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TECHNICAL MEMORANDUM
X-126

EFFECTS OF THREE SPANWISE TWIST VARIATIONS ON THE LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF A THIN 45° SWEPTBACK HIGHLY TAPERED WING AT TRANSONIC SPEEDS

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TECHNICAL MEMORANDUM X-126

EFFECTS OF THREE SPANWISE TWIST VARIATIONS ON THE LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF A THIN 45° SWEPTBACK HIGHLY TAPERED WING AT TRANSONIC SPEEDS*

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SUMMARY

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Tests were conducted at transonic speeds on four wings: an untwisted wing to serve as a reference, and wings with linear, quadratic, and cubic twist variations across the span. All of the twisted wings had 0° twist at 10 percent of the semispan and 6° washout at the tip. The tests covered a Mach number range from 0.80 to 1.20 and angle-of-attack range from -4° to 20°. Data were taken at stagnation pressures of 0.5 and 1.0 atmosphere which corresponded to Reynolds numbers of about 1.4×10^6 and 2.8×10^6 based on the wing mean aerodynamic chord, respectively. The wings have an aspect ratio of 4, taper ratio of 0.15, and 45° sweepback of the quarter-chord line. The wings were cambered and had a thickened root section.

Wing twist produced a pitching-moment shift at low lift in the direction to reduce trim drag. The twist was also responsible for an increase in the minimum drag coefficient over the Mach number range which resulted in decreases in the untrimmed maximum lift-drag ratio.

Author

INTRODUCTION

A research program has been conducted at the Langley Research Center to determine the loads due to wing twist at transonic and low supersonic speeds. As part of this program, tests have been made on four wings at transonic speeds: an untwisted wing to serve as a reference, and wings with linear, quadratic, and cubic variations of twist across the span.

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*Title, Unclassified.

Pressure measurements on these wings have been presented in references 1 to 4. The force measurements on these wings are presented herein.

SYMBOLS

A	aspect ratio
M	free-stream Mach number
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment about } \bar{c}/4}{qS\bar{c}}$
C_N	normal-force coefficient, $\frac{\text{Normal force}}{qS}$
C_A	axial-force coefficient, $\frac{\text{Axial force}}{qS}$
$(L/D)_{max}$	maximum value of lift-drag ratio
$C_{L,(L/D)_{max}}$	lift coefficient at $(L/D)_{max}$
$C_{D,min}$	minimum drag coefficient
S	total wing area
b	wing span
y	spanwise distance measured from body center line
$\bar{c}$	wing mean aerodynamic chord
R	Reynolds number based on wing mean aerodynamic chord

p_t stagnation pressure, atm

q free-stream dynamic pressure

α angle of attack of body center line

$\Delta\alpha$ aeroelastic twist angle (angle of attack of wing station minus angle of attack of wing-body center line)

ϕ built-in twist angle

L
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APPARATUS

Tunnel

The investigation was conducted in the Langley 8-foot transonic pressure tunnel. The test section of this facility is rectangular in cross section. The upper and lower walls are slotted longitudinally to allow continuous operation through the transonic speed range with negligible effects of choking and blockage. During this investigation, the tunnel was operated at stagnation pressures of approximately 0.5 and 1.0 atmosphere. The dewpoint of the tunnel air was controlled and was kept constant at approximately 0° F. The stagnation temperature of the tunnel air was automatically controlled and was kept constant and uniform across the tunnel at 123° F. Control of both dewpoint and stagnation temperature in this manner minimized humidity effects. Details of the test section are presented in reference 5.

Models

Each wing has a sweepback of 45° of the 0.25c line, an aspect ratio of 4, and a taper ratio of 0.15. The wing section varies linearly in thickness from an NACA 65A206 section with $a = 0$ at the root to an NACA 65A203 section with $a = 0.8$ (modified) at the 50-percent-semispan station. The airfoil section remains constant from the 50-percent-semispan station to the tip. Streamwise ordinates for this wing are presented in reference 1. Twist was built into three wings from 10 percent of the semispan to the tip. The twist varied linearly, quadratically, and cubicly, respectively, on the three wings. In each case the twist was 0° at the 10-percent-semispan station and 6° at the tip. The sections were twisted about the leading edge in planes parallel to the model plane of symmetry with the trailing edges up; therefore, the tips are at a lower angle of attack than the wing-body center line. The four wings were constructed of steel and tested as midwing configurations in combination with a central body. Ordinates for this central body are presented in table I. The shape of this body would be identical to the pressure body used in references 1 to 4 except that the base was cut off at station 35.3 inches to accommodate an internal strain-gage balance. Details of the wing-body combinations are presented in figure 1 and the built-in wing twist characteristics are presented in table II.

The model support sting extended from the base of the body and was, in turn, attached to the central support system of the tunnel. This support system kept the model near the center line of the tunnel throughout the angle-of-attack range.

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TESTS

Tests were made at Mach numbers from 0.80 to 1.20 at tunnel stagnation pressures of approximately 0.5 and 1.0 atmosphere. At Mach numbers between 1.03 and 1.13, boundary reflected disturbances struck the model, so that no data were recorded in this Mach number range. At a stagnation pressure of 0.5 atmosphere the angle-of-attack range extended generally from -4° to 20°; at a stagnation pressure of 1.0 atmosphere, the angle-of-attack range generally extended from -4° to 12°.

Transition strips were fixed on the model during all of the tests. The strips were about 0.10 inch wide and were formed by sprinkling No. 120 carborundum grains on a plastic adhesive. The strips extended from the wing-body juncture to the wing tip at 10 percent of the local chord on the upper and lower wing surfaces and formed a ring around the body at 10 percent of the body length.

The Reynolds number, based on a mean aerodynamic chord length of 8.42 inches, varied over the Mach number range from about 1.3×10^6 to 1.5×10^6 during tests at 0.5 atmosphere and from about 2.6×10^6 to 2.9×10^6 during tests at 1.0 atmosphere. The dynamic pressure varied over the Mach number range from about 310 to 435 pounds per square foot during tests at 0.5 atmosphere and from about 620 to 880 pounds per square foot during tests at 1.0 atmosphere. (See fig. 2.)

MEASUREMENTS AND ACCURACY

The pressure wings of references 1 to 4 were fitted to a body which housed a three-component internal strain-gage balance. The pressure orifices in the wing were not hooked up during these force tests. A study of factors affecting the accuracy of the results, such as balance accuracy, repeatability of data, and dynamic-pressure variations indicates that the measured coefficients are accurate within the following limits:

M	C_L and C_N	C_D and C_A	C_m
0.80	±0.028	±0.0011	±0.0054
1.20	±.019	±.0008	±.0038

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The angle of attack of the model was measured with a strain-gage attitude transmitter mounted in the nose of the model and is estimated to be accurate within $\pm 0.2^{\circ}$.

Calibrations of the tunnel test section indicate that local deviations from the average free-stream Mach number are of the order of ±0.005 at subsonic speeds. With increases in Mach number, these deviations increase but do not exceed ±0.010 in the region of the wing at M = 1.20. Several representative Mach number distributions along the center of the test section are presented in reference 5. The average free-stream Mach number was held to within ±0.005 of the nominal values shown on the figures.

The stagnation pressures of 1,058 and 2,116 pounds per square foot have been designated 0.5 and 1.0 atmosphere, respectively, throughout this study. During the tests, the stagnation pressure was held to within ±10 pounds per square foot during tests at 0.5 atmosphere and to within ±20 pounds per square foot during tests at 1.0 atmosphere.

CORRECTIONS

No corrections have been applied to the data for boundary-interference effects. At subsonic speeds, the slotted test section minimized boundary-interference effects such as blockage and boundary-induced upwash.

No corrections have been applied to the data for aeroelastic effects. The aeroelastic wing-twist angles have been computed for these wings using measured influence coefficients in conjunction with pressure data. (See refs. 1 to 4.) Figure 3 presents aeroelastic twist angles $\Delta\alpha$ near the tip $\left(\frac{y}{b/2} = 0.95\right)$ for the four wings.

The drag data have been adjusted to the condition of free-stream static pressure at the model base.

RESULTS

The force and moment characteristics of the wing-body combinations (untwisted, linearly twisted, quadratically twisted, and cubicly twisted wings) are presented in figures 4 to 7, respectively. Tabulated coefficients, about both the body and stability axes for the four configurations, are presented in tables III to VI. The effects of the three spanwise twist distributions on the significant aerodynamic parameters are presented in figure 8. Generally, the data taken at 0.5 atmosphere were used to obtain the analysis curves of figure 8. However, at $M = 0.80$ L
for the quadratically twisted wing-body combination, no data were 5
recorded at 0.5 atmosphere so the data at 1.0 atmosphere were used. 7
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DISCUSSION

Effects of Three Spanwise Twist Variations

<u>Lift characteristics</u>.- The most significant effect of twist on the lift characteristics is a decrement in the lift coefficient at low and moderate angles of attack up to about 12°. (See figs. 4(a), 5(a), 6(a), and 7(a).) A shift of this nature would be expected since the average angle of attack over the span for the twisted wings is less than the average angle of attack of the untwisted wing. At a Mach number of 0.80 near 0° angle of attack, the linear twist distribution causes the largest decrement (about -0.16) in lift coefficient; the quadratic and cubic distributions cause succeedingly lesser decrements. This same trend is evident through the Mach number range, although at the higher Mach numbers the magnitude of the decrement caused by the twist diminished slightly. With increases in angle of attack above 8°, the decrement in lift coefficient due to twist diminishes quite rapidly. At a Mach number of 0.80 and an angle of attack of 12°, for example, the decrement due to the linear twist distribution is -0.06 in lift coefficient as compared to -0.16 at 0° noted previously. Further increases in angle of attack above 12° cause this decrement to continue to diminish until it is about zero at 20° angle of attack.

The data of references 1 to 4 indicate that the untwisted wing is more flexible than the three twisted wings. Also, at a constant angle of attack the untwisted wing is generally carrying a greater load than the twisted wings. Therefore at a given angle of attack the untwisted wing experiences larger aeroelastic deflections than the twisted wings. However, the differences in aeroelastic deflections are not large enough to obscure the effects of the built-in twist. Considering the differences in aeroelastic deflections for the data at 0.5 atmosphere used in this analysis, it is estimated that the tip sections of the twisted wings were operating at angles of attack about 5° less than the tip sections of the untwisted wing at the higher angles. In other words, the more flexible untwisted wing twists about 1° more under load than the twisted wings.

The effects of the built-in twist on the lift-curve slopes measured in the region of zero lift are shown in figure 8(a). Wing twist is responsible for a small increase in lift-curve slope up to a Mach number around 1.0.

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Pitch characteristics.- Wing twist causes a positive increment in pitching-moment coefficient as might be expected. (See figs. 4(b), 5(b), 6(b), and 7(b).) This positive increment in the pitching moment is significant because it will result in lower trim drag for the twisted wing configurations. At a Mach number of 0.80 near zero lift, the linear twist distribution causes the largest increment (about 0.030) in pitching moment (figs. 4(b) and 5(b)); the quadratic and cubic distributions cause succeedingly lesser increments. This trend, which is exhibited throughout the Mach number range generally disappears at lift coefficients near those of the unstable break in the pitching-moment curves. The characteristics of the unstable break for the untwisted and twisted wings are generally very similar although the onset is usually delayed to a higher lift coefficient for the twisted wings.

The effects of twist on the static-longitudinal-stability parameter near zero lift are shown in figure 8(a). Wing twist causes a small decrease in $(\partial C_m/\partial C_L)_{C_L\approx 0}$ at the lower Mach numbers, this effect diminishing at the higher Mach numbers.

Drag characteristics.- The effects of twist on the drag characteristics are shown in figures 8(b) and 8(c). The drag-due-to-lift factor $\partial C_D/\partial C_L^2$ on figure 8(b) was obtained using experimental data at lift coefficients from minimum drag up to about 0.4. The drag-due-to-lift factor for full leading-edge suction at subsonic speeds $1/\pi A$ is shown for reference. The wing twist has very little effect on the drag-due-to-lift factor over the Mach number range. However, it is responsible for an increase in the minimum drag at all Mach numbers. This increase in minimum drag results in decreases in the maximum lift-drag ratio of about 1.0 at subsonic speeds and about 0.4 at supersonic speeds (fig. 8(c)). However, the decrease in maximum lift-drag ratio might be more than compensated for by the gains in trimmed lift-drag ratio associated with the positive pitching-moment increment previously noted. Wing twist increased the lift coefficient for maximum lift-drag ratio over the Mach number range. (See fig. 8(c).)

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Effects of Variations in Stagnation Pressure

In figures 4 to 7, the flagged symbols represent data obtained at a stagnation pressure of 1.0 atmosphere. Doubling the stagnation pressure doubled the Reynolds number from about 1.4×10^6 to about 2.8×10^6. (See fig. 2.) Transition was fixed during tests at both stagnation pressures and the data of references 1 to 4 indicate that fixing transition tended to minimize the effects of Reynolds number. The calculated aeroelastic twist angles in figure 3 show that generally the outboard wing sections are operating at a lesser angle of attack at a stagnation pressure of 1.0 atmosphere than at a stagnation pressure of 0.5 atmosphere because of the differences in dynamic pressures. Therefore, the differences in the force and moment coefficients in figures 4 to 7 between data taken at a stagnation pressure of 0.5 atmosphere and 1.0 atmosphere should be attributed mainly to aeroelastic effects rather than Reynolds number effects.

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CONCLUSIONS

An investigation of the effects of three spanwise twist variations on the aerodynamic characteristics in pitch of a thin 45° sweptback highly tapered wing at transonic speeds leads to the following conclusions:

1. A linear spanwise twist variation from 0° at the 10-percent semispan to 6° washout at the tip produced an appreciable pitching-moment shift at low lift in the direction to reduce trim drag. Quadratic and cubic distributions produced succeedingly lesser pitching-moment shifts.

2. All spanwise twist variations caused an increase in the minimum drag coefficient over the Mach number range which resulted in decreases in the untrimmed maximum lift-drag ratio.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., July 23, 1959.

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3. Mugler, John P., Jr.: Basic Pressure Measurements at Transonic Speeds on a Thin 45° Sweptback Highly Tapered Wing With Systematic Spanwise Twist Variations - Wing With Quadratic Spanwise Twist Variation. NASA MEMO 2-24-59L, 1959.

