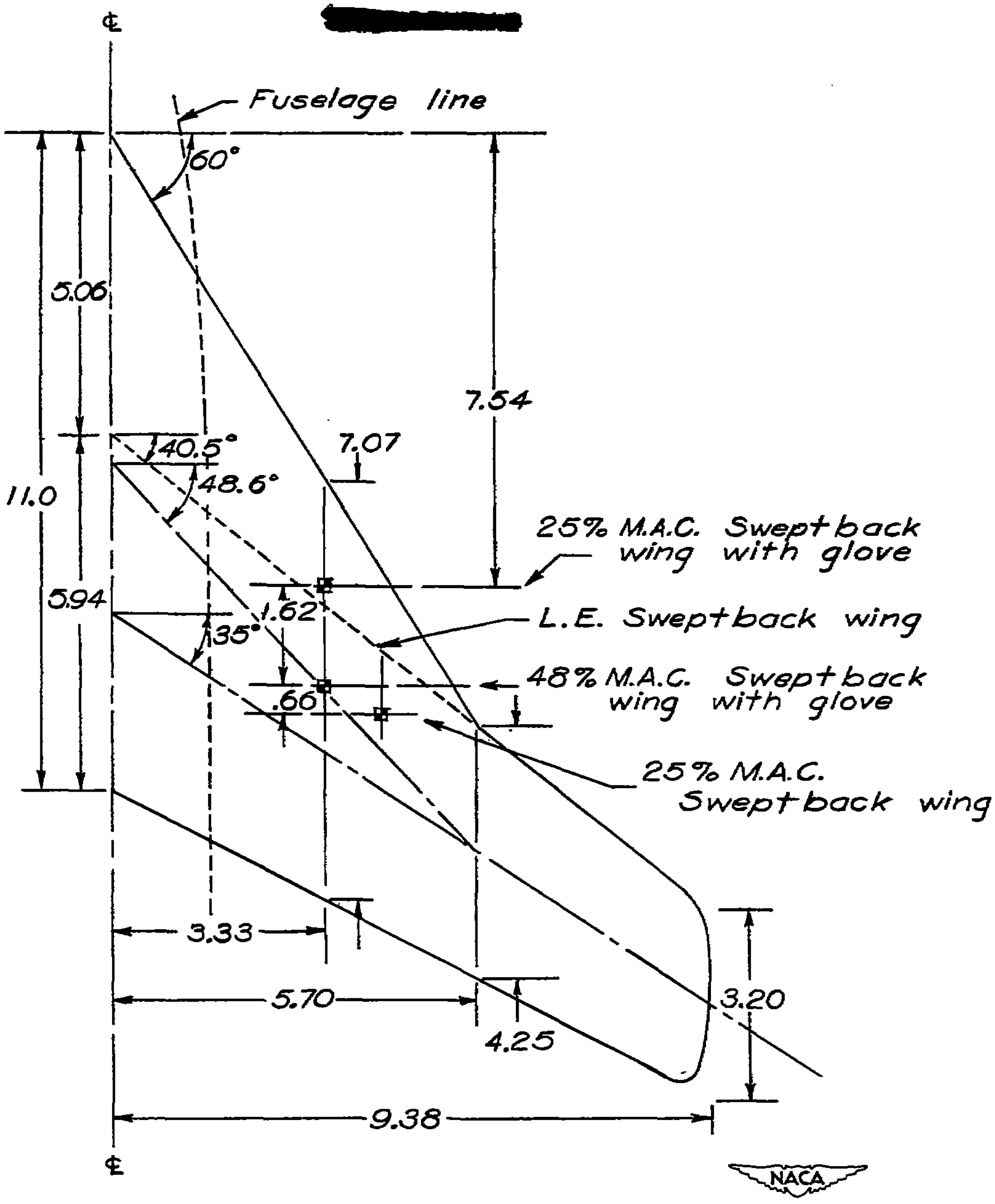

Figure 1.– Drawing of $\frac{1}{16}$ -scale sweptback wing with glove as fitted to the D-558 model for testing in the Langley 8-foot high-speed tunnel. All dimensions in inches.

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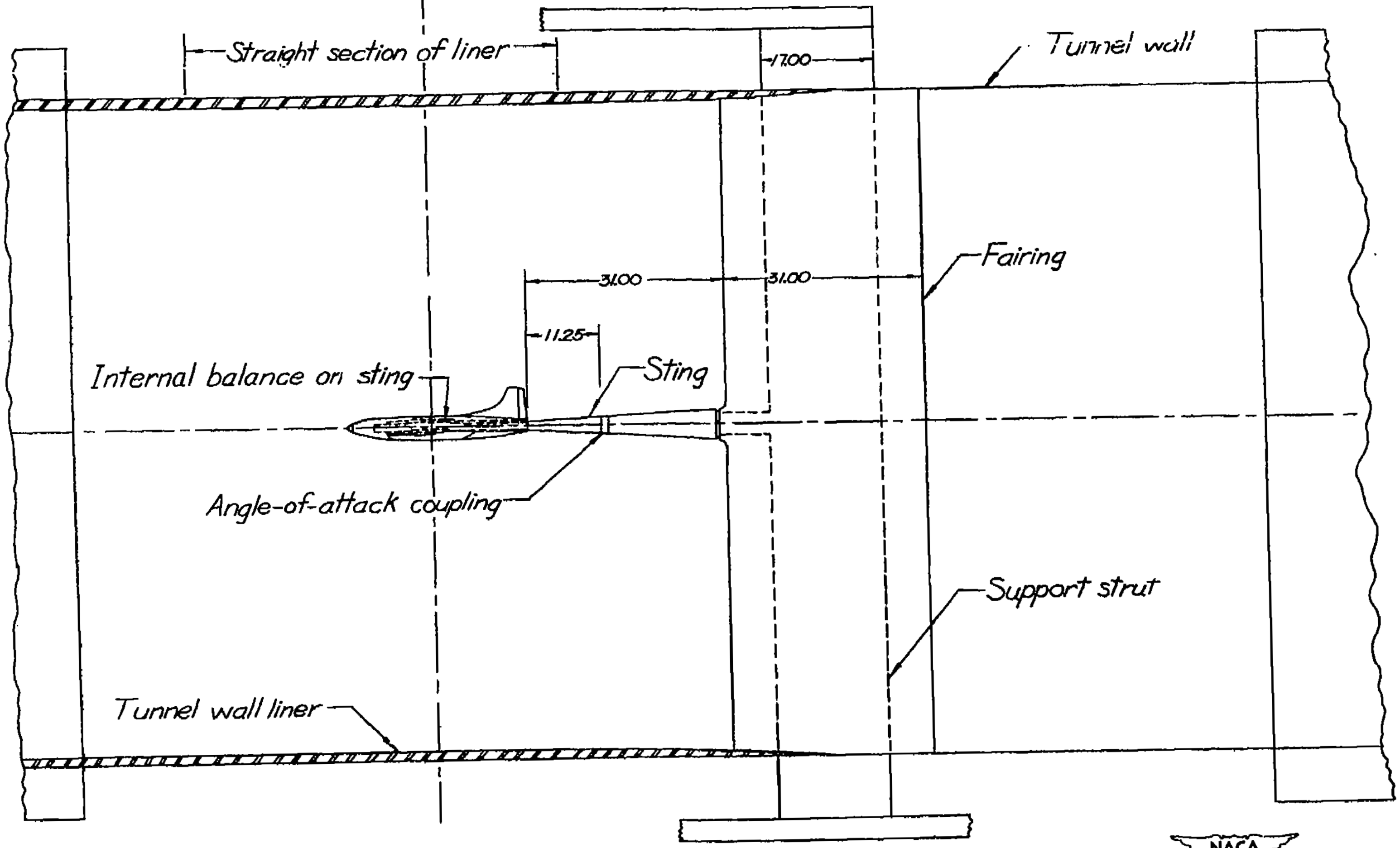

Figure 2.- Model on sting support in the Langley 8-foot high-speed tunnel. All dimensions in inches.

