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THE STATIC AND DYNAMIC STABILITY DERIVATIVES OF

A BLUNT HALF-CONE ENTRY CONFIGURATION

AT MACH NUMBERS FROM 0.70 TO 3.50

By Phillips J. Tunnell

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TECHNICAL MEMORANDUM X-577

THE STATIC AND DYNAMIC STABILITY DERIVATIVES OF A BLUNT HALF-CONE ENTRY CONFIGURATION AT MACH NUMBERS FROM 0.70 TO 3.50*

By Phillips J. Tunnell

SUMMARY

The static and dynamic stability derivatives of a blunt half-cone shape have been determined from wind-tunnel tests and are presented herein. The tests were conducted at Mach numbers from 0.70 to 3.50 at a Reynolds number of 2.5 million based on the model length and at angles of attack from -6° to $+14^{\circ}$. Measurements were made of the damping-in-pitch, -yaw, and -roll derivatives, the cross derivatives, and the static longitudinal and directional derivatives.

In general, the damping derivatives tend to approach relatively constant values with increasing supersonic Mach number. However, in the transonic range the damping is changing rapidly and, in some cases, is unstable. The damping and cross derivatives are relatively invariant with angle of attack except in the transonic speed range.

INTRODUCTION

The rapid increase in density experienced by vehicles entering the earth's atmosphere on a ballistic trajectory tends to damp any buildup of oscillatory motion. However, dynamic instability is a potential source of trouble for a manned vehicle in which the pilot is attempting attitude control. The pilot must, of necessity, fly a narrow corridor on re-entry due to deceleration and heating considerations. To assess the controllability of such a vehicle a knowledge of the stability and damping derivatives is essential.

The purpose of this report is to present one phase of an over-all program to assess the characteristics of a vehicle proposed for manned re-entry in reference 1. Other phases of this study are reported in references 2 through 5. The stability data obtained from wind-tunnel

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forced oscillation tests in the present investigation cover a Mach number range from 0.70 to 3.50 and angles of attack from -6° to $+14^{\circ}$. The derivatives obtained are referred to a body system of axes and include the following: static longitudinal stability (C_{m_α}), damping in pitch ($C_{m_q} + C_{m_{\dot{\alpha}}}$), damping in roll ($C_{l_p} + C_{l_{\dot{\beta}}} \sin \alpha$), yawing moment due to rolling ($C_{n_p} + C_{n_{\dot{\beta}}} \sin \alpha$), directional stability (C_{n_β}), damping in yaw ($C_{n_r} - C_{n_{\dot{\beta}}} \cos \alpha$), and rolling moment due to yawing ($C_{l_r} - C_{l_{\dot{\beta}}} \cos \alpha$).

NOTATION

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Moments and deflections are referred to a body system of axes (fig. 1). The various stability derivatives are defined as follows:

C_{m_α} $\quad \dfrac{\partial C_m}{\partial \alpha}$, per deg

$C_{m_{\dot{\alpha}}}$ $\quad \dfrac{\partial C_m}{\partial(\dot{\alpha} l/V)}$, per radian

C_{m_q} $\quad \dfrac{\partial C_m}{\partial(q l/V)}$, per radian

C_{n_β} $\quad \dfrac{\partial C_n}{\partial \beta}$, per deg

$C_{n_{\dot{\beta}}}$ $\quad \dfrac{\partial C_n}{\partial(\dot{\beta} b/V)}$, per radian

C_{n_r} $\quad \dfrac{\partial C_n}{\partial(rb/V)}$, per radian

C_{n_p} $\quad \dfrac{\partial C_n}{\partial(pb/V)}$, per radian

C_{l_p} $\quad \dfrac{\partial C_l}{\partial(pb/V)}$, per radian

$C_{l_{\dot{\beta}}}$ $\quad \dfrac{\partial C_l}{\partial(\dot{\beta} b/V)}$, per radian

C_{l_r} $\quad \dfrac{\partial C_l}{\partial(rb/V)}$, per radian

Additional symbols are as follows:

C_m	pitching-moment coefficient, $\frac{\text{pitching moment}}{(1/2)\rho V^2 S l}$
C_n	yawing-moment coefficient, $\frac{\text{yawing moment}}{(1/2)\rho V^2 S b}$
C_l	rolling-moment coefficient, $\frac{\text{rolling moment}}{(1/2)\rho V^2 S b}$
b	maximum base diameter, 1.5 ft
f	frequency of oscillation, cps
k	reduced frequency parameter, $\frac{2\pi f l}{V}$
l	model length, 1 ft
M_∞	free-stream Mach number
p	rolling velocity
q	pitching velocity
r	yawing velocity
R	Reynolds number based on l
S	model base area, ft^2
V	free-stream velocity
α	angle of attack
β	angle of sideslip
δ_U	upper flap angle measured from a line perpendicular to base
δ_L	lower flap angle measured from a line perpendicular to base, positive direction outward
ρ	density

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MODEL

The model used in the present investigation is shown in figures 2 and 3. The configuration is essentially the same as that described in reference 1. Basically it is formed from a cone having a half angle of 30°, cut by a plane inclined 6.6° with respect to the axis of the cone. The base diameter is 1.5 times the length, and the nose is blunted by a radius of 0.3 times the length. The juncture between the nose hemisphere and the conical surface is faired to give a continuous curvature of the profile. The edges formed by the cone-plane juncture are rounded with a radius of 0.14 times the length. Simple flap-type controls are mounted to the base with a small gap between their leading edges and the body base. The gap was provided to reduce boundary-layer shock-wave interaction. For all the data presented herein, the moment center corresponds to the center-of-gravity location shown in figure 2.

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APPARATUS

Tests were conducted in the 11- by 11-foot (M = 0.7 to 1.4), the 9- by 7-foot (M = 1.5 to 2.2), and the 8- by 7-foot (M = 2.5 to 3.5) test sections of the Ames Unitary Plan Wind Tunnel. These test sections provide continuous Mach number variation from 0.7 to 3.5 with stagnation pressure control. A more detailed description of the wind tunnel may be found in reference 6.

The damping and stability derivatives were measured with either a pitch or yaw balance, depending on the model orientation, and a roll balance. Basically, the balances supported the model on a set of crossed flexures, or springs, allowing the model to oscillate in a single degree of freedom about a fixed axis. The oscillation amplitude was maintained constant at the natural frequency of the system through a feedback loop. The frequency varied from 4 to 8 cycles per second, depending on the aerodynamic moment. A more detailed description of this apparatus and the technique used to measure the rotary derivatives is given in reference 7.

TESTS

The damping derivatives were measured at Mach numbers from 0.70 to 3.50 at a Reynolds number of 2.5 million based on model length and at angles of attack from -6° to $+14^{\circ}$. The amplitude of oscillation was maintained constant at $\pm 1^{\circ}$. Two data points were taken at each test condition, and each data point is the average of three readouts. The

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accuracy of the data at supersonic Mach numbers is reflected in the scatter between data points. At Mach numbers up to about 1.4, the model buffeted in pitch, and data obtained under these conditions may be subject to greater error.

The model was tested with and without control surfaces. Lower control surface deflections of 0°, 15°, and 30° were used when necessary to keep the pitching moment within allowable balance limits.

Corrections to the measured values of the damping coefficients due to internal damping of the oscillation apparatus were determined from wind-off measurements of the damping, with the tunnel evacuated to about 3 pounds per square inch absolute. These measurements were made prior to each test to determine the corrections to be applied.

RESULTS AND DISCUSSION

The stability data obtained on the model of this investigation are given in tables I, II, and III. The pitching derivatives are given in table I (C_{m_α} and $C_{m_q} + C_{m_{\dot{\alpha}}}$), the yawing derivatives in table II (C_{n_β}, $C_{n_r} - C_{n_{\dot{\beta}}} \cos \alpha$ and $C_{l_r} - C_{l_{\dot{\beta}}} \cos \alpha$), and the rolling derivatives in table III ($C_{l_p} + C_{l_{\dot{\beta}}} \sin \alpha$ and $C_{n_p} + C_{n_{\dot{\beta}}} \sin \alpha$). In addition, the reduced frequency parameter, k, is tabulated.