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[redacted]

TABLE I.- BODY ORDINATES

Station, in. from nose	Radius, in.
0	0
1	.282
2	.460
3	.612
4	.743
5	.862
6	.969
7	1.062
8	1.150
9	1.222
10	1.290
11	1.350
12	1.404
13	1.452
14	1.493
15	1.526
16	1.552
17	1.575
18	1.590
19	1.602
20	1.606
21	1.602
22	1.594
23	1.578
24	1.560
25	1.532
26	1.501
27	1.460
28	1.414
29	1.360
30	1.300
31	1.231
32	1.158
33	1.076
34	.984
35	.878
35.3	.844

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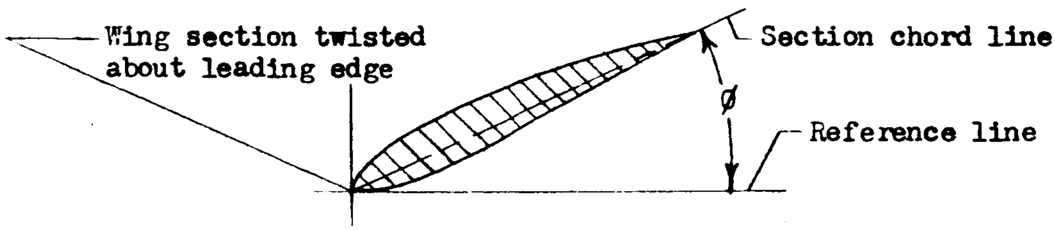
TABLE II.- WING TWIST CHARACTERISTICS



Typical Section

$\frac{y}{b/2}$	ø, deg			
	Untwisted wing	Wing with linear twist	Wing with quadratic twist	Wing with cubic twist
0	0	0	0	0
.10	0	0	0	0
.12	0	.133	.003	.000
.25	0	1.000	.167	.028
.40	0	2.000	.667	.222
.60	0	3.324	1.852	1.029
.80	0	4.667	3.630	2.823
.95	0	5.657	5.352	5.054
1.00	0	6.000	6.000	6.000

[redacted]

TABLE III.- AERODYNAMIC COEFFICIENTS FOR UNTWISTED WING

(a) Stagnation pressure of 0.5 atmosphere

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.80					
-0.03	0.090	0.0093	-0.0453	0.090	0.0093
-4.02	-.197	.0249	-.0050	-.198	.0110
-2.05	-.050	.0123	-.0262	-.051	.0105
1.97	.222	.0122	-.0621	.222	.0046
4.00	.355	.0222	-.0778	.356	-.0026
4.98	.434	.0322	-.0891	.435	-.0056
5.99	.495	.0438	-.0897	.497	-.0081
6.99	.557	.0579	-.0901	.560	-.0103
8.03	.615	.0745	-.0893	.619	-.0121
12.01	.778	.1530	-.0818	.793	-.0123
15.92	.886	.2439	-.0809	.919	-.0084
19.79	.953	.3387	-.0891	1.012	-.0040
-.09	.092	.0095	-.0455	.092	.0096
M = 0.98					
-0.06	0.107	0.0152	-0.0746	0.107	0.0153
-4.08	-.238	.0336	.0170	-.240	.0165
-2.07	-.069	.0189	-.0285	-.070	.0164
1.94	.254	.0212	-.1100	.255	.0126
3.96	.422	.0369	-.1515	.423	.0077
7.98	.723	.0972	-.2156	.730	-.0041
11.96	.892	.1848	-.1884	.911	-.0040
15.87	1.024	.2871	-.1782	1.064	-.0040
19.72	1.138	.4045	-.1848	1.208	-.0032
-.06	.097	.0153	-.0706	.097	.0154
M = 1.20					
-0.05	0.059	0.0189	-0.0471	0.059	0.0190
-4.06	-.228	.0354	.0324	-.230	.0191
-2.09	-.085	.0226	-.0077	-.086	.0195
1.96	.194	.0229	-.0827	.195	.0162
3.97	.333	.0352	-.1198	.335	.0120
7.98	.598	.0860	-.1902	.604	.0021
11.97	.841	.1708	-.2417	.858	-.0074
15.90	1.013	.2769	-.2474	1.051	-.0113
19.71	1.131	.3940	-.2393	1.198	-.0106
-.06	.048	.0188	-.0443	.048	.0189

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.90					
-0.03	0.101	0.0100	-0.0531	0.101	0.0101
-4.01	-.222	.0274	-.0004	-.223	.0118
-2.05	-.057	.0132	-.0276	-.057	.0112
1.97	.241	.0133	-.0735	.242	.0050
3.99	.411	.0265	-.1047	.412	-.0021
4.97	.484	.0367	-.1152	.485	-.0053
5.99	.562	.0517	-.1282	.564	-.0072
6.98	.624	.0691	-.1309	.628	-.0073
8.02	.674	.0877	-.1282	.680	-.0073
12.00	.797	.1628	-.1089	.813	-.0064
15.90	.902	.2530	-.1117	.937	-.0037
19.78	.993	.3565	-.1200	1.056	-.0007
-.09	.098	.0098	-.0520	.098	.0100
M = 1.03					
-0.08	0.079	0.0202	-0.0599	0.079	0.0203
-4.11	-.243	.0386	.0263	-.246	.0211
-2.07	-.084	.0243	-.0159	-.085	.0212
1.92	.234	.0248	-.1021	.234	.0170
3.97	.396	.0397	-.1446	.397	.0122
7.98	.696	.0971	-.2137	.702	-.0004
11.96	.900	.1858	-.2133	.919	-.0047
15.88	1.054	.2955	-.2070	1.095	-.0043
19.71	1.180	.4165	-.2059	1.252	-.0060
-.07	.068	.0203	-.0575	.068	.0204

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.94					
-0.03	0.118	0.0109	-0.0655	0.118	0.0110
-4.04	-.254	.0308	.0142	-.255	.0128
-2.05	-.066	.0144	-.0274	-.066	.0120
1.96	.280	.0167	-.1030	.280	.0071
3.99	.452	.0333	-.1477	.453	.0018
4.97	.526	.0452	-.1603	.528	-.0005
5.98	.579	.0591	-.1573	.582	-.0015
6.99	.637	.0755	-.1601	.641	-.0025
8.00	.683	.0925	-.1551	.689	-.0034
11.98	.832	.1717	-.1377	.849	-.0046
15.92	.952	.2683	-.1373	.989	-.0030
19.75	1.075	.3843	-.1533	1.141	-.0014
-.10	.117	.0110	-.0653	.117	.0112
M = 1.13					
-0.05	0.065	0.0186	-0.0516	0.065	0.0187
-4.10	-.231	.0354	.0302	-.233	.0187
-2.11	-.083	.0223	-.0120	-.084	.0192
1.95	.201	.0226	-.0884	.202	.0157
3.98	.348	.0355	-.1281	.350	.0112
7.98	.650	.0903	-.2057	.656	-.0008
11.96	.892	.1776	-.2487	.909	-.0111
15.86	.982	.2698	-.1971	1.018	-.0087
19.70	1.114	.3863	-.1944	1.179	-.0119
-.05	.074	.0184	-.0537	.074	.0185

TABLE III.- AERODYNAMIC COEFFICIENTS FOR UNTWISTED WING - Concluded

(b) Stagnation pressure of 1.0 atmosphere

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.80					
-0.08	0.088	0.0102	-0.0450	0.088	0.0103
-4.08	-.203	.0256	-.0065	-.205	.0110
-2.10	-.053	.0132	-.0272	-.054	.0112
1.96	.226	.0133	-.0621	.226	.0056
3.96	.362	.0223	-.0795	.362	-.0027
8.00	.614	.0717	-.0870	.618	-.0144
11.55	.769	.1406	-.0800	.781	-.0161
-.08	.084	.0102	-.0447	.084	.0103
M = 0.98					
-0.04	0.084	0.0161	-0.0627	0.084	0.0162
-3.98	-.245	.0337	.0207	-.246	.0166
-2.04	-.086	.0202	-.0183	-.086	.0171
1.96	.233	.0218	-.0973	.234	.0138
3.97	.395	.0347	-.1341	.397	.0072
8.01	.695	.0863	-.1979	.701	-.0114
9.82	.822	.1240	-.2185	.831	-.0180
-.09	.084	.0165	-.0613	.084	.0166
M = 1.20					
-0.01	0.072	0.0194	-0.0477	0.072	0.0194
-4.03	-.194	.0328	.0216	-.196	.0190
-2.01	-.070	.0225	-.0115	-.071	.0200
1.95	.196	.0235	-.0785	.197	.0168
4.05	.323	.0345	-.1105	.325	.0116
8.02	.583	.0787	-.1749	.589	-.0034
10.22	.723	.1185	-.2046	.732	-.0116
-.19	.069	.0193	-.0466	.069	.0195

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.90					
-0.08	0.098	0.0104	-0.0519	0.098	0.0105
-4.07	-.226	.0277	-.0029	-.227	.0116
-2.09	-.057	.0137	-.0295	-.057	.0116
1.96	.253	.0144	-.0759	.254	.0057
3.96	.416	.0258	-.1049	.416	-.0030
7.99	.679	.0840	-.1304	.684	-.0111
10.60	.769	.1328	-.1158	.780	-.0109
-.06	.099	.0104	-.0527	.099	.0105
M = 1.03					
-0.03	0.074	0.0207	-0.0571	0.074	0.0207
-4.04	-.236	.0373	.0215	-.238	.0206
-2.05	-.087	.0245	-.0158	-.088	.0213
1.97	.218	.0253	-.0931	.219	.0178
3.98	.373	.0372	-.1284	.375	.0112
8.01	.670	.0875	-.1950	.676	-.0068
9.93	.799	.1252	-.2173	.808	-.0144
-.06	.076	.0205	-.0578	.076	.0206

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.94					
-0.09	0.109	0.0112	-0.0622	0.109	0.0114
-4.09	-.256	.0310	.0126	-.258	.0126
-2.06	-.066	.0147	-.0283	-.066	.0123
1.94	.279	.0171	-.1002	.279	.0077
3.97	.439	.0312	-.1376	.440	.0007
7.99	.682	.0874	-.1548	.688	-.0083
10.96	.801	.1453	-.1440	.814	-.0096
-.07	.109	.0114	-.0631	.109	.0115
M = 1.13					
-0.05	0.065	0.0190	-0.0485	0.065	0.0191
-3.98	-.216	.0334	.0231	-.218	.0183
-2.26	-.076	.0226	-.0131	-.076	.0196
1.99	.199	.0231	-.0815	.199	.0162
3.96	.334	.0337	-.1153	.336	.0105
7.98	.619	.0801	-.1847	.625	-.0067
9.86	.741	.1143	-.2083	.750	-.0143
-.22	.067	.0188	-.0490	.066	.0191

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TABLE IV.- AERODYNAMIC COEFFICIENTS FOR WING WITH LINEAR TWIST

(a) Stagnation pressure of 0.5 atmosphere

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.80					
-0.08	-0.070	0.0161	0.0113	-0.070	0.0160
-4.08	-.361	.0522	.0433	-.364	.0264
-2.12	-.221	.0304	.0303	-.222	.0222
1.95	.078	.0112	-.0144	.079	.0085
4.01	.223	.0141	-.0355	.223	-.0015
6.03	.361	.0235	-.0511	.362	-.0146
8.09	.511	.0451	-.0661	.512	-.0273
10.07	.628	.0774	-.0638	.632	-.0336
12.10	.719	.1175	-.0631	.728	-.0359
15.97	.853	.2084	-.0630	.877	-.0343
19.81	.930	.3015	-.0722	.977	-.0315
-.06	-.070	.0160	.0113	-.070	.0159
M = 0.98					
-0.08	-0.075	0.0234	0.0119	-0.075	0.0233
-4.16	-.424	.0669	.1021	-.428	.0360
-2.12	-.251	.0394	.0605	-.253	.0301
1.97	.103	.0186	-.0399	.104	.0150
4.01	.269	.0249	-.0848	.270	.0060
6.03	.432	.0403	-.1205	.434	-.0053
8.09	.605	.0663	-.1642	.608	-.0195
10.07	.762	.1035	-.2006	.769	-.0314
12.10	.906	.1524	-.2266	.918	-.0409
15.97	1.005	.2510	-.1719	1.035	-.0351
19.81	1.142	.3701	-.1789	1.200	-.0389
-.08	-.084	.0233	.0155	-.084	.0232
M = 1.20					
-0.02	-0.065	0.0256	0.0195	-0.065	0.0256
-4.10	-.342	.0595	.0960	-.346	.0349
-2.14	-.215	.0391	.0626	-.217	.0310
1.97	.069	.0219	-.0204	.070	.0195
4.03	.208	.0265	-.0602	.210	.0118
6.07	.349	.0388	-.0981	.351	.0017
8.09	.495	.0610	-.1387	.499	-.0093
10.07	.632	.0925	-.1747	.639	-.0194
12.08	.762	.1336	-.2033	.773	-.0287
15.95	.970	.2335	-.2389	.997	-.0421
19.83	1.108	.3526	-.2363	1.162	-.0442
-.06	-.067	.0256	.0211	-.067	.0255

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.90					
-0.08	-0.073	0.0169	0.0114	-0.073	0.0168
-4.12	-.396	.0576	.0557	-.399	.0291
-2.12	-.244	.0330	.0395	-.245	.0239
1.97	.092	.0117	-.0219	.093	.0085
4.01	.255	.0158	-.0503	.256	-.0021
6.05	.420	.0282	-.0776	.420	-.0162
8.09	.601	.0541	-.1145	.602	-.0310
10.07	.705	.0917	-.1107	.710	-.0329
12.10	.770	.1331	-.0982	.781	-.0313
15.97	.867	.2174	-.0932	.893	-.0294
19.81	.976	.3204	-.1077	1.027	-.0294
-.08	-.072	.0168	.0116	-.072	.0167
M = 1.03					
-0.09	-0.083	0.0272	0.0187	-0.083	0.0271
-4.14	-.404	.0679	.1046	-.407	.0386
-2.10	-.243	.0422	.0617	-.244	.0332
1.95	.088	.0225	-.0325	.089	.0195
4.01	.252	.0283	-.0776	.253	.0106
6.05	.411	.0430	-.1162	.413	-.0005
8.09	.574	.0673	-.1584	.577	-.0140
10.05	.728	.1022	-.1946	.734	-.0263
12.10	.871	.1496	-.2238	.883	-.0363
15.95	1.025	.2551	-.2036	1.056	-.0364
19.79	1.151	.3718	-.1989	1.209	-.0399
-.08	-.082	.0270	.0186	-.082	.0269

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.94					
-0.06	-0.083	0.0180	0.0154	-0.083	0.0179
-4.14	-.426	.0628	.0813	-.429	.0319
-2.00	-.261	.0351	.0535	-.262	.0259
1.97	.119	.0127	-.0350	.119	.0086
4.01	.300	.0193	-.0810	.301	-.0017
6.03	.456	.0352	-.1152	.457	-.0129
8.11	.626	.0632	-.1492	.629	-.0258
10.07	.740	.0981	-.1522	.745	-.0327
12.10	.800	.1400	-.1308	.811	-.0307
15.97	.909	.2287	-.1190	.937	-.0302
-.08	-.080	.0180	.0139	-.080	.0179
M = 1.13					
-0.08	-0.078	0.0257	0.0225	-0.078	0.0256
-4.18	-.362	.0614	.0942	-.365	.0349
-2.12	-.224	.0393	.0621	-.225	.0310
1.95	.074	.0215	-.0232	.075	.0189
3.99	.225	.0260	-.0668	.226	.0103
6.03	.372	.0385	-.1050	.374	-.0008
8.07	.552	.0633	-.1538	.555	-.0148
10.11	.683	.0966	-.1873	.690	-.0249
12.08	.811	.1389	-.2141	.823	-.0340
15.95	1.015	.2408	-.2417	1.042	-.0474
19.81	1.085	.3447	-.1883	1.137	-.0434
-.04	-.074	.0255	.0209	-.074	.0254

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TABLE IV.- AERODYNAMIC COEFFICIENTS FOR WING WITH LINEAR TWIST - Concluded

(b) Stagnation pressure of 1.0 atmosphere

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.80					
-0.04	-0.061	0.0152	0.0087	-0.061	0.0152
-4.04	-.354	.0503	.0415	-.357	.0253
-2.06	-.208	.0286	.0267	-.209	.0211
2.00	.090	.0112	-.0175	.091	.0080
4.04	.227	.0140	-.0348	.228	-.0020
6.09	.370	.0230	-.0523	.370	-.0164
8.13	.519	.0436	-.0669	.520	-.0302
10.11	.637	.0760	-.0649	.640	-.0369
12.11	.733	.1167	-.0615	.741	-.0396
.00	-.051	.0149	.0058	-.051	.0149
M = 0.98					
-0.04	-0.064	0.0224	0.0082	-0.064	0.0224
-4.08	-.404	.0616	.0937	-.407	.0328
-2.06	-.239	.0366	.0561	-.241	.0280
2.02	.107	.0185	-.0386	.107	.0147
4.03	.263	.0243	-.0783	.264	.0057
6.07	.429	.0385	-.1150	.430	-.0070
8.13	.596	.0620	-.1556	.599	-.0229
10.13	.751	.0968	-.1908	.756	-.0368
12.13	.891	.1421	-.2148	.901	-.0483
-.02	-.067	.0223	.0095	-.067	.0223
M = 1.20					
-0.09	-0.058	0.0247	0.0178	-0.058	0.0246
-4.12	-.312	.0540	.0839	-.315	.0315
-1.93	-.175	.0341	.0500	-.176	.0282
1.97	.080	.0216	-.0214	.081	.0188
4.01	.224	.0263	-.0611	.225	.0105
6.07	.365	.0383	-.0982	.367	-.0005
8.24	.507	.0598	-.1360	.511	-.0135
10.09	.631	.0879	-.1675	.637	-.0241
12.15	.757	.1274	-.1961	.767	-.0349
-.02	-.039	.0240	.0116	-.039	.0240