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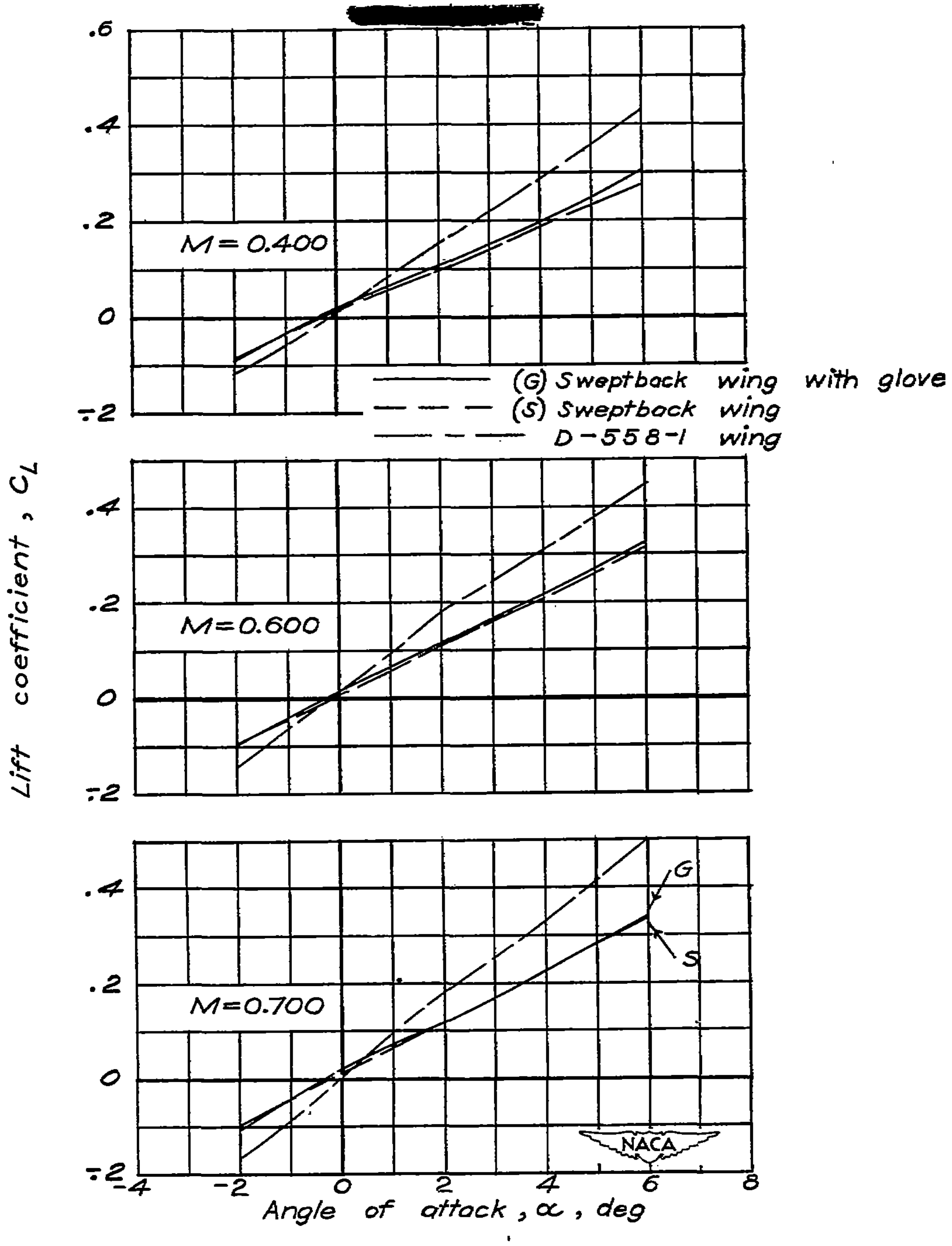

Figure 3.— Variations of lift coefficient with angle of attack for various Mach numbers for the sweptback wing and the sweptback wing with glove with comparable plots of the D-558-1 wing.

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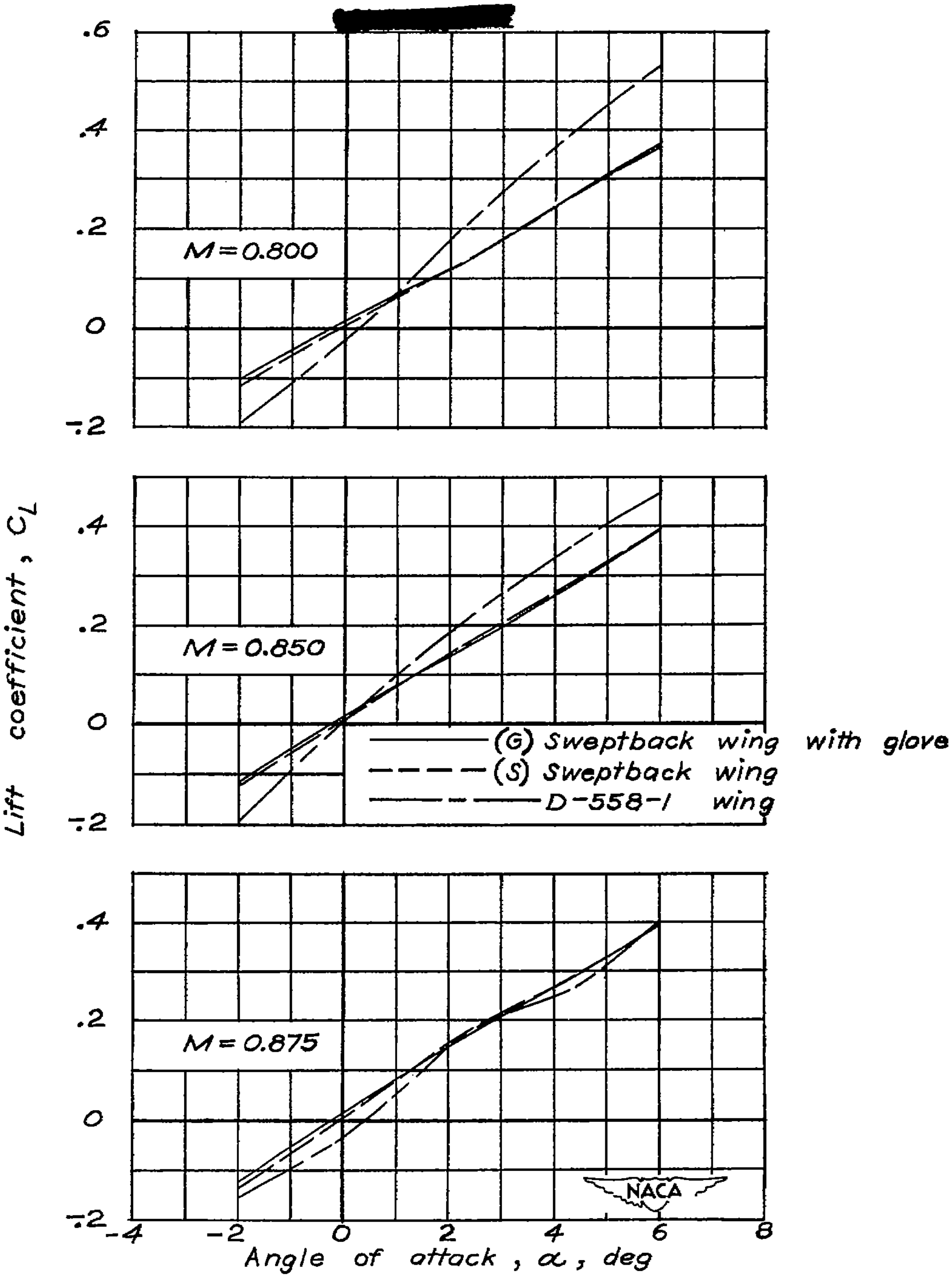

Figure 3.— Continued.