The variations, with Mach number at zero angle of attack, of the damping derivatives about the three model axes and the variation of roll due to yawing and yaw due to rolling are shown in figures 4 and 5, respectively. In the transonic range the derivatives change rapidly, particularly the damping in yaw which is also highly unstable both with and without control surfaces. However, in general, these derivatives tend to approach relatively constant values with increasing Mach number and for this reason it might be anticipated that the values at high Mach numbers would not differ largely from those measured at Mach numbers from 2 to 3.5.

Shown in figures 6 to 10 are some of the measured variations with angle of attack of these derivatives. The data shown in these figures are typical and, in general, the damping and cross derivatives are seen to be relatively invariant with changing angle of attack except in the transonic range. Schlieren motion pictures, taken during oscillatory motion, indicated the model was subject to buffeting in pitch which could be attributed to separated flow and a rapidly changing shock field over the top surface of the vehicle. This was observed at transonic Mach numbers where the damping in pitch was erratic with changes in angle of attack.

To investigate more fully the unstable damping-in-yaw characteristics observed at transonic speeds, traverses in sideslip were made at angles where the damping was the most unstable. The results are presented in figure 11. It is observed that the damping is initially unstable at $\beta = 0$, but as β is increased either in the positive or negative direction the damping becomes stable. The resultant unstable bucket in the damping curve is typical of that found with other blunt bodies where the flow separated symmetrically from the nose (ref. 8). This was also observed from schlieren motion pictures of these tests at transonic speeds which show a very unstable flow field about the model due to separation from the blunt nose. Where this type of dynamic instability has been observed on other vehicles, limit-cycle-oscillatory motion has developed in free flight (ref. 9).

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National Aeronautics and Space Administration
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TABLE I.- PITCHING DERIVATIVES

(a) With flap control

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot\alpha}}$
[1]M = 0.70			
δ_L = 15° δ_U = 0°			
01.2	.0606	-.0029	-0.367
01.2	.0602	-.0024	-0.275
04.1	.0606	-.0029	-0.263
04.1	.0593	-.0014	-0.406
06.9	.0597	-.0019	-0.256
06.9	.0596	-.0019	-0.321
09.8	.0598	-.0019	-0.226
09.8	.0589	-.0010	-0.204
12.6	.0597	-.0024	-0.211
12.6	.0599	-.0024	-0.211
15.3	.0594	-.0019	-0.174
15.3	.0595	-.0019	-0.193
δ_L = 30° δ_U = 0°			
-05.5	.0589	-.0023	-0.333
-05.5	.0584	-.0018	-0.584
-02.6	.0592	-.0025	-0.344
-02.6	.0585	-.0018	-0.352
00.1	.0593	-.0028	-0.406
00.1	.0590	-.0025	-0.372
02.9	.0593	-.0025	-0.419
02.9	.0588	-.0020	-0.366
05.7	.0593	-.0025	-0.292
05.7	.0595	-.0028	-0.191
[1]M = 0.80			
δ_L = 15° δ_U = 0°			
01.3	.0535	-.0027	-0.471
01.3	.0532	-.0022	-0.414
04.2	.0524	-.0013	-0.463
04.2	.0526	-.0013	-0.410
07.0	.0525	-.0013	-0.103
07.0	.0525	-.0013	-0.118
10.0	.0521	-.0009	-0.277
10.0	.0523	-.0009	-0.255
12.8	.0537	-.0027	-0.180
12.8	.0537	-.0027	-0.293
δ_L = 30° δ_U = 0°			
-05.6	.0529	-.0027	-0.433
-05.6	.0525	-.0023	-0.402
-02.7	.0534	-.0028	-0.605
-02.7	.0531	-.0025	-0.438
00.0	.0535	-.0030	-0.403
00.0	.0531	-.0025	-0.343
02.7	.0529	-.0023	-0.397
02.7	.0528	-.0021	-0.327
05.6	.0529	-.0021	-0.211
05.6	.0526	-.0019	-0.198