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.90					
-0.02	-0.059	0.0156	0.0066	-0.059	0.0156
-4.10	-.389	.0553	.0550	-.392	.0274
-2.06	-.227	.0305	.0332	-.228	.0223
1.98	.102	.0113	-.0227	.102	.0078
4.04	.258	.0153	-.0475	.259	-.0029
6.09	.428	.0269	-.0773	.428	-.0186
8.13	.606	.0513	-.1142	.607	-.0348
10.11	.715	.0889	-.1130	.720	-.0380
12.13	.778	.1305	-.0988	.788	-.0359
-.02	-.051	.0154	.0042	-.051	.0154
M = 1.03					
-0.02	-0.071	0.0262	0.0157	-0.071	0.0262
-4.08	-.384	.0629	.0949	-.387	.0354
-2.06	-.235	.0402	.0579	-.236	.0317
1.98	.091	.0227	-.0311	.092	.0195
4.03	.249	.0280	-.0737	.250	.0104
6.07	.402	.0410	-.1091	.404	-.0017
8.11	.564	.0629	-.1489	.567	-.0173
10.11	.719	.0966	-.1858	.725	-.0311
12.13	.860	.1412	-.2135	.870	-.0427
-.02	-.063	.0261	.0126	-.063	.0261

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.94					
-0.02	-0.065	0.0166	0.0081	-0.065	0.0166
-4.08	-.410	.0589	.0777	-.413	.0296
-2.06	-.252	.0333	.0482	-.253	.0242
2.00	.113	.0124	-.0320	.113	.0084
4.04	.293	.0188	-.0744	.294	-.0019
6.09	.452	.0332	-.1092	.453	-.0150
8.13	.617	.0585	-.1439	.619	-.0294
10.09	.739	.0937	-.1504	.744	-.0372
12.11	.803	.1355	-.1305	.813	-.0359
-.02	-.061	.0164	.0077	-.061	.0164
M = 1.13					
0.06	-0.056	0.0241	0.0154	-0.056	0.0242
-3.93	-.324	.0538	.0833	-.327	.0315
-2.04	-.186	.0352	.0490	-.187	.0285
2.02	.091	.0210	-.0261	.092	.0178
3.95	.228	.0255	-.0644	.230	.0097
8.24	.568	.0617	-.1516	.571	-.0203
9.96	.691	.0899	-.1821	.696	-.0310
12.17	.812	.1325	-.2056	.821	-.0416
.04	-.048	.0238	.0119	-.048	.0238

TABLE V.- AERODYNAMIC COEFFICIENTS FOR WING WITH QUADRATIC TWIST

(a) Stagnation pressure of 0.5 atmosphere

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.80					
(No data recorded)					
M = 0.98					
-0.08	0.017	0.0179	-0.0275	0.017	0.0179
-4.04	-.336	.0485	.0708	-.338	.0248
-2.01	-.156	.0275	.0226	-.157	.0220
2.03	.190	.0183	-.0734	.190	.0116
4.04	.351	.0299	-.1099	.353	.0051
6.02	.515	.0493	-.1494	.517	-.0049
8.05	.681	.0809	-.1905	.686	-.0153
10.04	.826	.1225	-.2167	.835	-.0235
11.77	.942	.1680	-.2287	.957	-.0277
13.01	.933	.1963	-.1822	.953	-.0188
15.92	1.022	.2722	-.1723	1.058	-.0186
19.76	1.141	.3892	-.1801	1.206	-.0195
-.08	.018	.0179	-.0295	.018	.0179
M = 1.20					
-0.06	-0.002	0.0217	-0.0082	-0.002	0.0217
-3.99	-.277	.0464	.0699	-.279	.0271
-2.03	-.144	.0300	.0328	-.145	.0249
2.03	.135	.0213	-.0464	.136	.0165
4.02	.276	.0294	-.0854	.277	.0100
6.03	.421	.0463	-.1257	.423	.0019
8.07	.562	.0732	-.1637	.567	-.0065
10.02	.691	.1077	-.1938	.699	-.0141
12.01	.817	.1528	-.2215	.831	-.0206
15.90	1.011	.2579	-.2455	1.043	-.0289
19.76	1.136	.3784	-.2398	1.197	-.0277
-.06	.001	.0216	-.0083	.001	.0216
M = 0.90					
-0.08	0.016	0.0122	-0.0144	0.016	0.0122
-4.04	-.317	.0421	.0396	-.319	.0196
-2.01	-.153	.0219	.0173	-.154	.0165
2.03	.187	.0118	-.0478	.188	.0052
4.02	.344	.0201	-.0715	.344	-.0040
6.02	.517	.0382	-.1078	.518	-.0163
8.07	.659	.0727	-.1216	.663	-.0205
10.02	.727	.1098	-.1092	.735	-.0184
12.01	.784	.1494	-.0995	.798	-.0170
15.92	.892	.2393	-.1048	.923	-.0145
19.76	.973	.3370	-.1204	1.029	-.0117
-.09	.018	.0120	-.0156	.018	.0120
M = 1.03					
-0.06	0.006	0.0228	-0.0171	0.006	0.0228
-4.02	-.316	.0508	.0694	-.319	.0286
-2.01	-.157	.0319	.0290	-.158	.0263
2.05	.174	.0229	-.0645	.174	.0167
4.04	.333	.0329	-.1064	.334	.0094
6.02	.489	.0515	-.1438	.492	-.0001
8.07	.651	.0815	-.1847	.656	-.0106
10.04	.794	.1215	-.2142	.803	-.0188
12.01	.919	.1699	-.2327	.934	-.0250
15.92	1.069	.2834	-.2152	1.106	-.0207
19.76	1.180	.3997	-.2032	1.245	-.0226
-.08	.004	.0227	-.0169	.004	.0227
M = 0.94					
-0.06	0.027	0.0126	-0.0217	0.027	0.0126
-4.04	-.341	.0454	.0559	-.343	.0213
-2.01	-.159	.0230	.0210	-.159	.0174
2.03	.223	.0140	-.0720	.223	.0061
4.04	.389	.0259	-.1119	.390	-.0016
6.02	.542	.0450	-.1449	.544	-.0121
8.05	.650	.0766	-.1396	.654	-.0151
10.04	.744	.1150	-.1355	.752	-.0165
11.99	.815	.1567	-.1278	.830	-.0160
15.90	.930	.2495	-.1278	.963	-.0148
19.76	1.052	.3625	-.1441	1.113	-.0146
-.08	.030	.0126	-.0231	.030	.0126
M = 1.13					
-0.04	-0.001	0.0214	-0.0104	-0.001	0.0214
-4.04	-.291	.0471	.0691	-.294	.0265
-2.01	-.145	.0298	.0312	-.146	.0247
2.07	.149	.0211	-.0525	.150	.0157
4.02	.297	.0295	-.0936	.298	.0086
6.02	.446	.0470	-.1339	.448	.0000
7.88	.608	.0737	-.1759	.612	-.0104
10.00	.742	.1121	-.2054	.750	-.0184
11.99	.862	.1577	-.2287	.876	-.0248
15.94	.999	.2598	-.2049	1.032	-.0244
19.76	1.113	.3706	-.1905	1.172	-.0273
-.08	.003	.0214	-.0114	.003	.0214

C[redacted]

TABLE V.- AERODYNAMIC COEFFICIENTS FOR WING WITH QUADRATIC TWIST - Concluded

(b) Stagnation pressure of 1.0 atmosphere

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.80					
-0.02	0.015	0.0117	-0.0101	0.015	0.0117
-3.97	-.277	.0366	.0299	-.279	.0173
-1.99	-.135	.0199	.0148	-.135	.0152
2.09	.159	.0118	-.0325	.159	.0060
4.08	.297	.0174	-.0499	.298	-.0038
5.09	.370	.0223	-.0552	.370	-.0106
6.09	.440	.0305	-.0639	.441	-.0163
7.13	.508	.0435	-.0706	.509	-.0199
8.14	.574	.0586	-.0699	.576	-.0232
-.09	.012	.0118	-.0102	.012	.0118
M = 0.98					
0.00	0.011	0.0187	-0.0207	0.011	0.0187
-3.93	-3.12	.0448	.0624	-.314	.0234
-1.99	-.153	.0275	.0237	-.154	.0221
2.05	.177	.0197	-.0643	.177	.0134
4.04	.339	.0294	-.1026	.340	.0055
5.08	.419	.0369	-.1192	.421	-.0004
6.09	.497	.0468	-.1362	.500	-.0062
7.11	.577	.0590	-.1566	.580	-.0129
-.06	.010	.0187	-.0208	.010	.0187
M = 1.20					
-0.19	0.010	0.0214	-0.0099	0.010	0.0214
-4.10	-.238	.0419	.0553	-.240	.0248
-2.01	-.100	.0271	.0198	-.100	.0236
2.22	.164	.0225	-.0515	.165	.0161
3.89	.290	.0292	-.0850	.292	.0094
8.20	.548	.0694	-.1513	.552	-.0095
11.02	.726	.1182	-.1911	.735	-.0227
-.15	.022	.0211	-.0131	.022	.0212

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.90					
0.00	0.023	0.0119	-0.0150	0.023	0.0119
-4.00	-.303	.0396	.0379	-.305	.0183
-1.97	-.138	.0207	.0132	-.139	.0159
2.07	.179	.0124	-.0413	.179	.0059
4.04	.333	.0195	-.0661	.333	-.0040
5.09	.416	.0262	-.0826	.417	-.0108
6.03	.501	.0348	-.0990	.502	-.0180
7.07	.599	.0496	-.1233	.601	-.0245
-.04	.025	.0119	-.0152	.025	.0119
M = 1.03					
-0.02	0.003	0.0230	-0.0144	0.003	0.0230
-3.97	-.298	.0476	.0626	-.300	.0269
-1.97	-.150	.0309	.0274	-.151	.0257
2.07	.165	.0236	-.0600	.166	.0176
4.10	.317	.0325	-.0962	.319	.0097
7.28	.558	.0623	-.1526	.561	-.0089
.00	.007	.0228	-.0152	.007	.0228

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.94					
-0.02	0.028	0.0126	-0.0206	0.028	0.0126
-3.97	-.336	.0434	.0580	-.338	.0200
-1.97	-.156	.0224	.0210	-.157	.0170
2.09	.203	.0145	-.0604	.204	.0071
4.06	.365	.0246	-.0989	.366	-.0013
5.08	.447	.0322	-.1147	.448	-.0075
6.07	.525	.0418	-.1339	.527	-.0140
7.09	.607	.0555	-.1531	.609	-.0199
.00	.034	.0125	-.0222	.034	.0125
M = 1.13					
0.00	0.006	0.0212	-0.0108	0.006	0.0212
-3.97	-.280	.0440	.0627	-.283	.0245
-1.97	-.138	.0285	.0284	-.139	.0237
2.12	.152	.0218	-.0499	.153	.0162
3.93	.298	.0289	-.0889	.299	.0084
-.58	-.011	.0215	-.0057	-.011	.0214

TABLE VI.- AERODYNAMIC COEFFICIENTS FOR WING WITH CUBIC TWIST

(a) Stagnation pressure of 0.5 atmosphere

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.80					
-0.04	0.048	0.0110	-0.0231	0.048	0.0110
-4.06	-.261	.0345	.0237	-.263	.0159
-2.12	-.118	.0186	.0069	-.118	.0142
2.00	.183	.0121	-.0427	.184	.0057
4.03	.322	.0194	-.0586	.323	-.0033
5.07	.401	.0268	-.0676	.402	-.0087
6.05	.471	.0379	-.0746	.472	-.0120
7.03	.534	.0507	-.0767	.536	-.0150
8.03	.593	.0663	-.0758	.596	-.0172
11.94	.764	.1438	-.0756	.777	-.0173
15.78	.869	.2308	-.0738	.899	-.0142
19.54	.925	.3195	-.0902	.979	-.0084
-.09	.045	.0108	-.0214	.045	.0109
M = 0.98					
-0.06	0.038	0.0181	-0.0357	0.038	0.0181
-4.12	-.306	.0444	.0567	-.308	.0224
-2.10	-.144	.0263	.0174	-.145	.0210
2.00	.200	.0209	-.0803	.201	.0139
4.03	.368	.0330	-.1199	.370	.0070
5.08	.456	.0430	-.1412	.458	.0024
6.03	.534	.0542	-.1594	.537	-.0022
7.03	.615	.0692	-.1791	.619	-.0066
8.03	.695	.0869	-.1959	.700	-.0110
11.91	.904	.1740	-.2008	.920	-.0163
15.80	1.020	.2759	-.1748	1.057	-.0123
19.58	1.134	.3896	-.1831	1.199	-.0128
-.06	.042	.0182	-.0368	.042	.0182
M = 1.20					
-0.09	0.005	0.0212	-0.0141	0.005	0.0212
-4.20	-.276	.0449	.0647	-.279	.0246
-2.10	-.139	.0283	.0264	-.140	.0232
1.98	.145	.0222	-.0531	.146	.0172
4.06	.285	.0315	-.1918	.287	.0112
8.03	.559	.0758	-.1644	.564	-.0030
11.91	.805	.1545	-.2207	.820	-.0150
15.74	1.001	.2586	-.2465	1.034	-.0226
19.58	1.122	.3771	-.2378	1.184	-.0208
-.06	.013	.0209	-.0161	.013	.0209

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.90					
-0.08	0.049	0.0113	-0.0261	0.049	0.0114
-4.14	-.288	.0377	.0330	-.290	.0167
-2.12	-.125	.0194	.0084	-.126	.0148
2.00	.207	.0128	-.0538	.208	.0056
4.03	.370	.0226	-.0815	.371	-.0034
5.07	.468	.0320	-.1021	.469	-.0095
6.01	.551	.0439	-.1220	.553	-.0141
7.01	.611	.0608	-.1233	.614	-.0142
8.01	.656	.0784	-.1187	.660	-.0137
11.93	.779	.1528	-.1012	.793	-.0114
15.76	.887	.2409	-.1067	.919	-.0090
19.58	.976	.3402	-.1200	1.034	-.0065
-.08	.048	.0111	-.0253	.048	.0112
M = 1.03					
-0.06	0.026	0.0225	-0.0279	0.026	0.0225
-4.14	-.301	.0480	.0618	-.304	.0262
-2.15	-.146	.0306	.0220	-.147	.0251
2.00	.193	.0244	-.0756	.194	.0176
4.06	.355	.0359	-.1161	.357	.0106
7.96	.659	.0856	-.1908	.665	-.0065
11.94	.929	.1769	-.2397	.945	-.0191
15.76	1.039	.2796	-.2016	1.075	-.0130
19.54	1.167	.3972	-.2009	1.232	-.0158
-.06	.027	.0224	-.0285	.027	.0224

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.94					
-0.08	0.056	0.0118	-0.0316	0.056	0.0119
-4.16	-.325	.0420	.0508	-.327	.0183
-2.14	-.139	.0210	.0136	-.140	.0158
2.00	.238	.0153	-.0766	.238	.0070
4.01	.406	.0281	-.1182	.407	-.0003
5.05	.493	.0384	-.1385	.494	-.0051
6.05	.570	.0508	-.1563	.572	-.0096
7.03	.637	.0668	-.1629	.641	-.0117
8.03	.658	.0825	-.1413	.663	-.0102
11.89	.810	.1594	-.1277	.826	-.0109
15.78	.931	.2535	-.1325	.965	-.0091
19.60	1.047	.3636	-.1458	1.108	-.0085
M = 1.13					
-0.04	0.015	0.0206	-0.0187	0.015	0.0206
-4.16	-.281	.0443	.0615	-.283	.0238
-2.14	-.139	.0283	.0245	-.140	.0231
2.04	.161	.0222	-.0607	.161	.0165
4.04	.309	.0319	-.1010	.310	.0100
7.94	.615	.0788	-.1797	.620	-.0069
12.00	.868	.1646	-.2310	.883	-.0194
15.76	.976	.2572	-.1961	1.009	-.0176
19.50	1.095	.3660	-.1895	1.155	-.0207
-.02	.013	.0209	-.0185	.013	.0209