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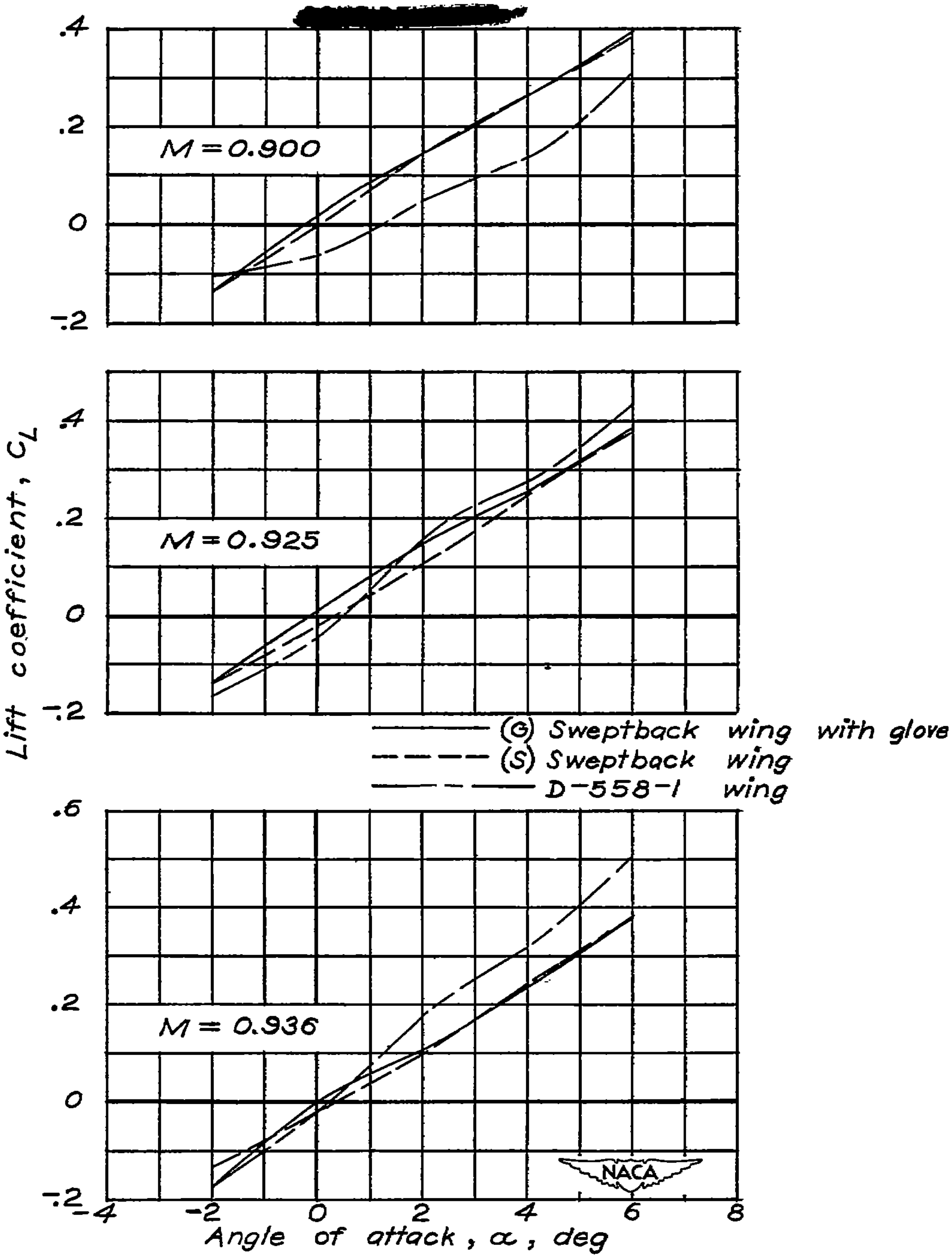

Figure 3.— Concluded.

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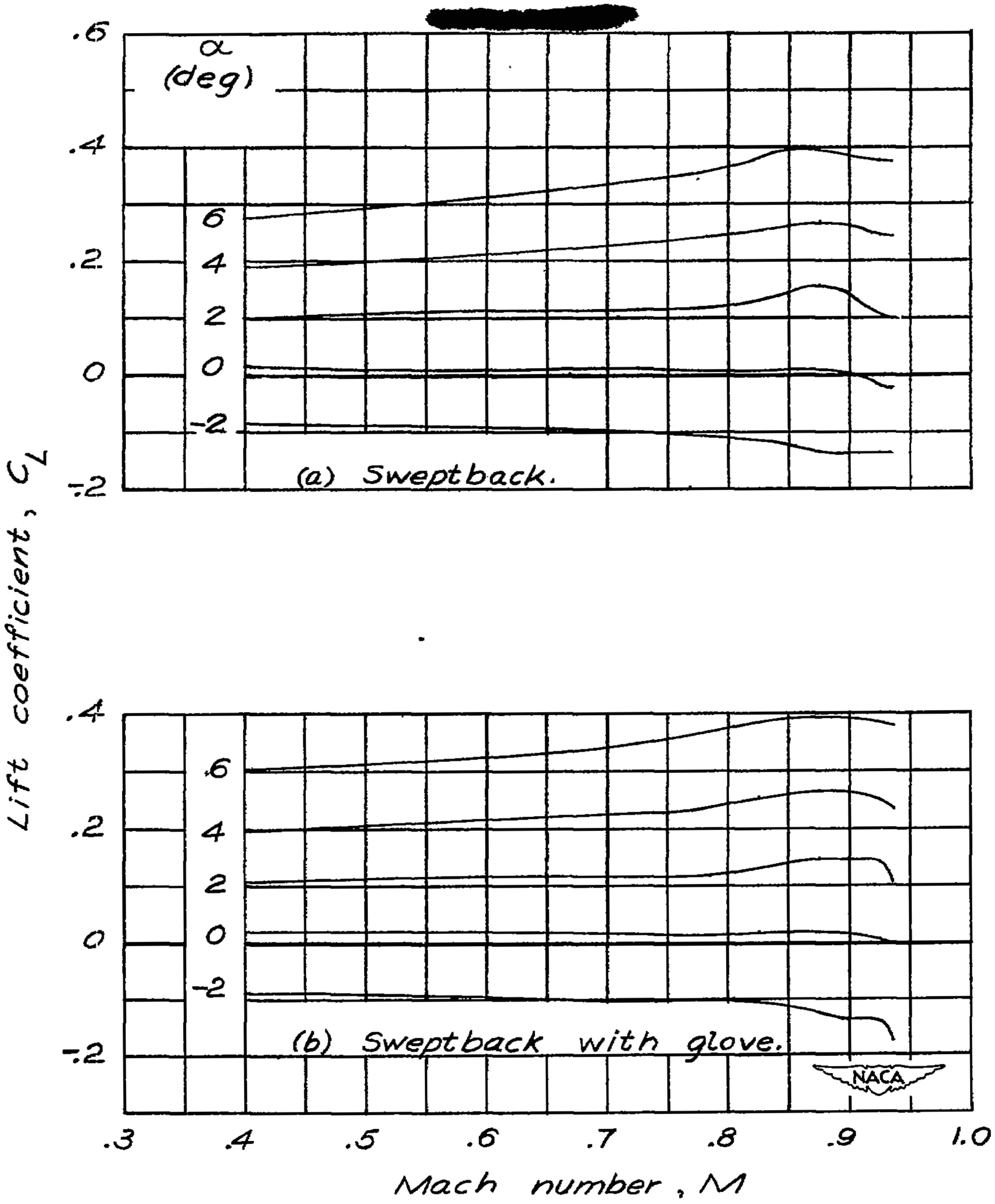

Figure 4.-Variation of lift coefficient with Mach number for various angles of attack for the sweptback wing and the sweptback wing with glove.