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot\alpha}}$
[1]M = 0.90			
δ_L = 15° δ_U = 0°			
01.3	.0486	-.0029	-0.619
01.3	.0472	-.0012	-0.637
04.0	.0471	-.0012	-0.165
04.0	.0485	-.0029	-0.067
07.0	.0447	.0018	-1.370
07.0	.0441	.0024	-1.416
09.8	.0490	-.0033	-0.139
09.8	.0485	-.0029	-0.239
12.6	.0486	-.0029	0.131
12.6	.0485	-.0029	0.131
14.7	.0525	-.0078	0.238
14.7	.0529	-.0084	0.411
δ_L = 30° δ_U = 0°			
-05.8	.0488	-.0035	-0.020
-05.8	.0484	-.0030	0.092
-03.1	.0486	-.0033	-0.422
-03.1	.0490	-.0039	-0.303
-00.3	.0485	-.0033	-0.845
-00.3	.0481	-.0028	-0.977
02.4	.0481	-.0026	-1.084
02.4	.0482	-.0028	-1.342
[1]M = 0.95			
δ_L = 15° δ_U = 0°			
01.2	.0467	-.0032	-0.267
01.2	.0467	-.0032	-0.378
03.9	.0451	-.0012	-0.874
03.9	.0450	-.0012	-0.932
06.8	.0426	.0017	-1.841
06.8	.0420	.0024	-1.927
09.6	.0478	-.0046	-0.222
09.6	.0477	-.0046	-0.157
12.2	.0470	-.0037	-0.517
12.2	.0470	-.0037	-0.524
14.6	.0486	-.0056	-0.088
14.6	.0492	-.0065	-0.152
δ_L = 30° δ_U = 0°			
-06.0	.0463	-.0034	-0.043
-06.0	.0461	-.0027	-0.170
-03.3	.0469	-.0038	-1.102
-03.3	.0460	-.0027	-0.855
-00.6	.0473	-.0043	-1.280
-00.6	.0467	-.0036	-0.721
02.1	.0470	-.0040	-1.328
02.1	.0485	-.0059	-1.337

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot\alpha}}$
[1]M = 1.00			
δ_L = 15° δ_U = 0°			
01.2	.0450	-.0035	-0.333
01.2	.0454	-.0040	-0.250
03.8	.0443	-.0027	-1.236
03.8	.0428	-.0008	-1.263
06.6	.0443	-.0027	-0.503
06.6	.0443	-.0027	-0.458
09.3	.0464	-.0054	0.006
09.3	.0463	-.0054	0.008
11.9	.0453	-.0040	-0.422
11.9	.0453	-.0040	-0.482
14.2	.0457	-.0044	-0.637
14.2	.0457	-.0044	-0.637
δ_L = 30° δ_U = 0°			
-06.1	.0439	-.0026	-0.105
-06.1	.0433	-.0018	-0.238
-03.4	.0447	-.0035	-1.010
-03.4	.0445	-.0033	-1.036
-00.7	.0453	-.0044	-0.853
-00.7	.0450	-.0039	-1.002
01.8	.0458	-.0048	-0.922
01.8	.0445	-.0033	-0.960
[1]M = 1.05			
δ_L = 15° δ_U = 0°			
01.1	.0431	-.0034	-0.627
01.1	.0430	-.0034	-0.544
03.8	.0425	-.0026	-1.381
03.8	.0421	-.0020	-1.351
06.5	.0434	-.0039	0.029
06.5	.0432	-.0035	0.043
09.1	.0438	-.0043	-0.120
09.1	.0438	-.0043	-0.089
11.6	.0444	-.0052	-0.174
11.6	.0445	-.0052	-0.131
14.0	.0441	-.0048	-0.468
14.0	.0434	-.0039	-0.449
δ_L = 30° δ_U = 0°			
-06.2	.0428	-.0034	-0.519
-06.2	.0415	-.0018	-0.639
-03.5	.0428	-.0034	-1.041
-03.5	.0425	-.0030	-1.213
-00.8	.0428	-.0034	-0.838
-00.8	.0433	-.0040	-0.811
01.7	.0438	-.0047	-1.003
01.7	.0441	-.0051	-1.047

[1]Model subject to buffeting

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[redacted]