TABLE VI.- AERODYNAMIC COEFFICIENTS FOR WING WITH CUBIC TWIST - Concluded

(b) Stagnation pressure of 1.0 atmosphere

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.80					
-0.08	0.040	0.0108	-0.0192	0.040	0.0109
-4.14	-.263	.0339	.0243	-.265	.0148
-2.14	-.114	.0178	.0053	-.114	.0135
2.00	.183	.0123	-.0407	.183	.0059
4.04	.325	.0186	-.0563	.325	-.0043
5.07	.397	.0251	-.0639	.398	-.0101
6.05	.468	.0355	-.0715	.469	-.0140
6.99	.532	.0478	-.0754	.534	-.0173
7.01	.533	.0479	-.0756	.535	-.0175
8.01	.589	.0626	-.0730	.592	-.0201
11.70	.756	.1353	-.0710	.767	-.0207
-.11	.047	.0108	-.0210	.047	.0109
M = 0.98					
-0.06	0.038	0.0179	-0.0313	0.038	0.0179
-4.14	-.288	.0417	.0508	-.290	.0209
-2.10	-.125	.0246	.0111	-.126	.0200
2.00	.201	.0204	-.0748	.202	.0134
4.03	.364	.0320	-.1132	.365	.0064
5.03	.442	.0400	-.1293	.444	.0011
6.03	.521	.0500	-.1477	.524	-.0050
7.01	.599	.0630	-.1663	.603	-.0106
7.98	.673	.0785	-.1819	.678	-.0158
10.17	.831	.1229	-.2118	.839	-.0257
-.04	.051	.0177	-.0364	.051	.0177
M = 1.20					
-0.08	0.033	0.0210	-0.0211	0.033	0.0210
-4.21	-.238	.0407	.0512	-.240	.0232
-2.08	-.098	.0264	.0138	-.099	.0228
2.06	.170	.0233	-.0571	.171	.0172
4.03	.307	.0323	-.0929	.309	.0106
7.96	.570	.0727	-.1598	.575	-.0070
10.66	.728	.1192	-.1949	.738	-.0175
-.09	.036	.0209	-.0212	.036	.0210

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.90					
-0.06	0.048	0.0111	-0.0245	0.048	0.0111
-4.16	-.285	.0362	.0287	-.287	.0154
-2.14	-.123	.0186	.0070	-.124	.0140
1.97	.196	.0128	-.0483	.196	.0061
4.03	.361	.0213	-.0748	.361	-.0041
5.07	.456	.0293	-.0955	.457	-.0111
6.05	.546	.0404	-.1165	.547	-.0173
7.01	.612	.0554	-.1232	.614	-.0196
7.98	.658	.0731	-.1195	.662	-.0189
10.47	.748	.1207	-.1057	.757	-.0172
-.08	.060	.0108	-.0276	.060	.0109
M = 1.03					
-0.09	0.023	0.0224	-0.0252	0.023	0.0224
-4.14	-.288	.0457	.0550	-.291	.0248
-2.15	-.137	.0294	.0175	-.138	.0242
2.00	.186	.0247	-.0695	.186	.0182
4.01	.341	.0345	-.1053	.343	.0105
7.98	.644	.0791	-.1767	.649	-.0111
10.11	.792	.1200	-.2063	.801	-.0208
-.08	.027	.0223	-.0254	.027	.0223

α, deg	C_L	C_D	C_m	C_N	C_A
M = 0.94					
-0.09	0.058	0.0116	-0.0304	0.058	0.0117
-4.14	-.306	.0389	.0463	-.308	.0167
-2.08	-.131	.0196	.0108	-.132	.0148
1.98	.226	.0151	-.0689	.226	.0073
4.01	.390	.0267	-.1083	.391	-.0007
5.05	.475	.0353	-.1276	.476	-.0066
6.03	.554	.0463	-.1470	.555	-.0121
7.01	.627	.0601	-.1605	.629	-.0168
8.03	.662	.0791	-.1413	.666	-.0141
10.87	.780	.1338	-.1322	.791	-.0157
.04	.078	.0116	-.0371	.078	.0115
M = 1.13					
-0.11	0.031	0.0206	-0.0221	0.031	0.0207
-4.06	-.251	.0403	.0511	-.254	.0225
-2.23	-.117	.0272	.0172	-.118	.0226
2.00	.173	.0227	-.0603	.173	.0167
3.91	.310	.0310	-.0948	.311	.0098
8.13	.627	.0770	-.1741	.632	-.0124
9.75	.740	.1067	-.1979	.748	-.0202
-.02	.033	.0206	-.0224	.033	.0206

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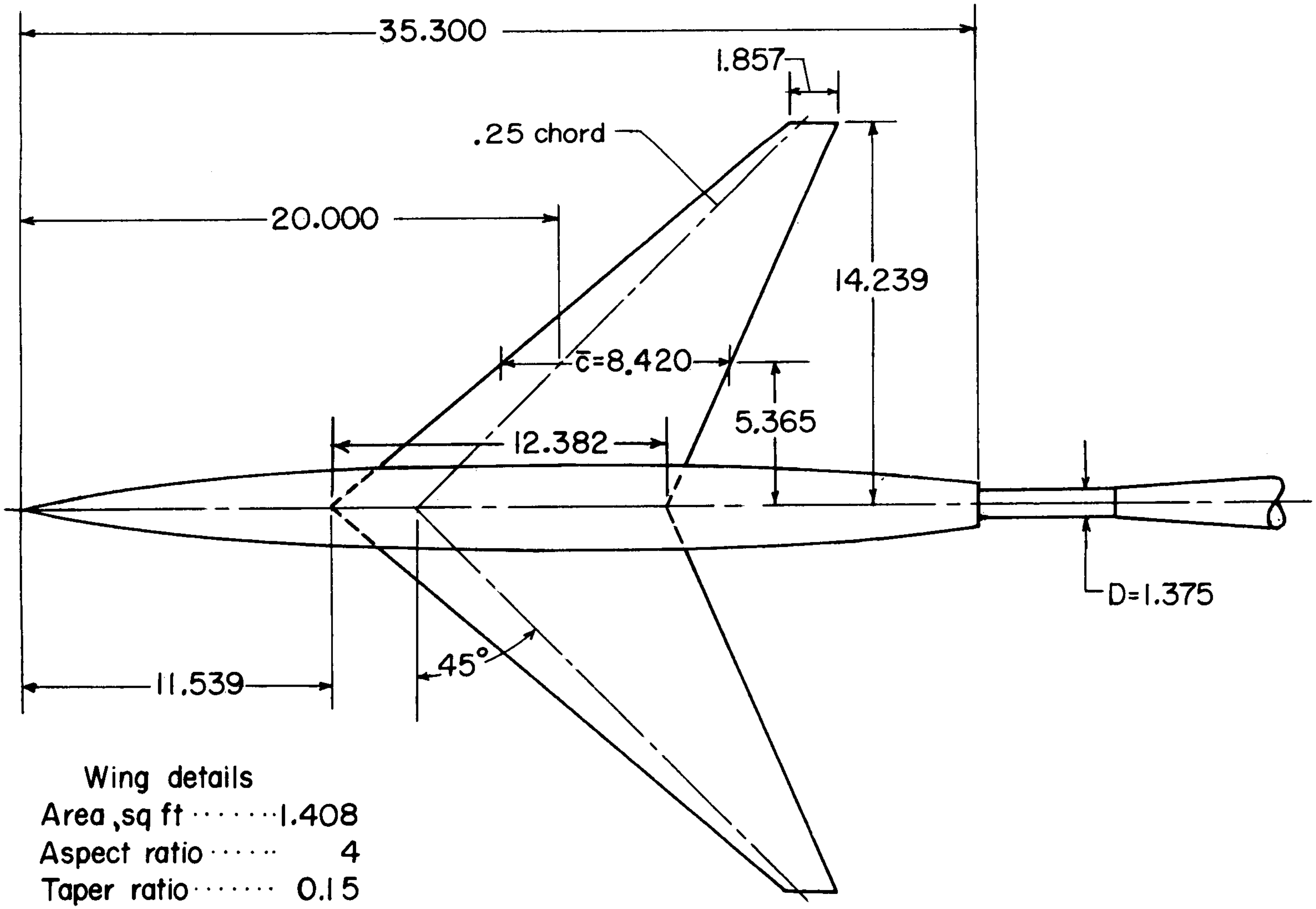

Wing details

Area, sq ft	1.408
Aspect ratio	4
Taper ratio	0.15
Dihedral, deg	0

Figure 1.- Model details. All dimensions in inches unless otherwise noted.

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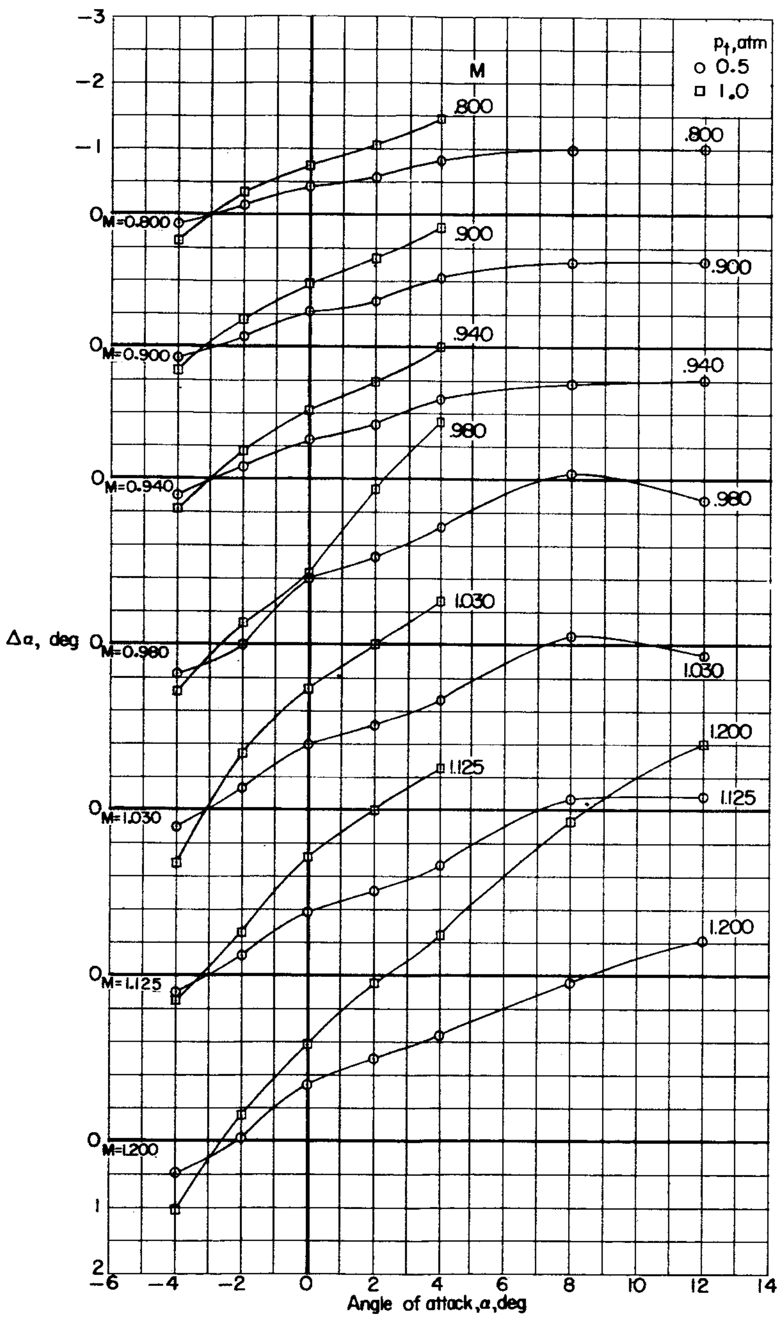

(a) Untwisted wing.

Figure 3.- Variation with angle of attack of the aeroelastic twist angles near the tip $\left(\frac{y}{b/2} = 0.95\right)$ for the four wings. (Data from refs. 1 to 4.)

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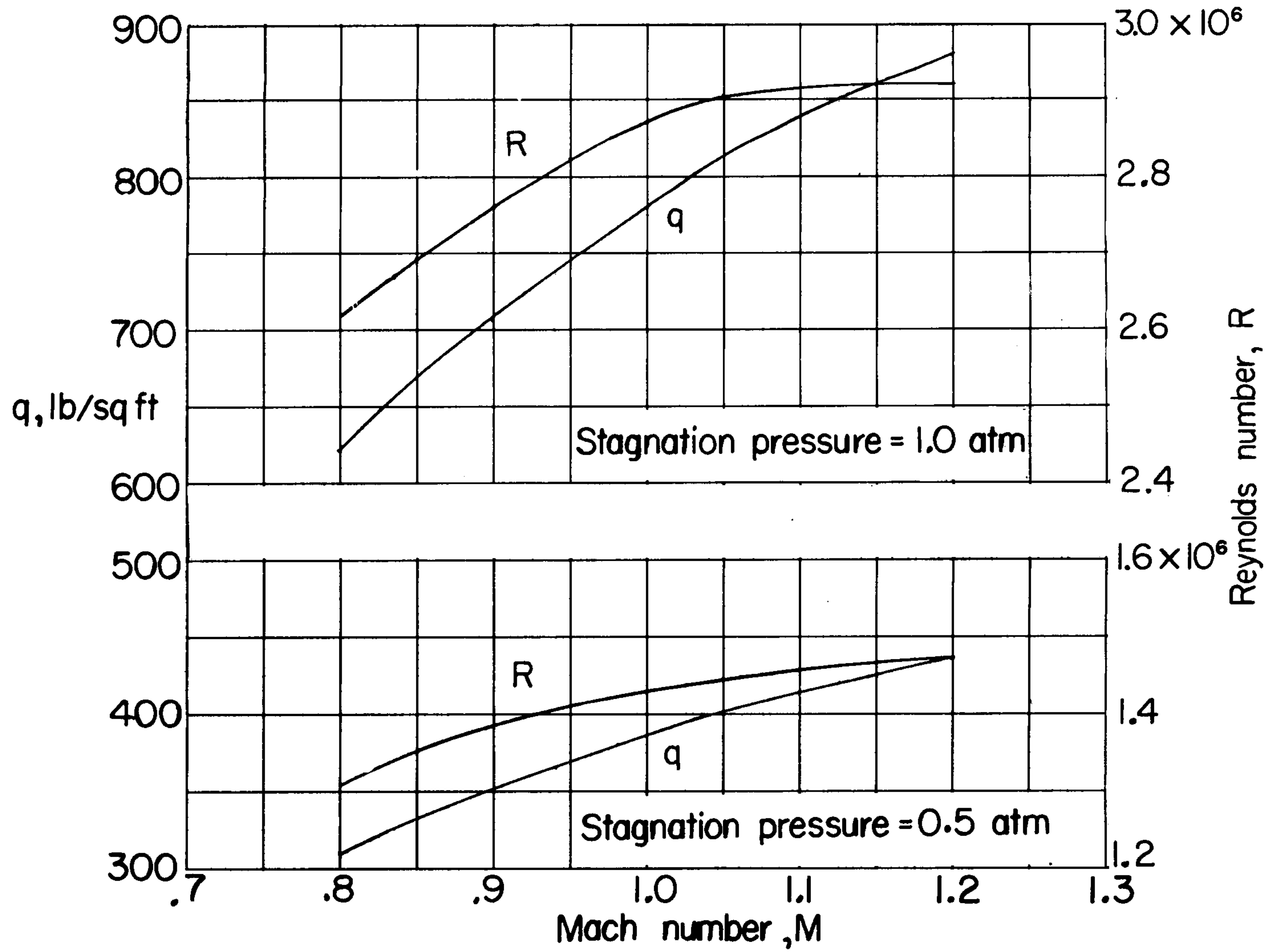

Figure 2.- Variation of the average Reynolds number and free-stream dynamic pressure with Mach number.