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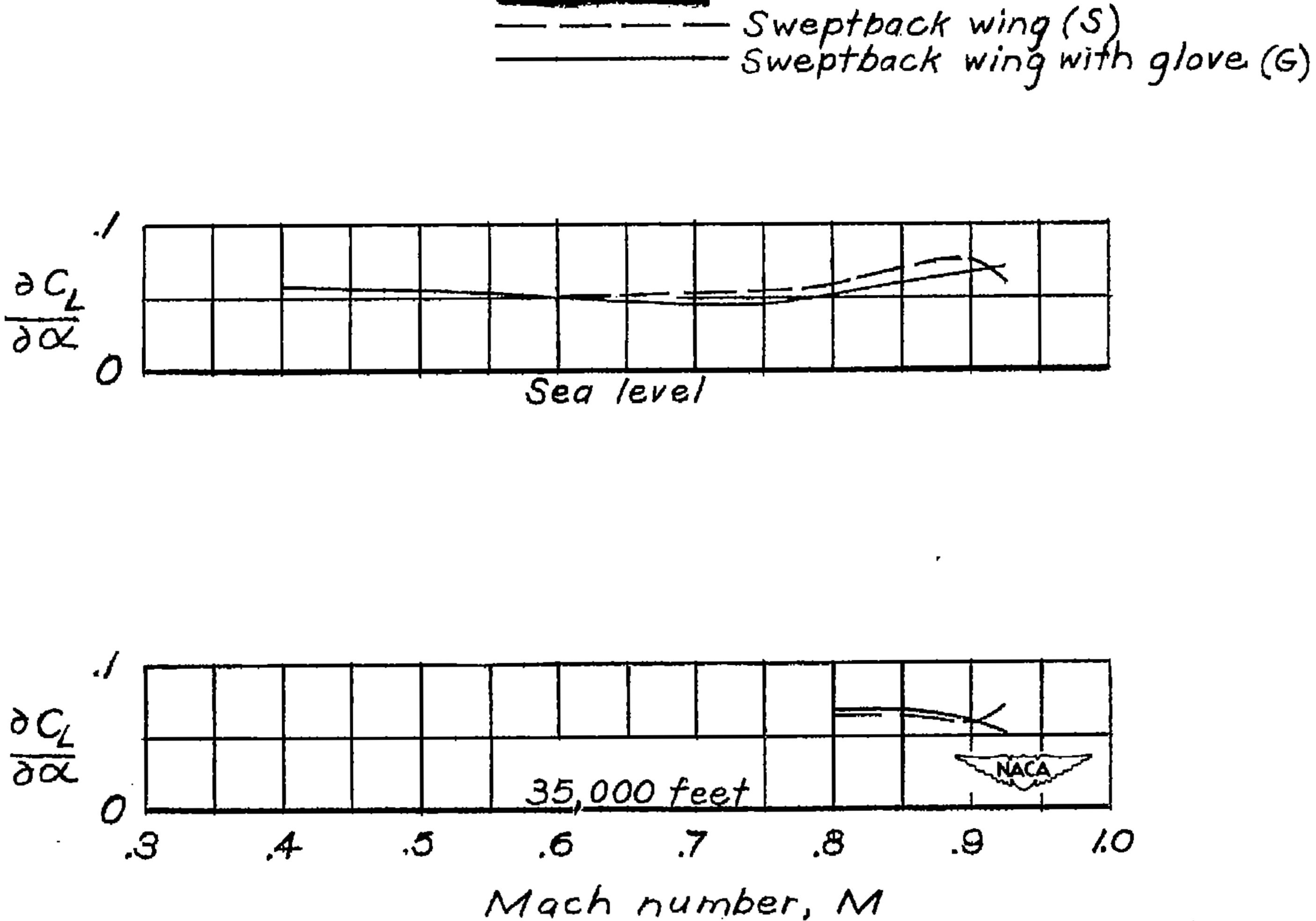

Figure 5.— Variation of the slope of the lift curve with Mach number for the sweptback wing and the sweptback wing with glove for two altitude conditions.

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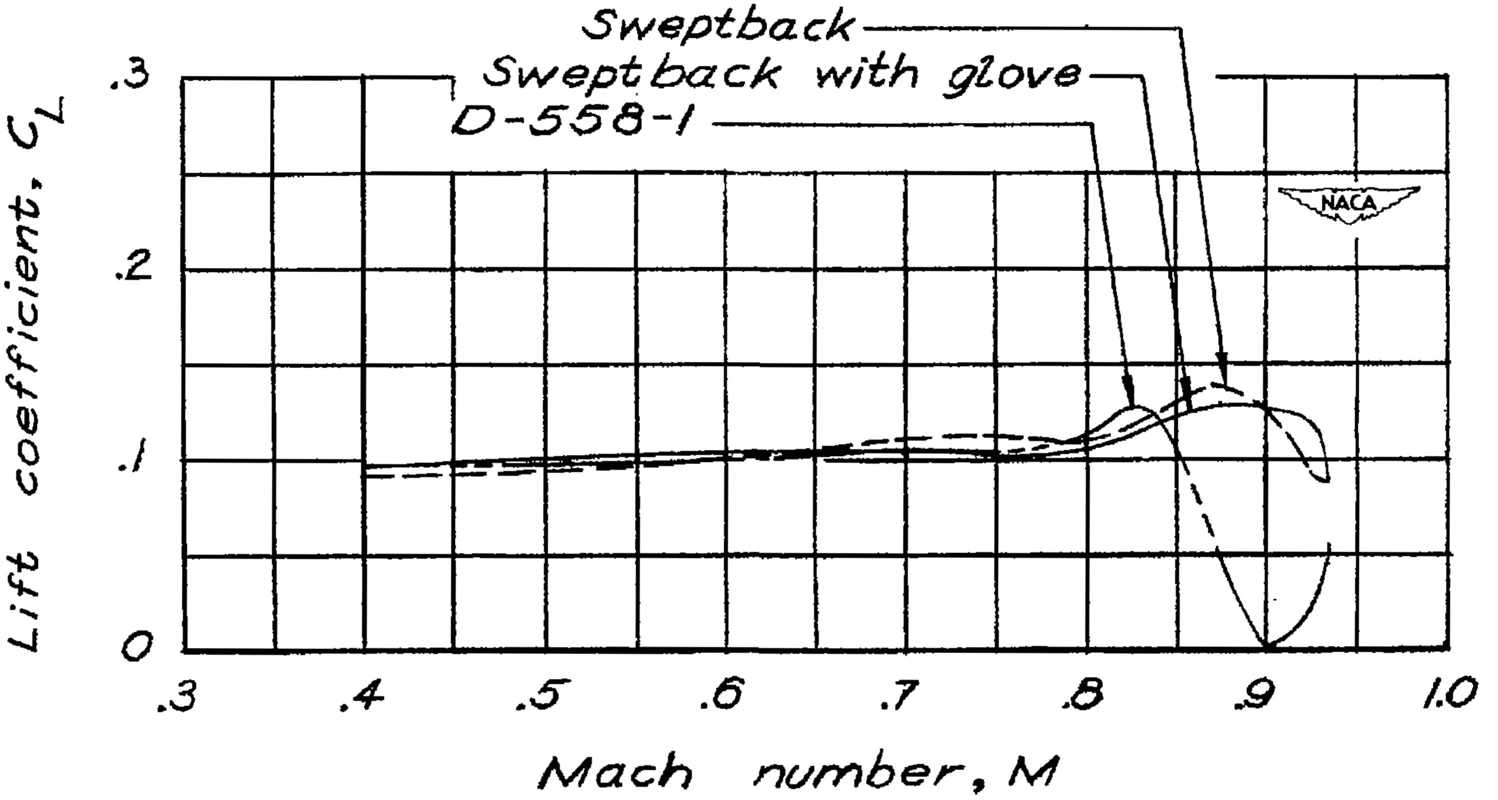

Figure 6.- Variation of lift coefficient at constant angles of attack with Mach number for the sweptback wing and the sweptback wing with glove. D-558-1 data also shown.