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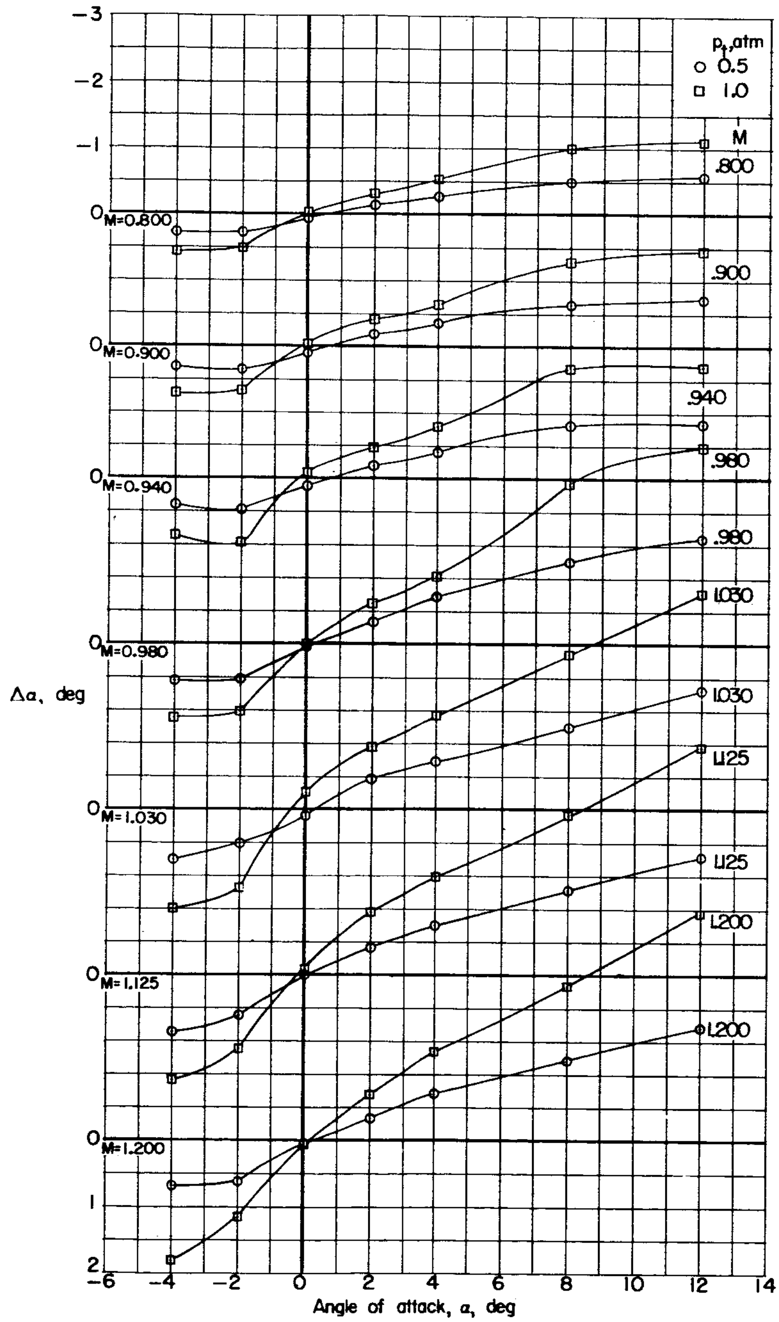

(b) Wing with linear twist.

Figure 3.- Continued.

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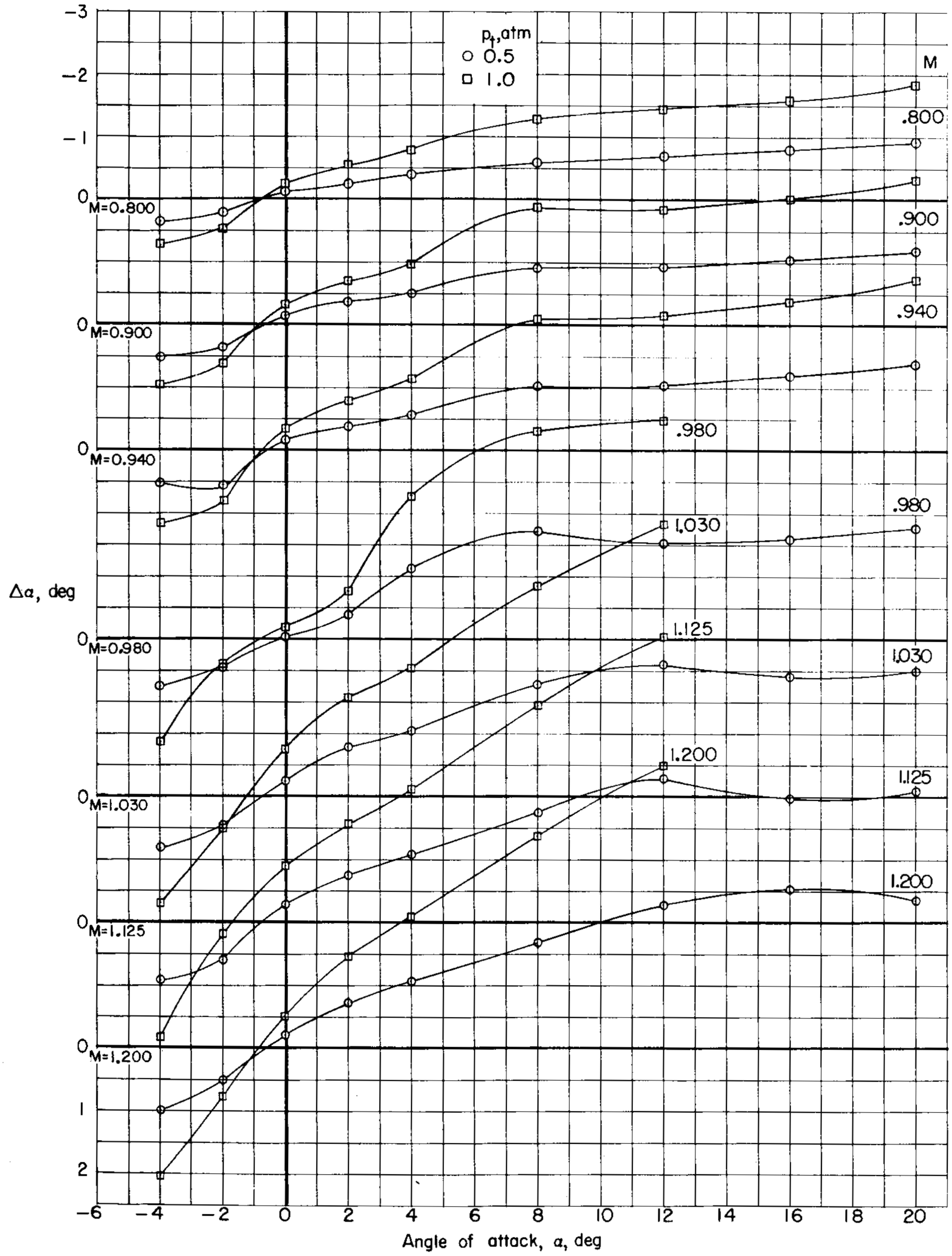

(c) Wing with quadratic twist.

Figure 3.- Continued.

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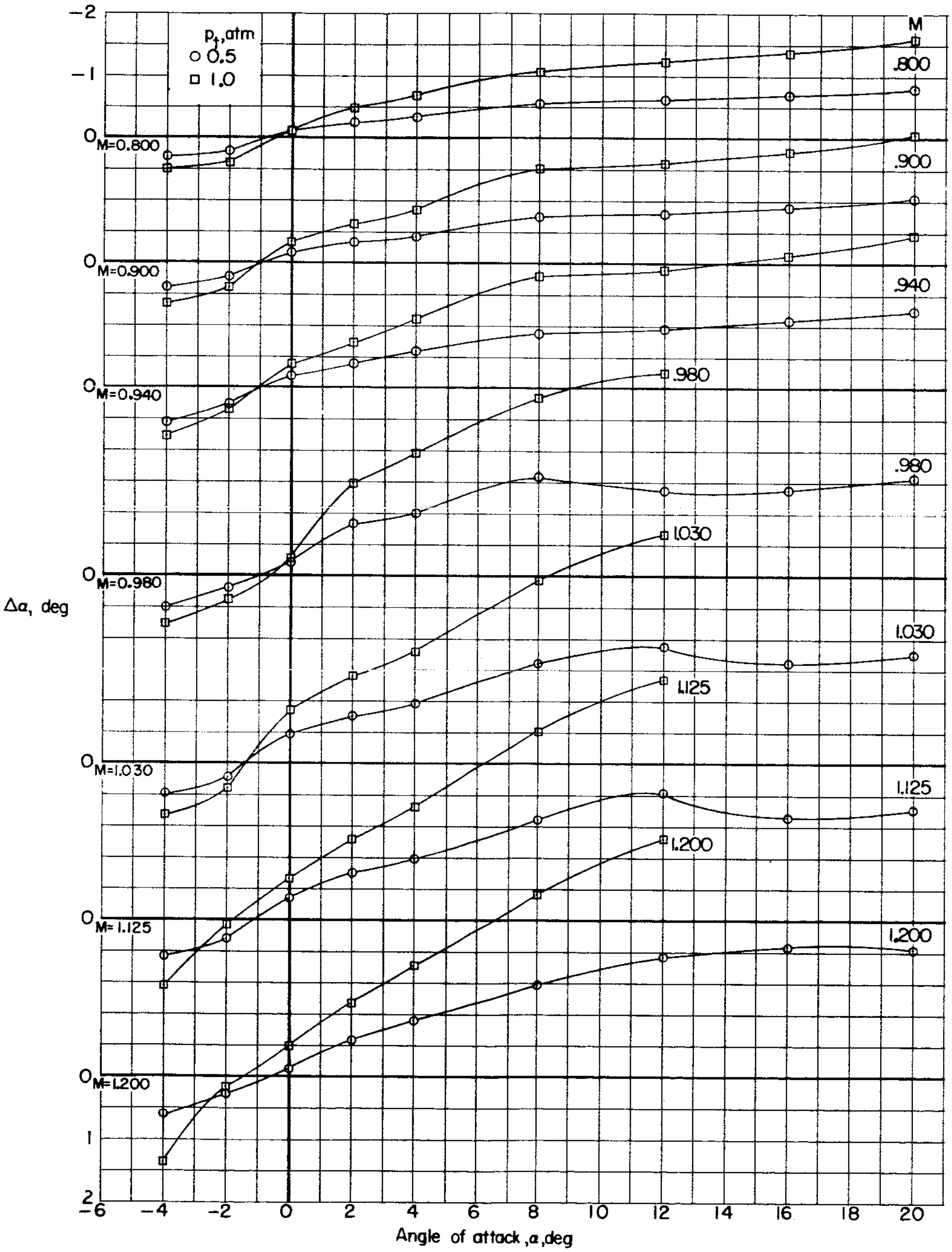
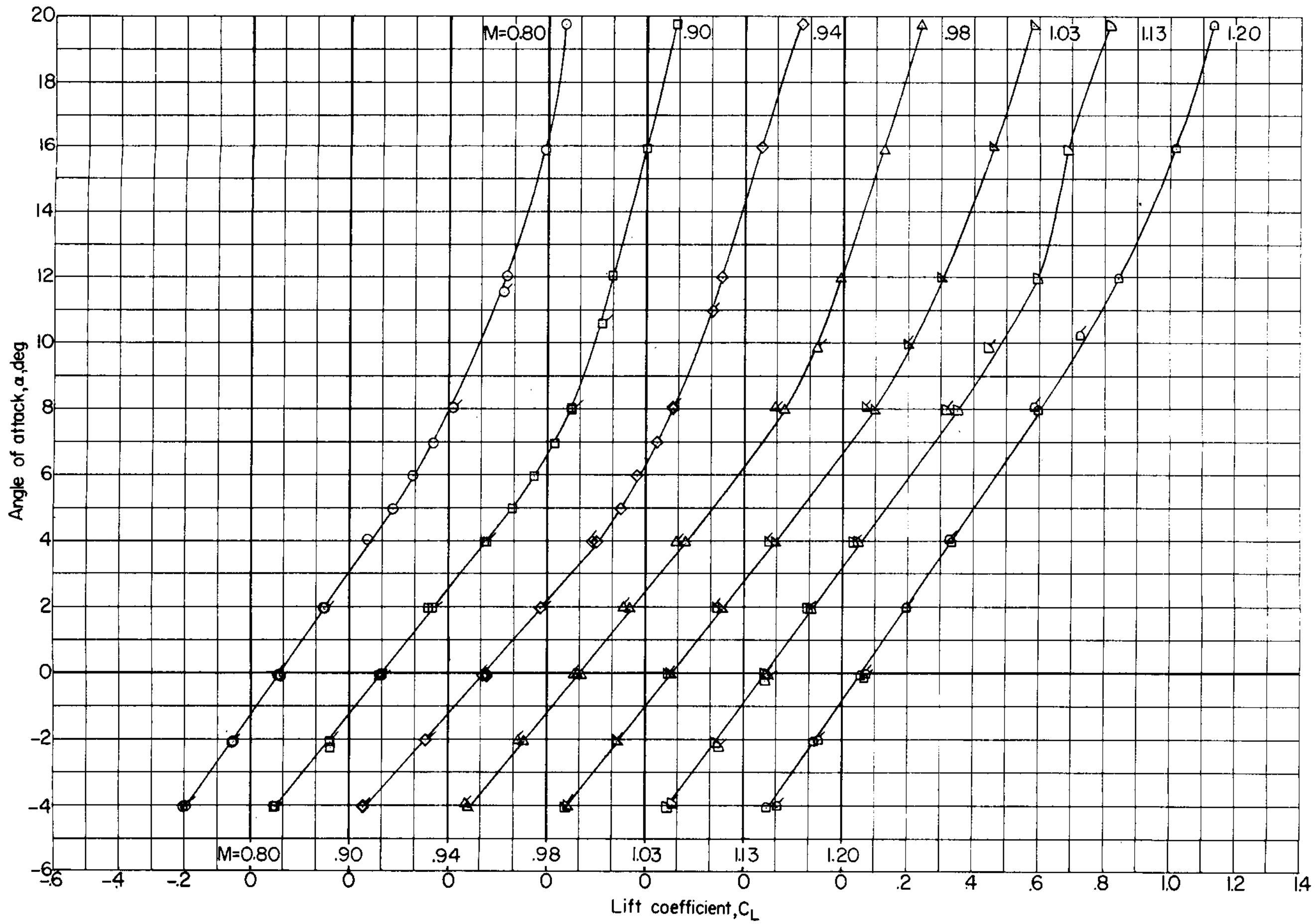


(d) Wing with cubic twist.

Figure 3.- Concluded.



(a) Angle of attack.

Figure 4.- Aerodynamic characteristics of the untwisted wing-body combination. (Unflagged symbols and faired curves denote data taken at a stagnation pressure of 0.5 atmosphere; flagged symbols denote data taken at a stagnation pressure of 1.0 atmosphere.)