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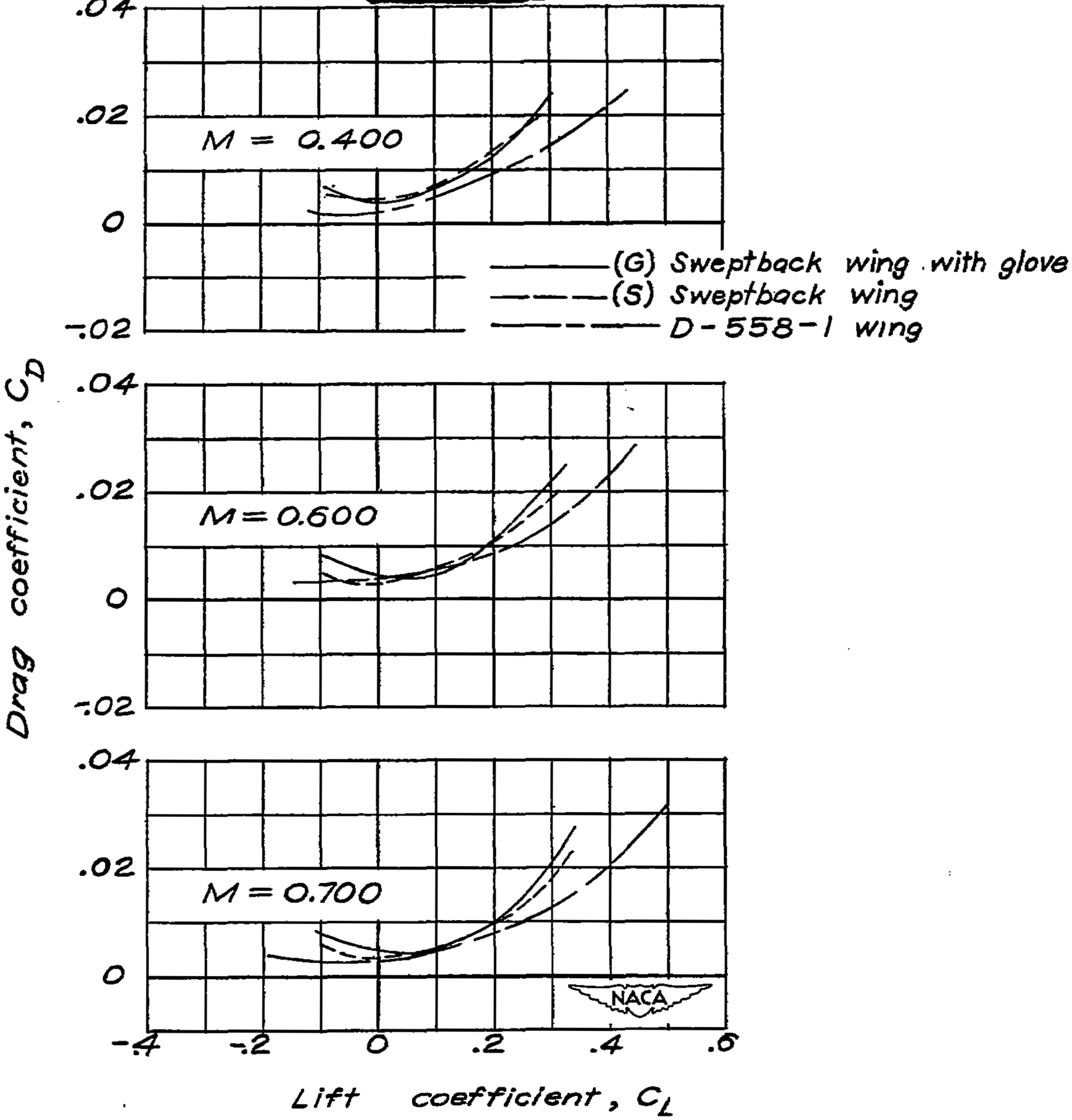

Figure 7.— Variation of drag coefficient with lift coefficient for various Mach numbers for the sweptback wing and the sweptback wing with glove with comparable plots of the D-558-1 wing.

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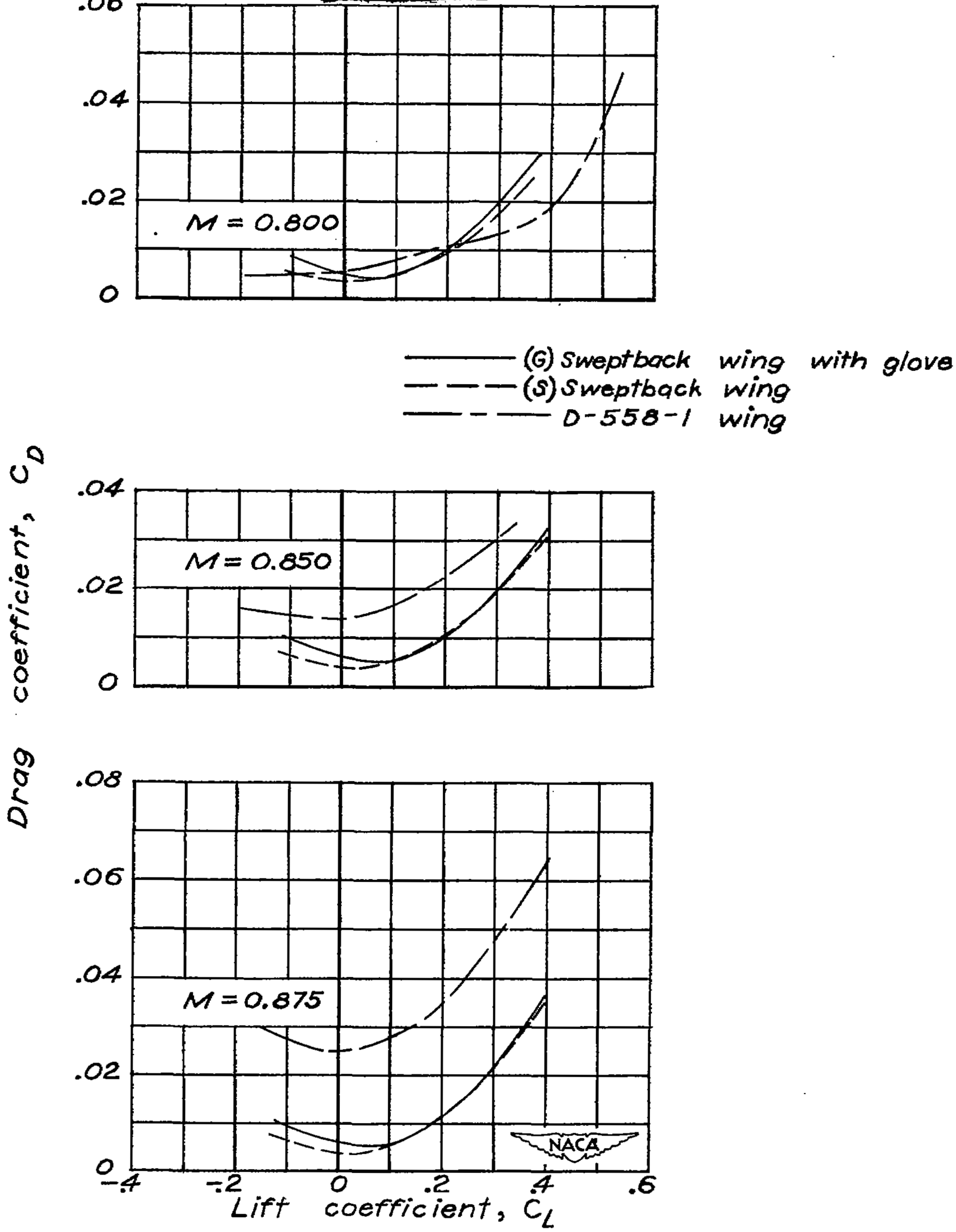

Figure 7.—Continued.

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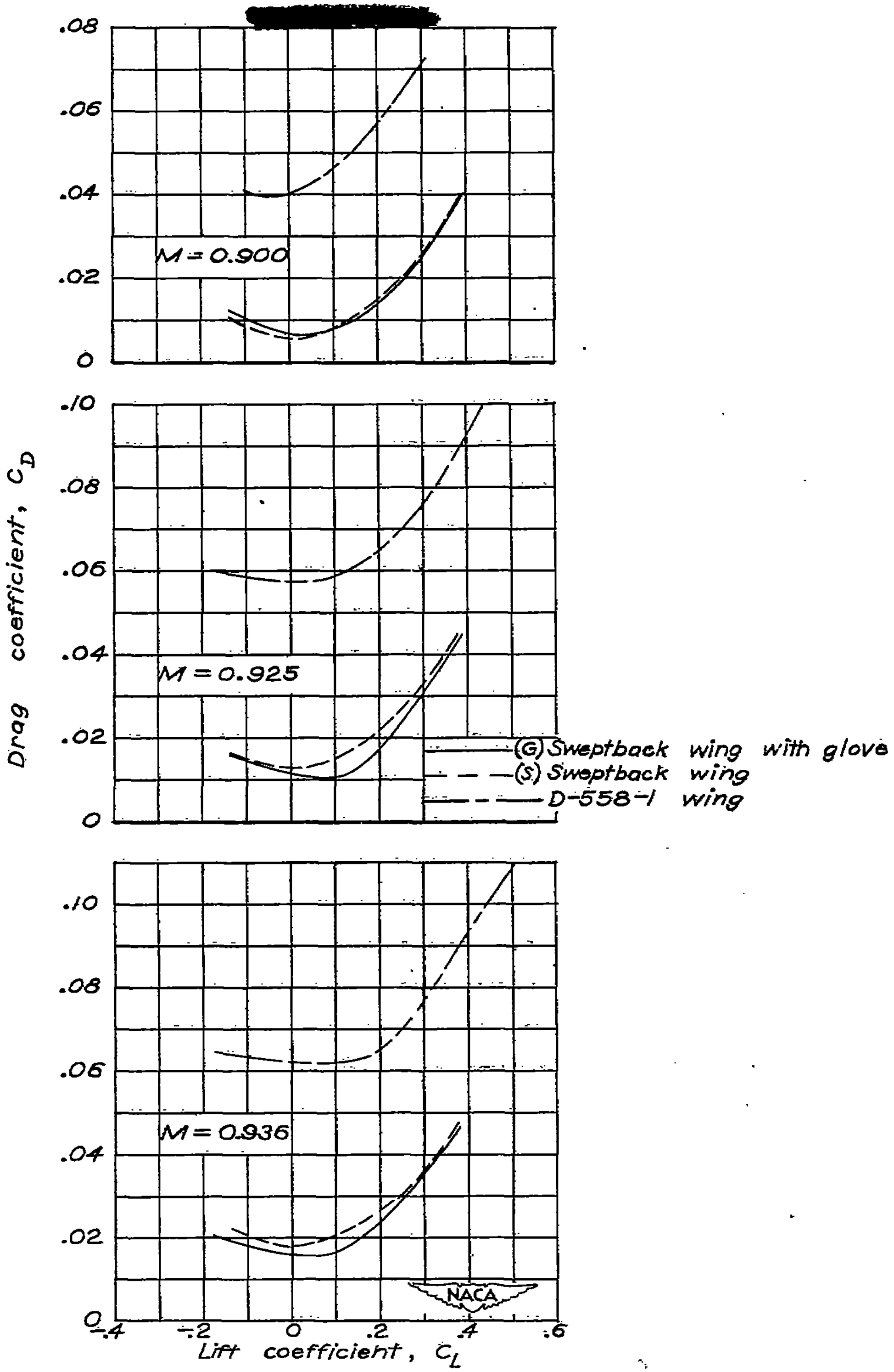

Figure 7.— Concluded.

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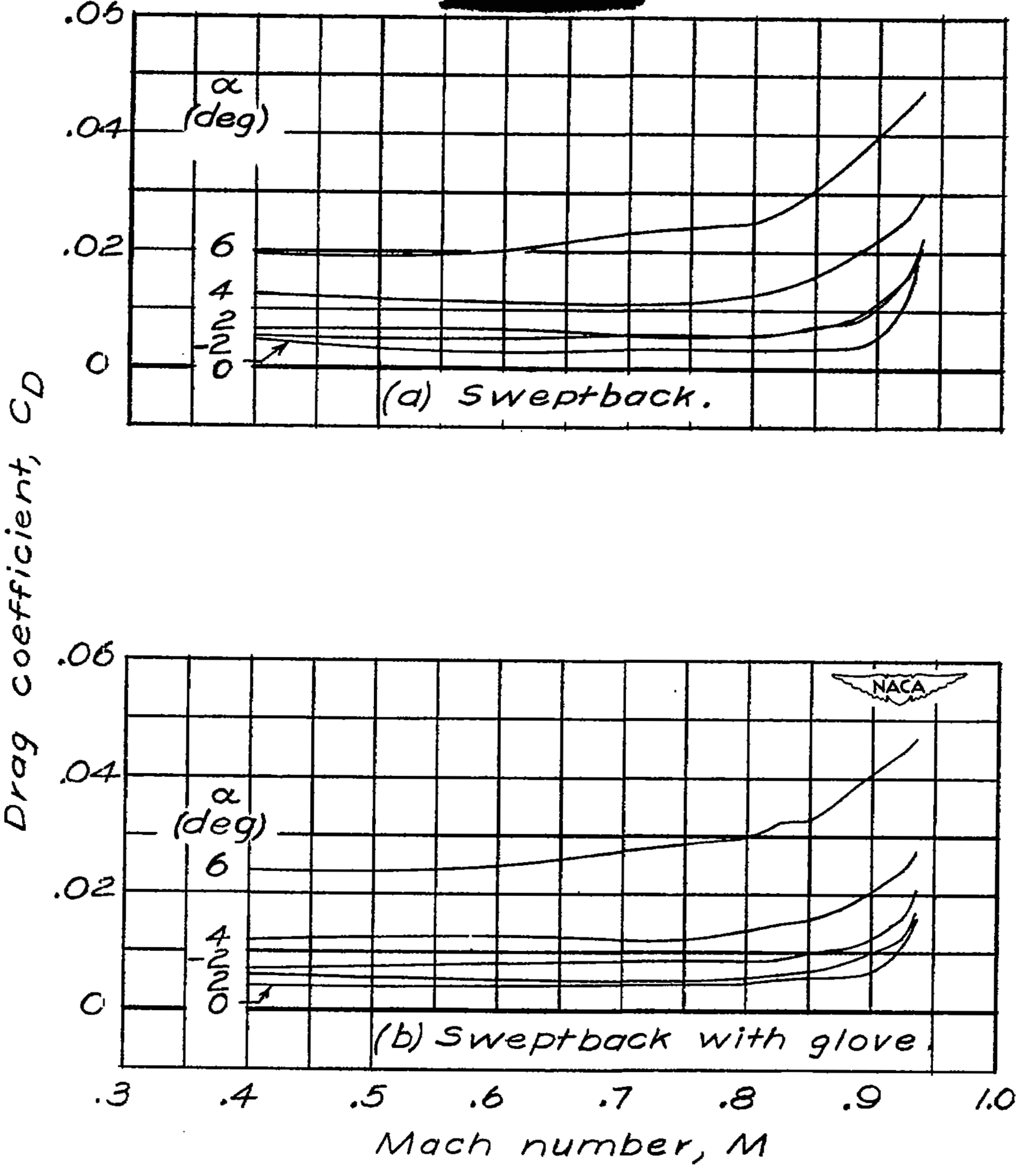

Figure 8.- Variation of drag coefficient with Mach number for various angles of attack for the sweptback wing and the sweptback wing with glove.