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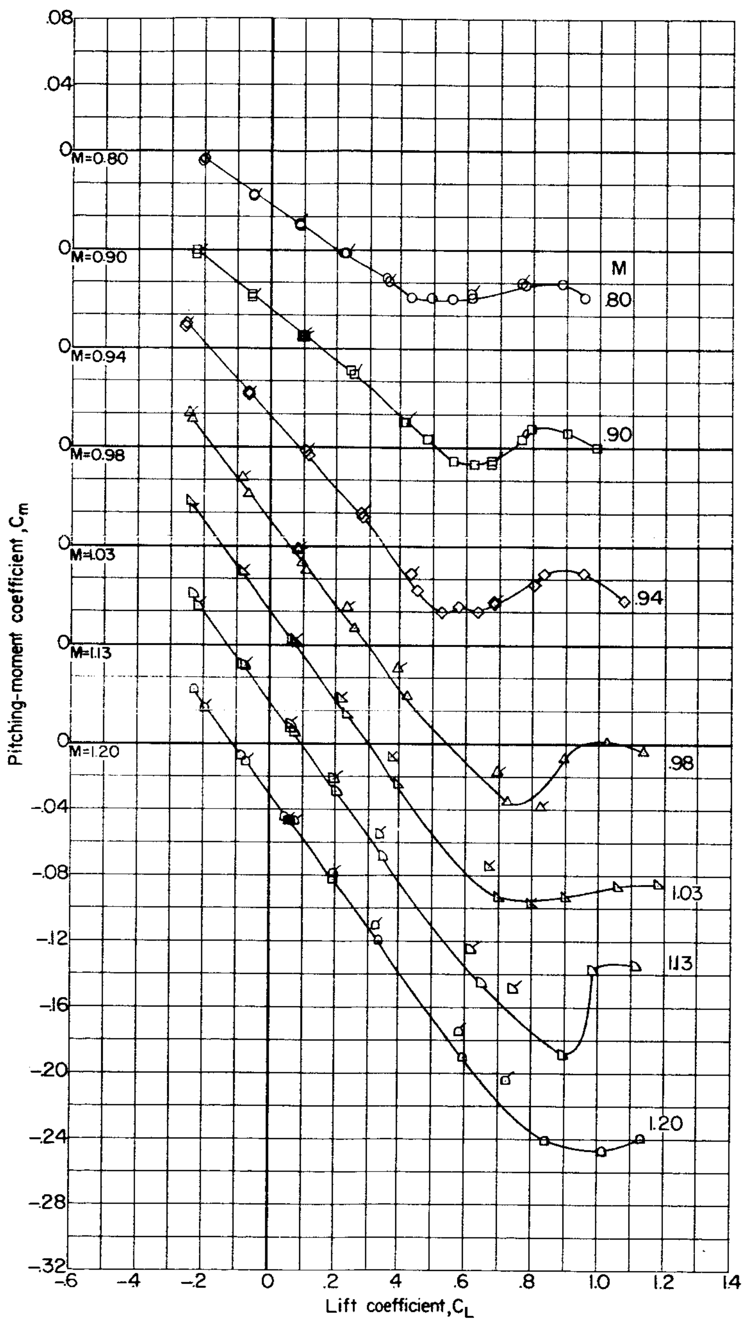
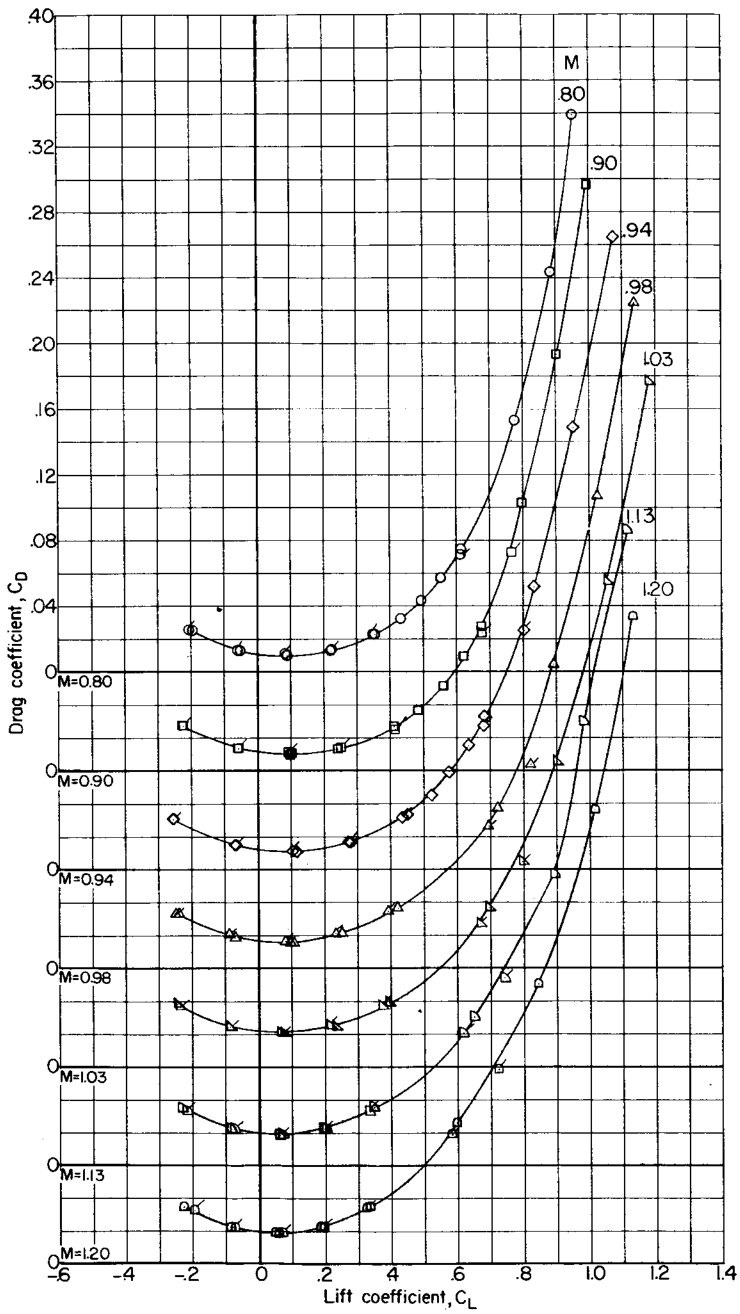


(b) Pitching-moment coefficient.

Figure 4.- Continued.

[redacted]

[redacted]



(c) Drag coefficient.

Figure 4.- Concluded.

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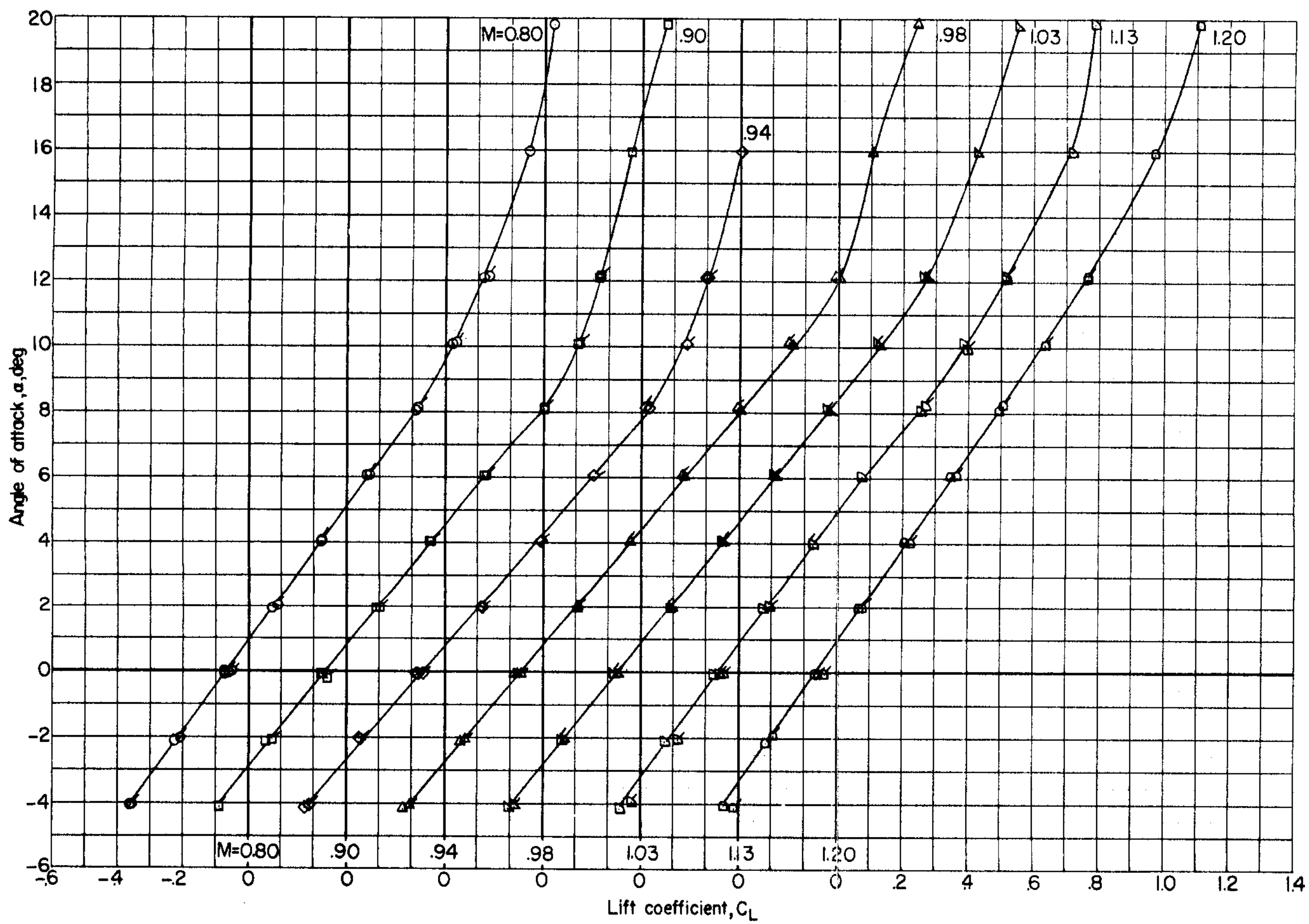
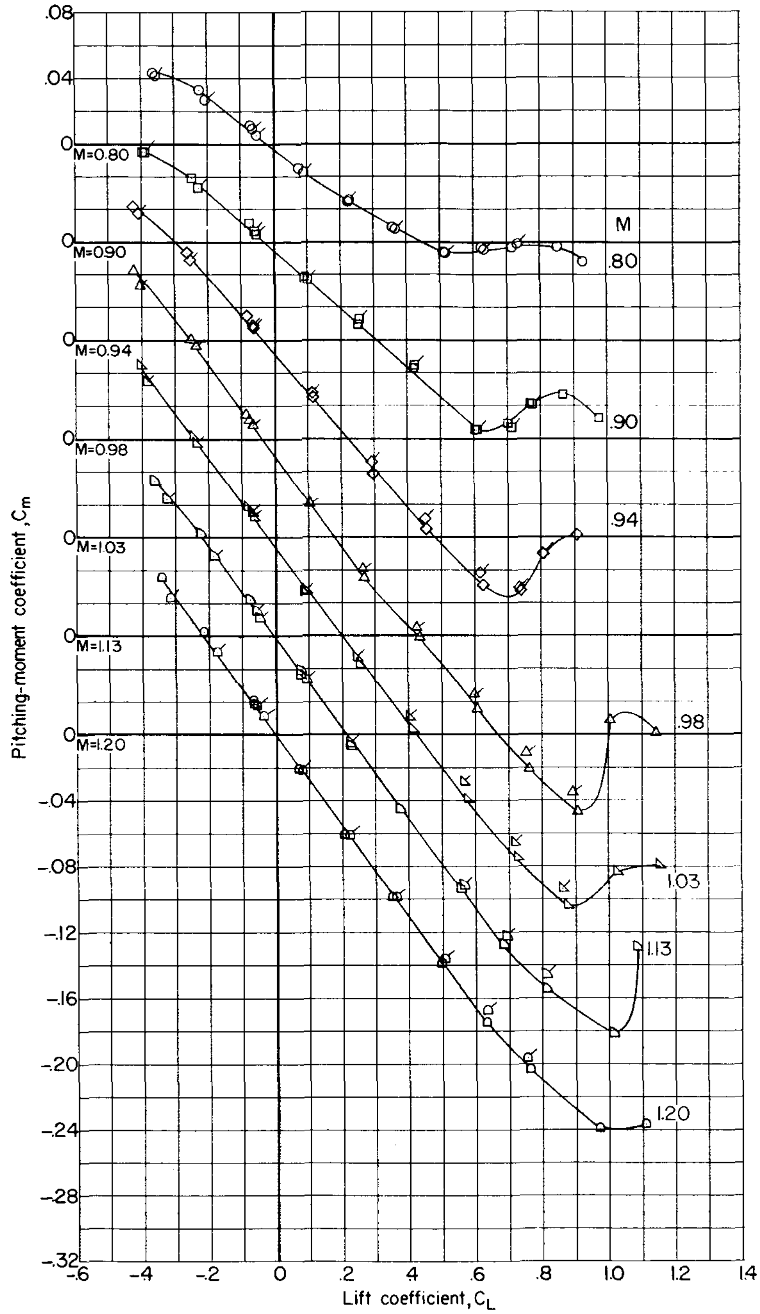


(a) Angle of attack.

Figure 5.- Aerodynamic characteristics of the linearly twisted wing-body combination. (Unflagged symbols and faired curves denote data taken at a stagnation pressure of 0.5 atmosphere; flagged symbols denote data taken at a stagnation pressure of 1.0 atmosphere.)

[redacted]



(b) Pitching-moment coefficient.

Figure 5.- Continued.

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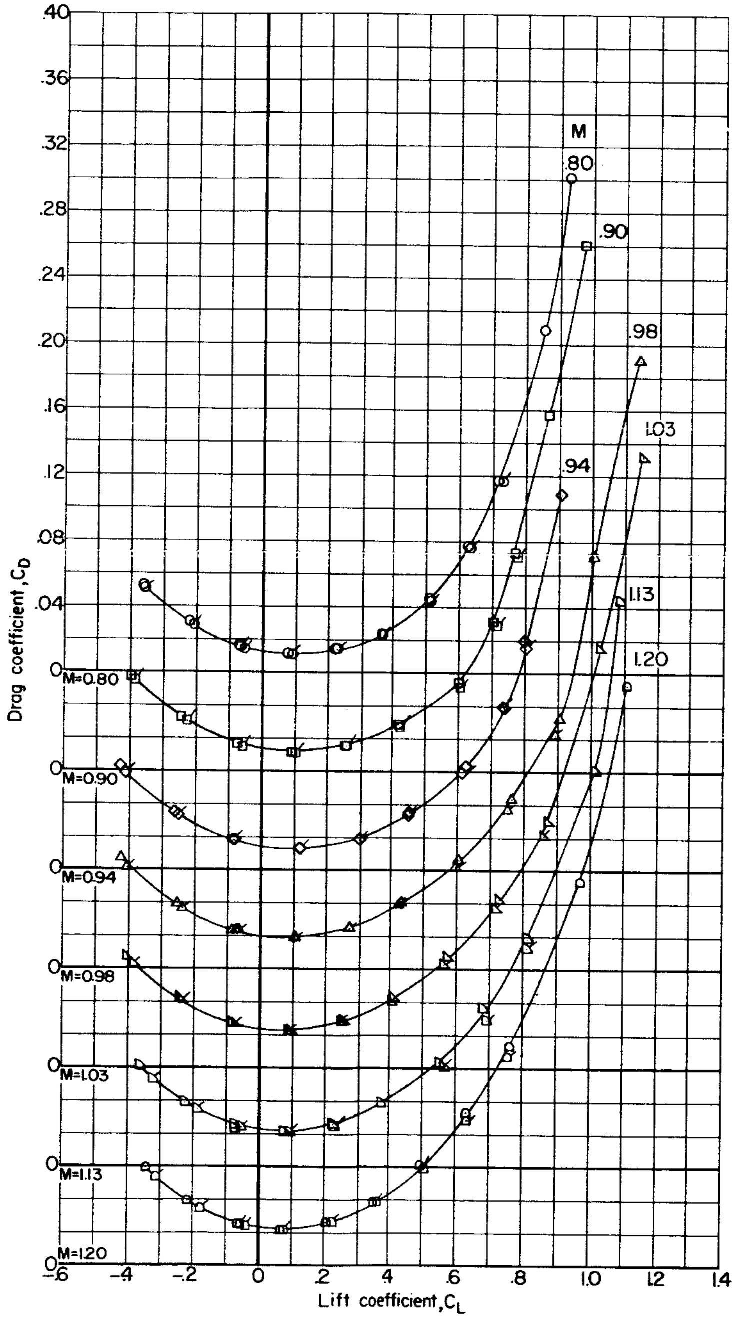

(c) Drag coefficient.

Figure 5.- Concluded.