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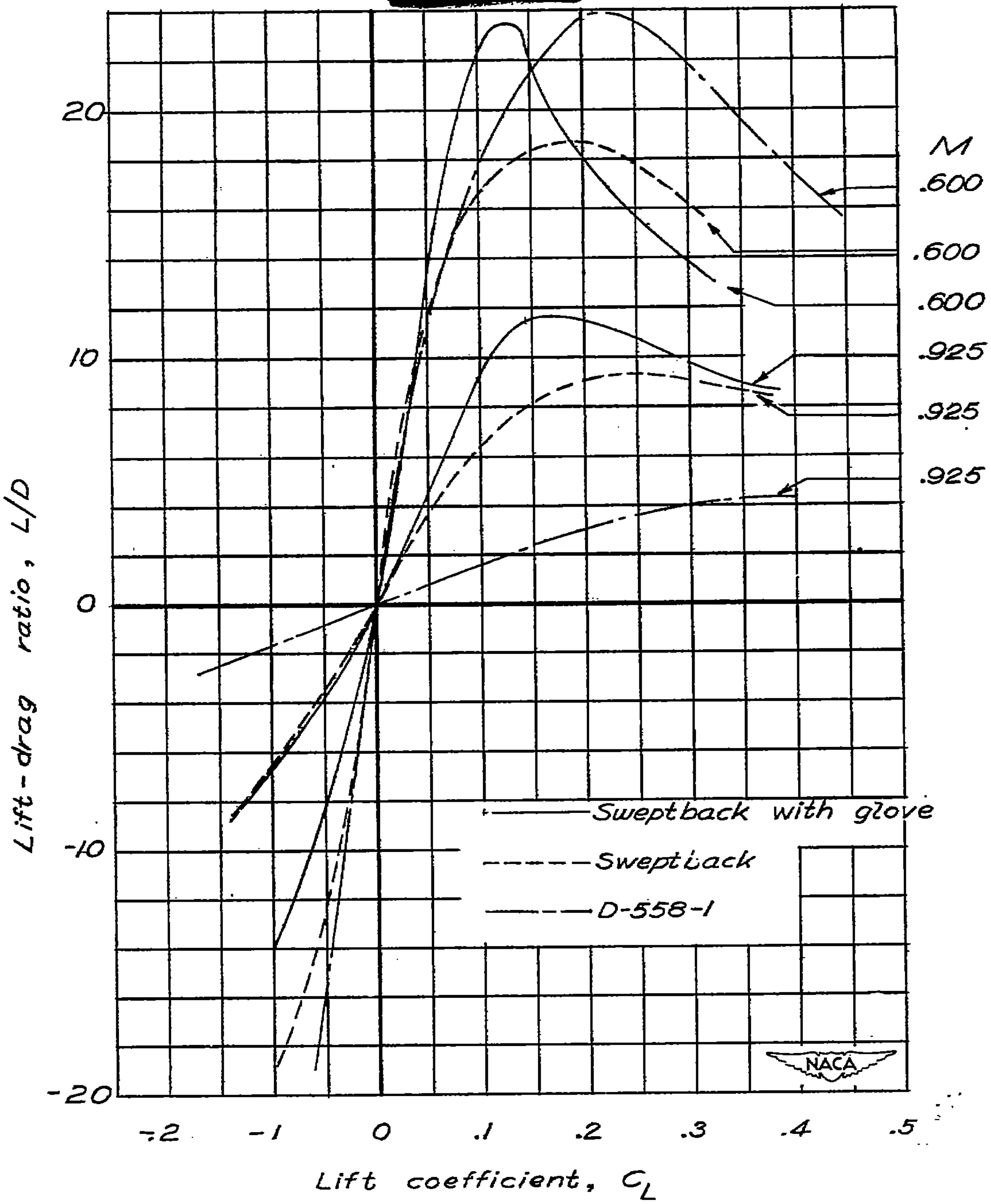

Figure 9.- Variation of lift-drag ratio with lift coefficient for two Mach numbers for the sweptback wing and the sweptback wing with glove with comparable data for the D-558-1 wing.

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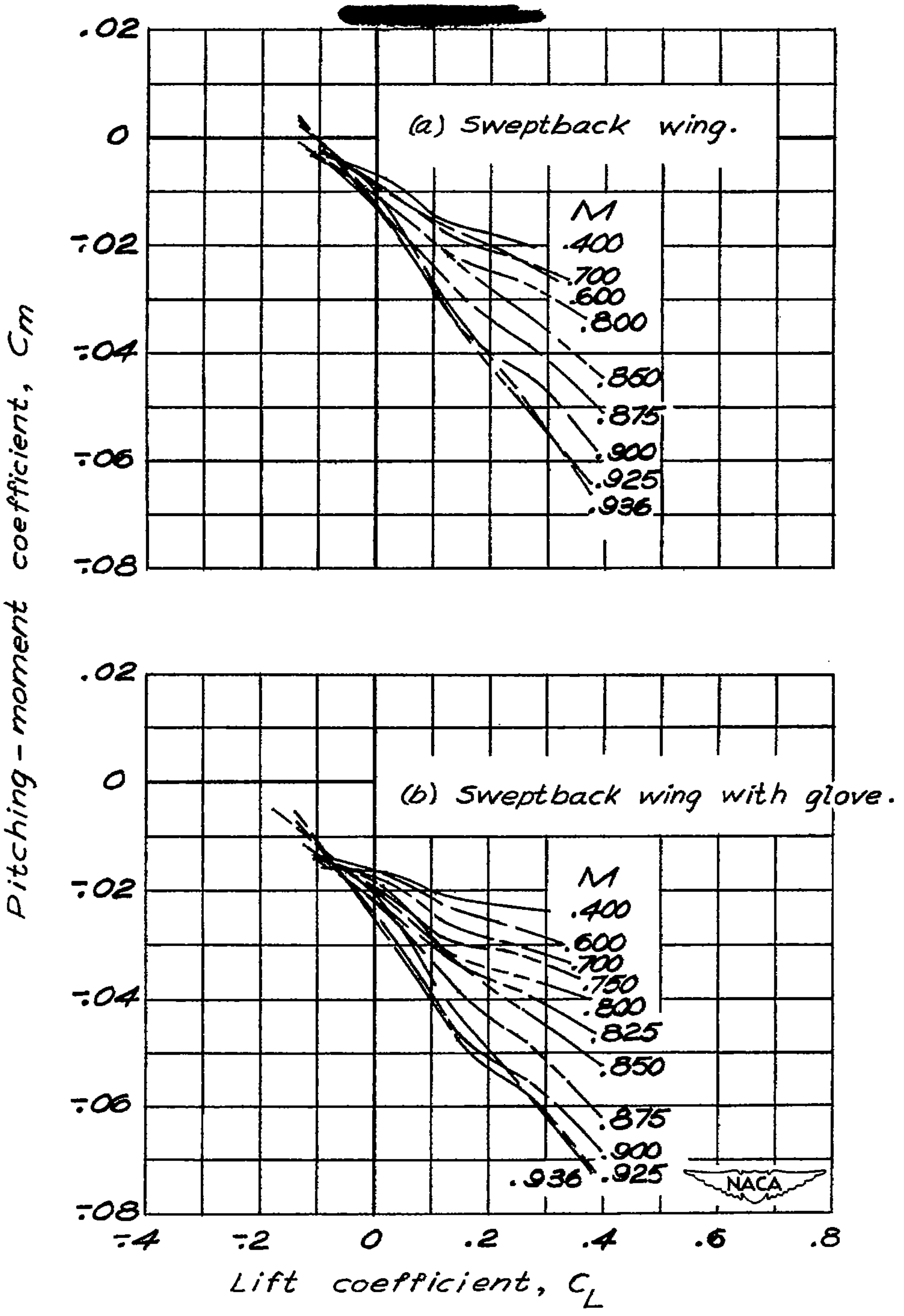

Figure 10.-Variation of pitching-moment coefficient with lift coefficient for various Mach numbers for the sweptback wing and the sweptback wing with glove.