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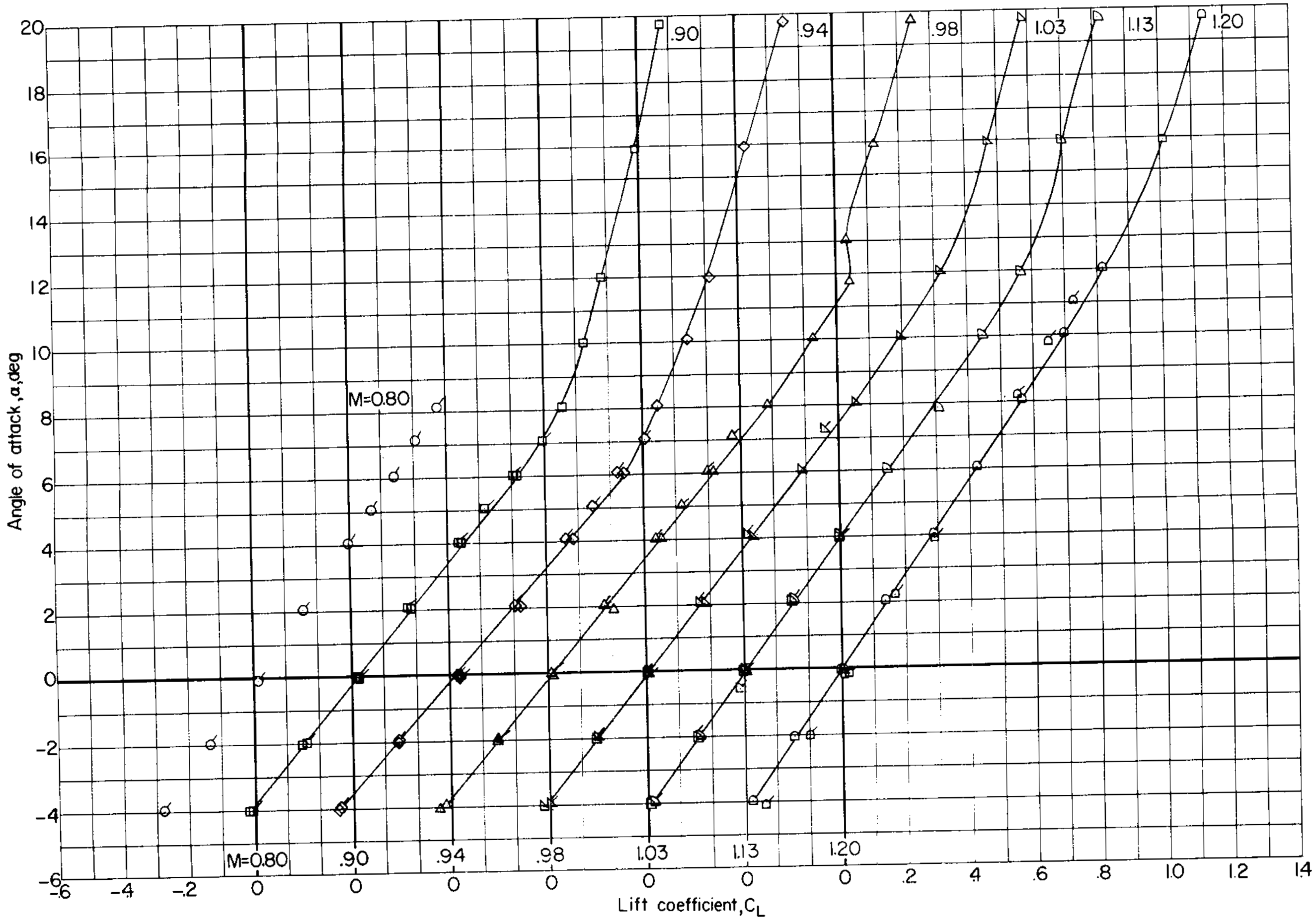

(a) Angle of attack.

Figure 6.- Aerodynamic characteristics of the quadratically twisted wing-body combination. (Unflagged symbols and faired curves denote data taken at a stagnation pressure of 0.5 atmosphere; flagged symbols denote data taken at a stagnation pressure of 1.0 atmosphere.)

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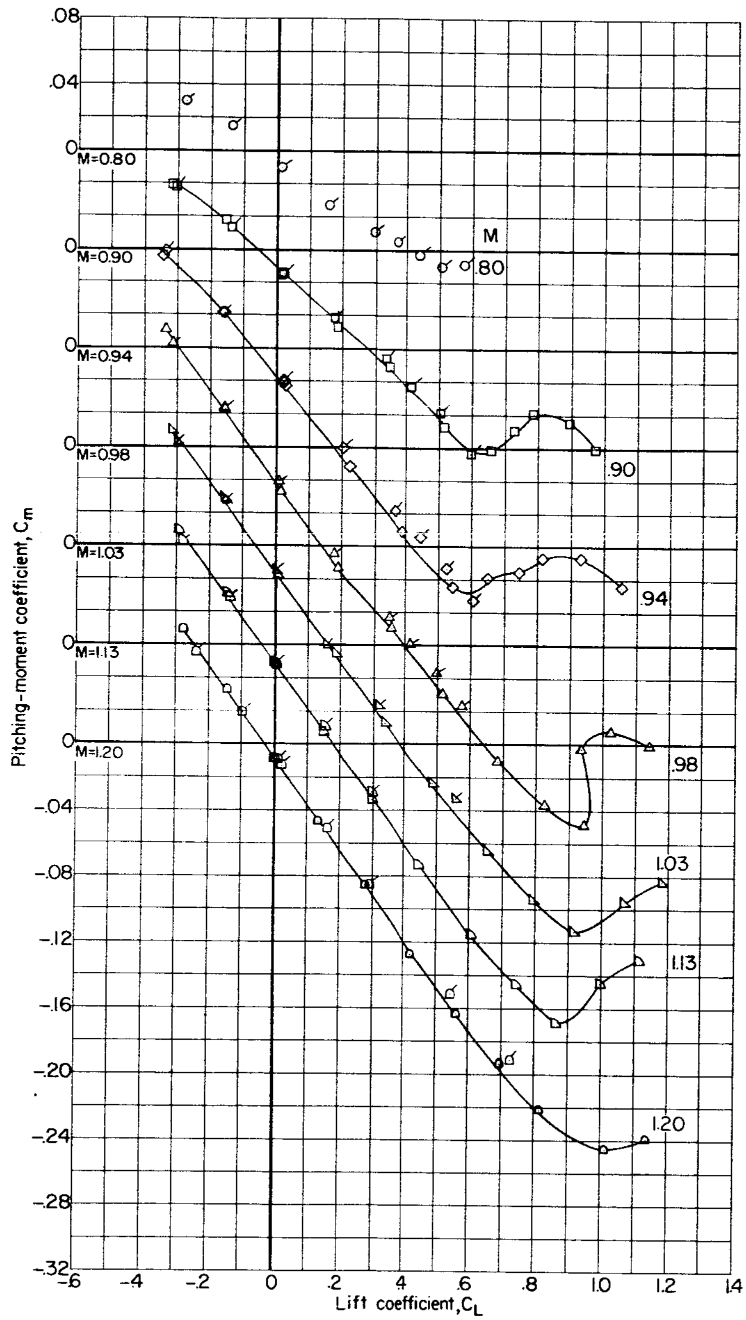

(b) Pitching-moment coefficient.

Figure 6.- Continued.

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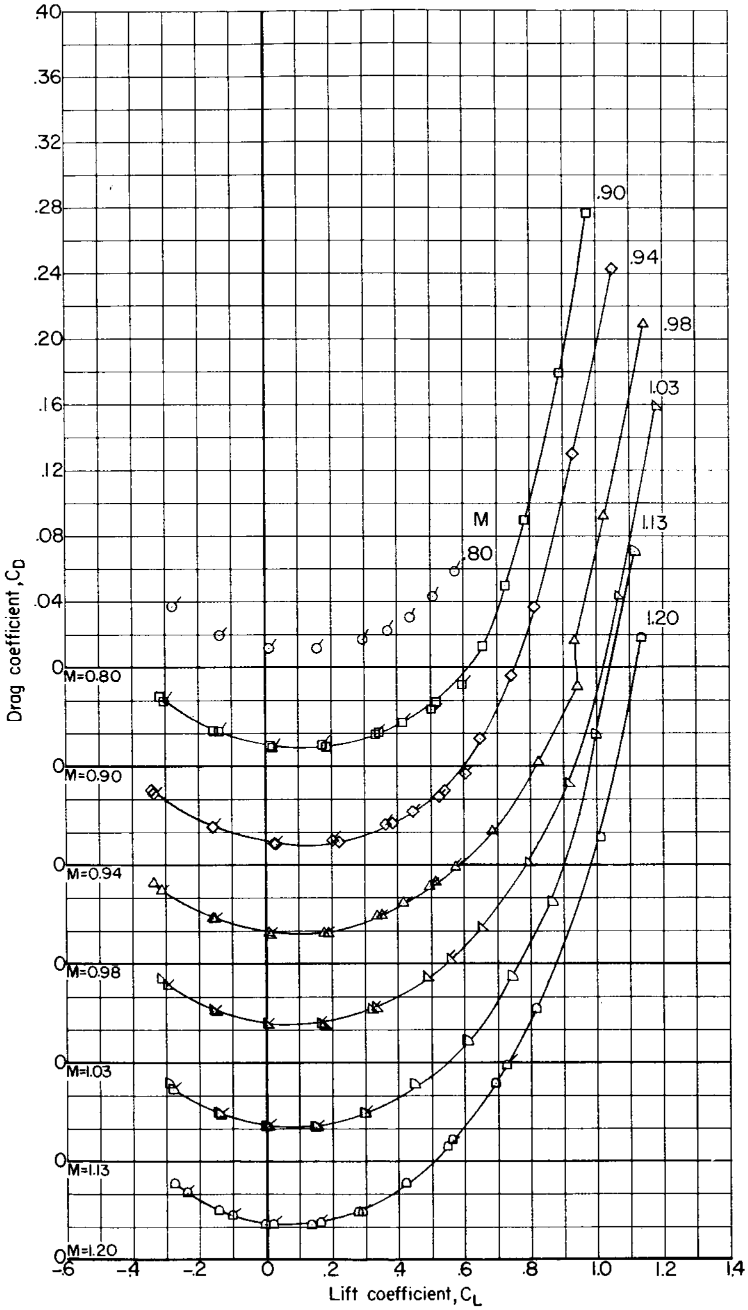
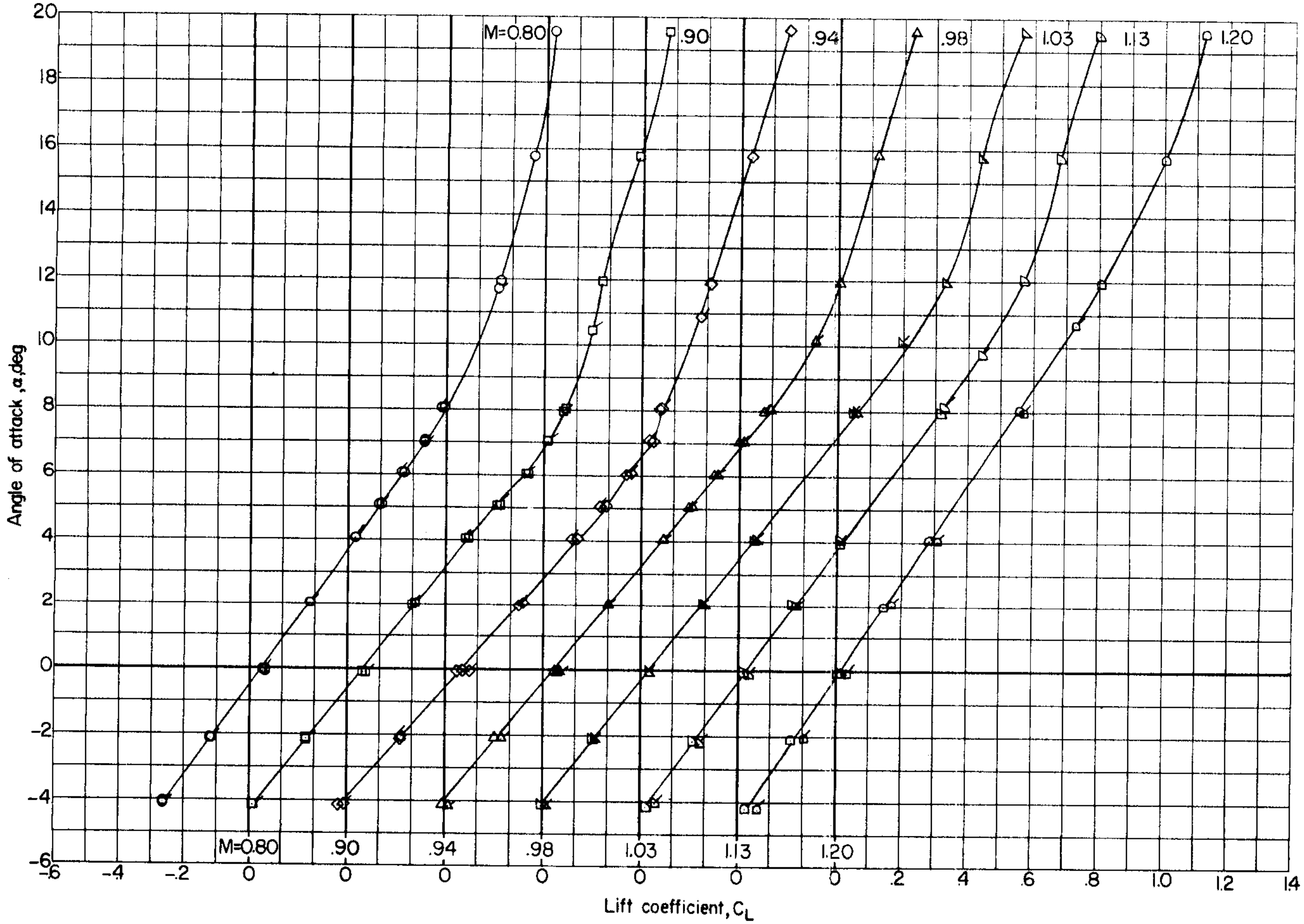


(c) Drag coefficient.

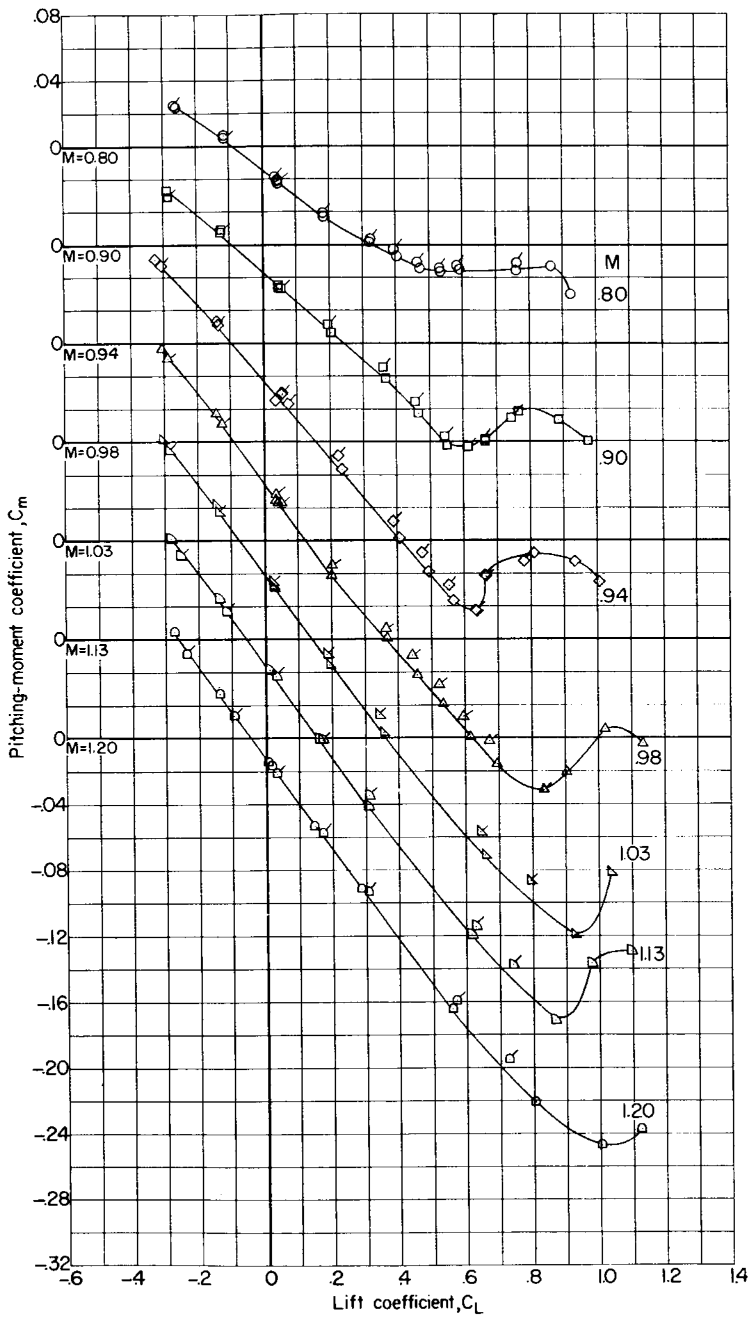
Figure 6.- Concluded.

[redacted]



(a) Angle of attack.

Figure 7.- Aerodynamic characteristics of the cubicly twisted wing-body combination. (Unflagged symbols and faired curves denote data taken at a stagnation pressure of 0.5 atmosphere; flagged symbols denote data taken at a stagnation pressure of 1.0 atmosphere.)



(b) Pitching-moment coefficient.

Figure 7.- Continued.

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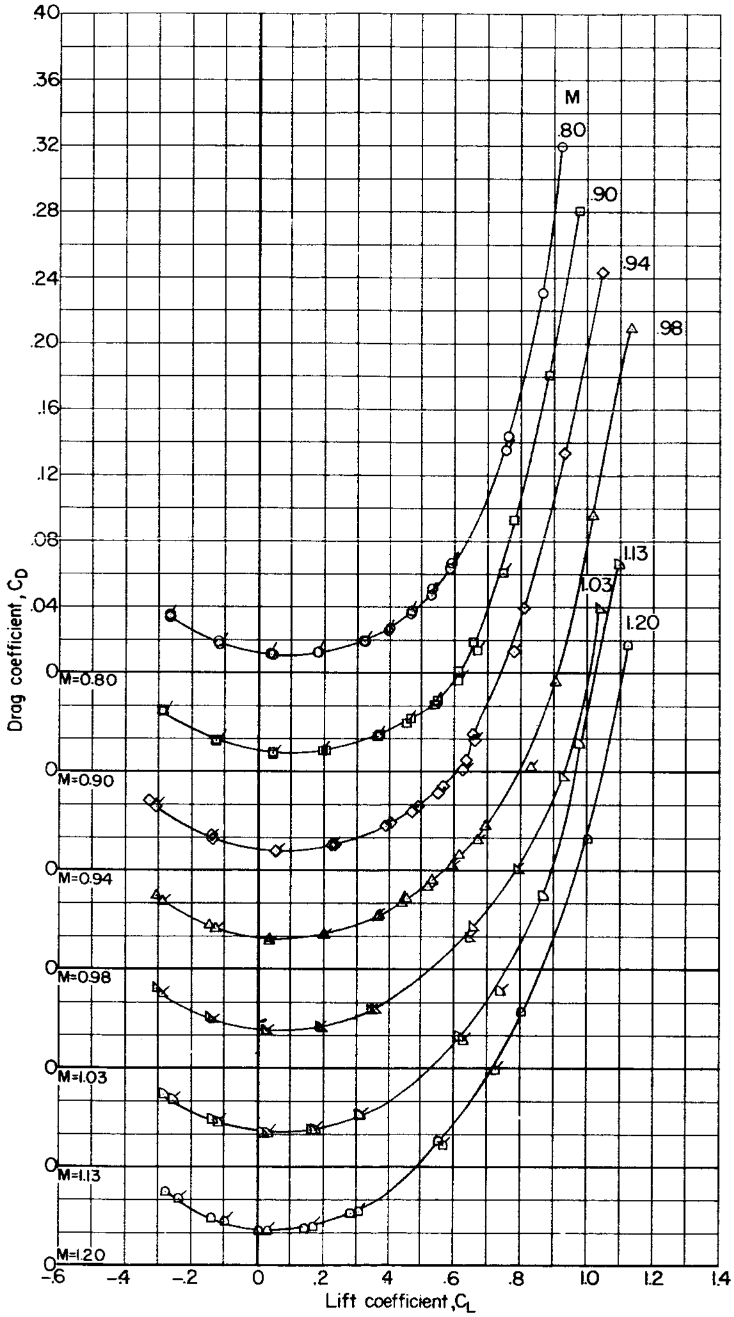
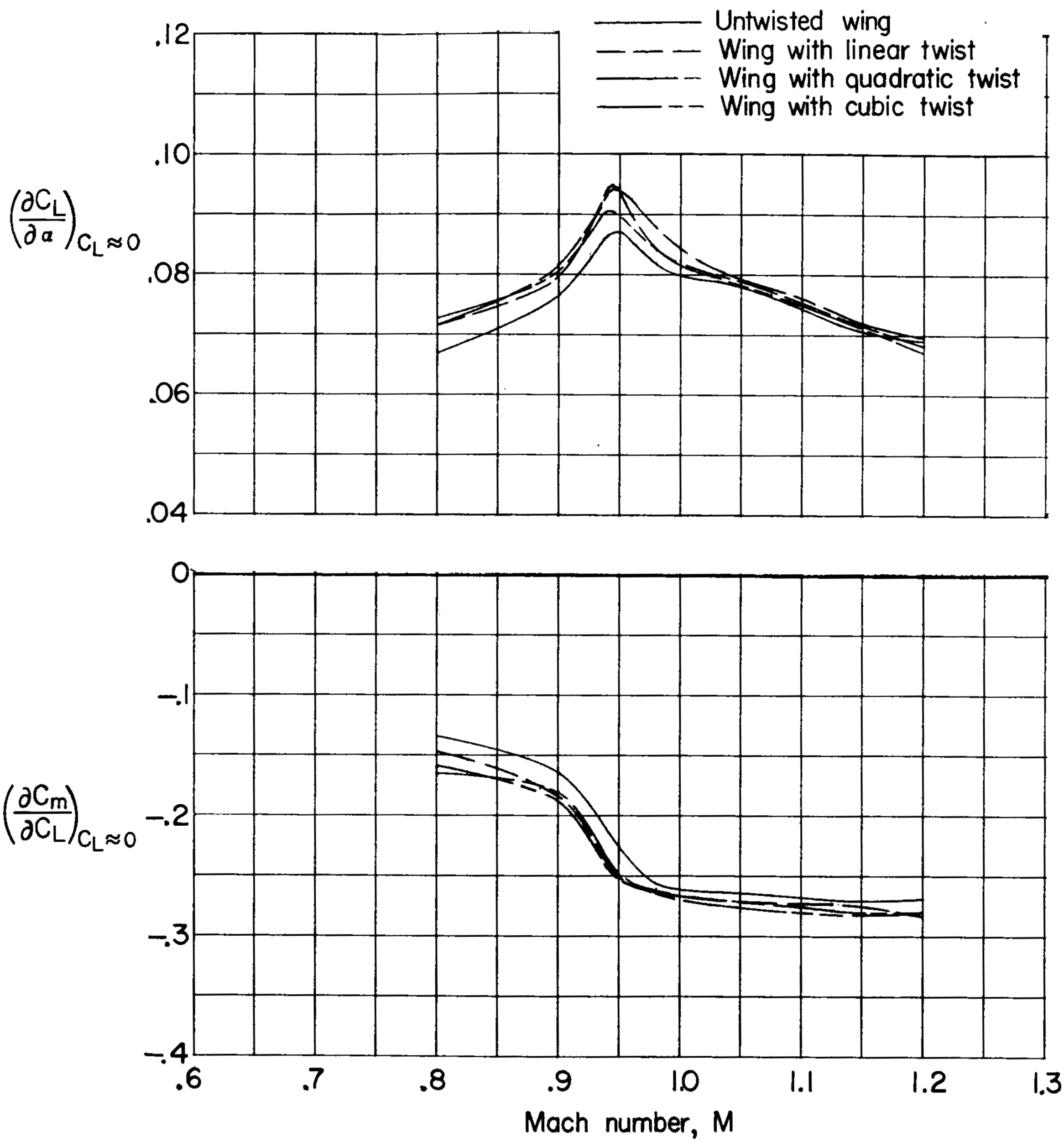


(c) Drag coefficient.

Figure 7.- Concluded.

[redacted]

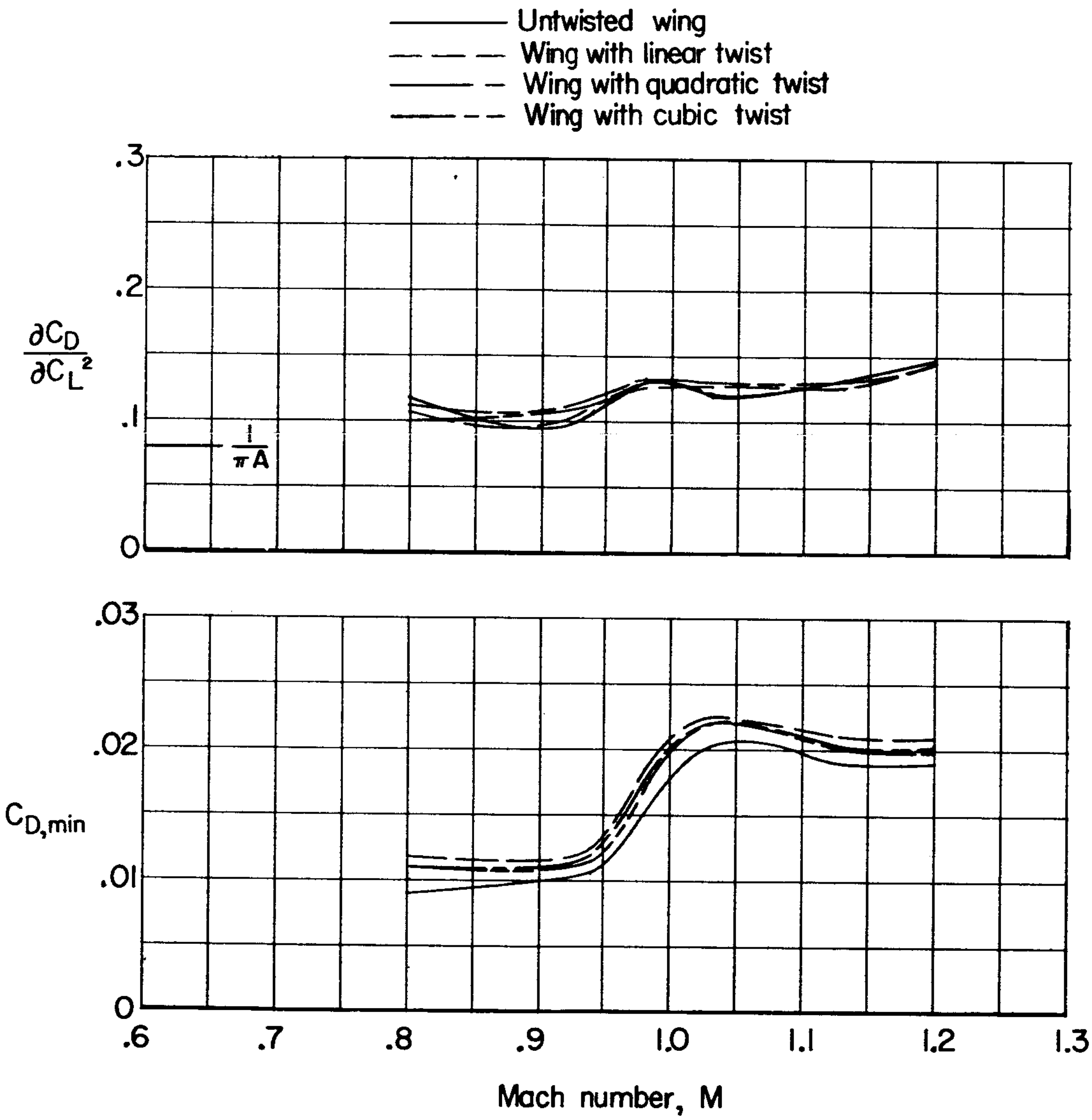
[redacted]



(a) Lift-curve slope and static-longitudinal-stability parameter.

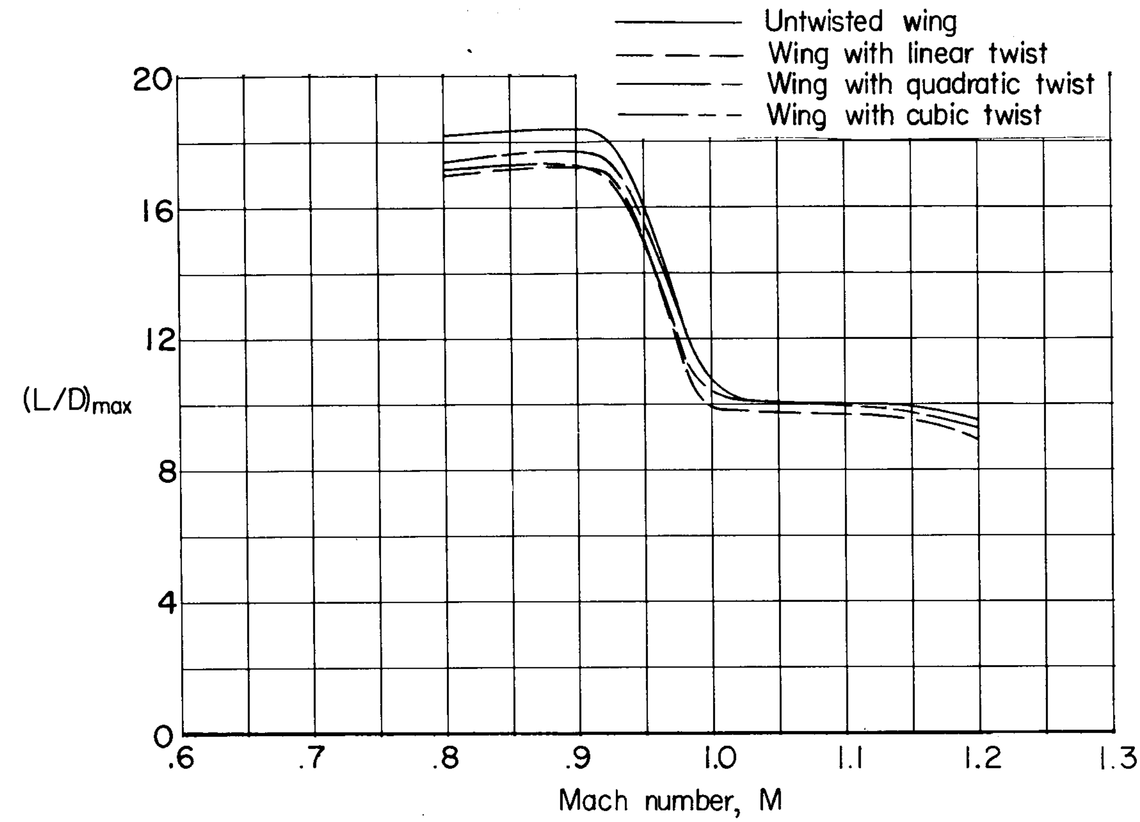
Figure 8.- Effects of three spanwise twist variations on the aerodynamic parameters.

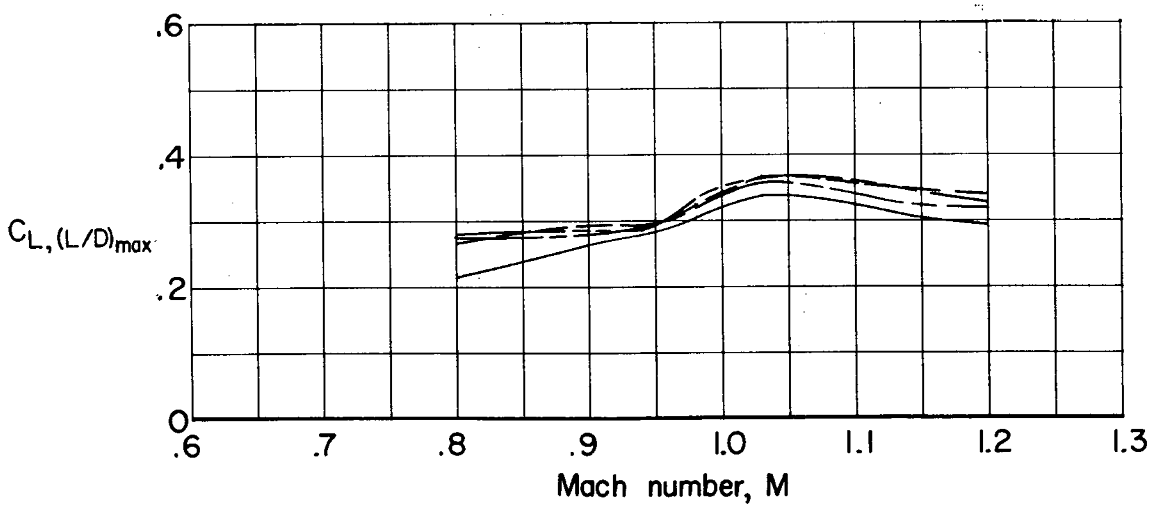
[redacted]



(b) Drag characteristics.

Figure 8.- Continued.





(c) Maximum lift-drag ratio characteristics.

Figure 8.- Concluded.

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