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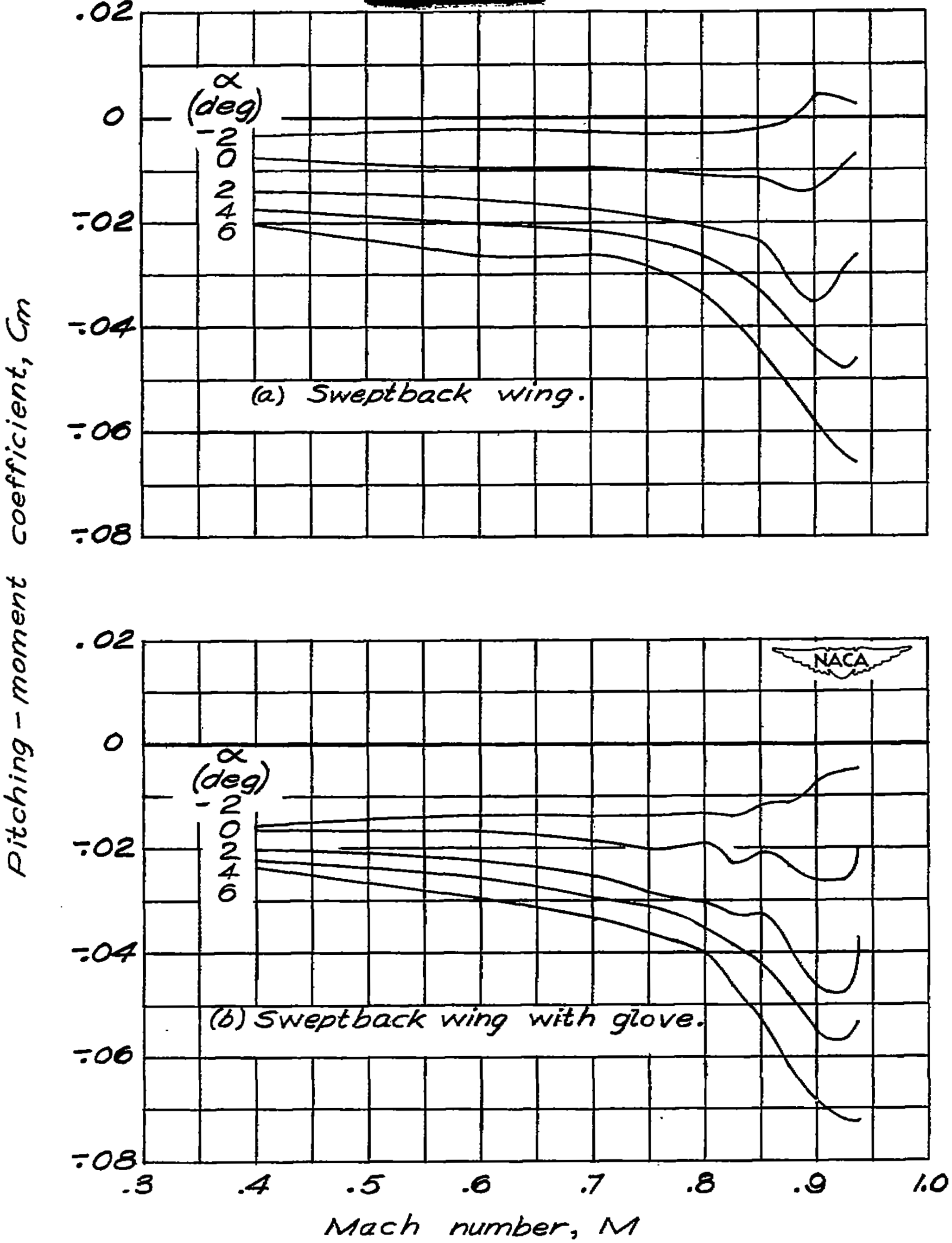

Figure 11.-Variation of pitching-moment coefficient with Mach number for various angles of attack for the sweptback wing and the sweptback wing with glove.

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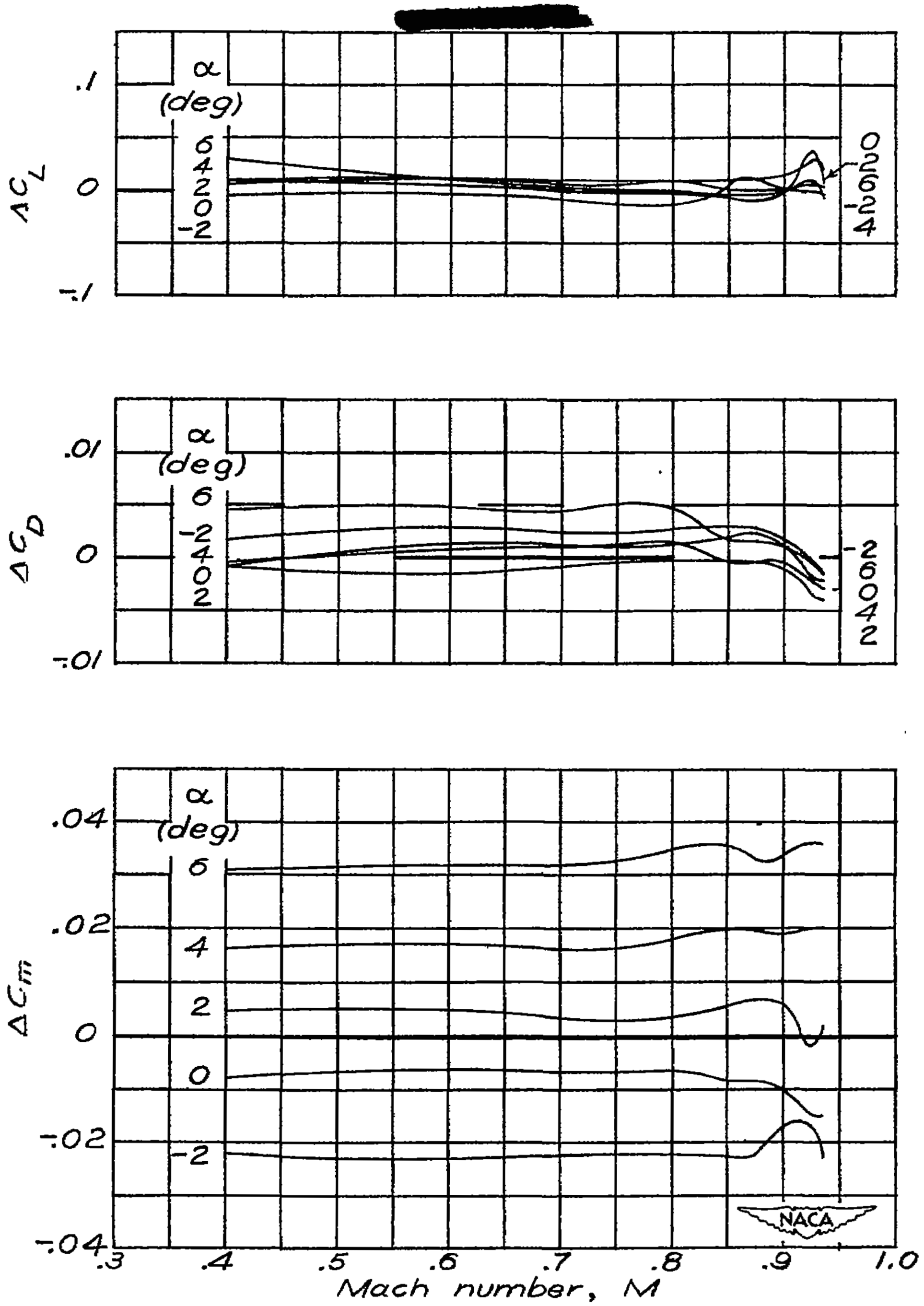

Figure 12.- Variation of incremental lift, drag, and pitching-moment coefficients due to the addition of the glove to the sweptback wing with Mach number for various angles of attack.

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