TABLE I.- PITCHING DERIVATIVES - Continued

(a) With flap control - Continued

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot{\alpha}}}$
[1] M = 1.10			
δ_L = 15° δ_U = 0°			
01.1	.0409	-.0028	-0.775
01.1	.0411	-.0030	-0.806
03.8	.0412	-.0031	-0.757
03.8	.0410	-.0029	-0.780
06.4	.0419	-.0042	-0.050
06.4	.0418	-.0040	0.112
09.1	.0418	-.0038	-0.351
09.1	.0419	-.0038	-0.321
11.5	.0433	-.0060	-0.056
11.5	.0428	-.0051	0.010
δ_L = 30° δ_U = 0°			
-06.2	.0407	-.0025	-0.779
-06.2	.0407	-.0029	-1.225
-03.5	.0410	-.0029	-0.869
-03.5	.0414	-.0035	-0.977
-00.9	.0419	-.0044	-0.909
-00.9	.0418	-.0042	-1.019
01.7	.0417	-.0040	-0.913
01.7	.0419	-.0042	-1.031
[1] M = 1.20			
δ_L = 15° δ_U = 0°			
01.1	.0394	-.0045	-0.152
01.1	.0395	-.0044	-0.112
03.7	.0389	-.0036	-0.278
03.7	.0391	-.0040	-0.346
06.3	.0375	-.0019	-0.582
06.3	.0376	-.0021	-0.645
08.9	.0386	-.0035	-0.375
08.9	.0386	-.0035	-0.343
11.5	.0391	-.0040	-0.710
11.5	.0386	-.0034	-0.631
14.0	.0391	-.0040	-0.573
14.0	.0393	-.0042	-0.602
δ_L = 30° δ_U = 0°			
-06.1	.0376	-.0019	-0.852
-06.1	.0376	-.0021	-0.918
-03.4	.0373	-.0017	-1.057
-03.4	.0374	-.0017	-1.317
-00.7	.0397	-.0049	-0.509
-00.7	.0394	-.0044	-0.697
01.7	.0400	-.0053	-0.661
01.7	.0404	-.0060	-0.646

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot{\alpha}}}$
[1] M = 1.38			
δ_L = 15° δ_U = 0°			
-04.5	.0355	-.0046	0.106
-04.5	.0355	-.0046	-0.564
-01.9	.0353	-.0042	-0.514
-01.9	.0355	-.0046	-0.432
00.5	.0355	-.0046	-0.714
00.5	.0355	-.0046	-0.696
03.0	.0345	-.0030	-1.985
03.0	.0345	-.0030	-1.623
05.6	.0348	-.0034	-0.453
05.6	.0348	-.0034	-0.434
08.1	.0370	-.0067	-0.654
08.1	.0383	-.0088	-0.637
10.4	.0355	-.0046	-1.114
10.4	.0361	-.0054	-1.310
δ_L = 30° δ_U = 0°			
-06.2	.0348	-.0035	-0.730
-06.2	.0346	-.0033	-0.745
-03.6	.0358	-.0051	-0.535
-03.6	.0356	-.0049	-0.595
-01.2	.0370	-.0068	-0.706
-01.2	.0369	-.0066	-0.663
M = 1.55			
δ_L = 0° δ_U = 0°			
-01.9	.0327	-.0037	-0.490
-01.9	.0326	-.0036	-0.530
00.7	.0325	-.0036	-0.460
00.7	.0326	-.0036	-0.450
03.3	.0318	-.0024	-1.100
03.3	.0318	-.0024	-1.100
06.0	.0322	-.0031	-0.430
06.0	.0322	-.0031	-0.430
08.7	.0324	-.0034	-0.210
08.7	.0324	-.0034	-0.220
11.4	.0317	-.0024	-0.390
11.4	.0317	-.0024	-0.400
13.9	.0319	-.0027	-0.520
13.9	.0319	-.0027	-0.490
δ_L = 15° δ_U = 0°			
-05.4	.0321	-.0030	-0.560
-05.4	.0321	-.0030	-0.520
-02.8	.0332	-.0047	-0.430
-02.8	.0330	-.0043	-0.440
-00.3	.0333	-.0048	-0.450
-00.3	.0333	-.0048	-0.460
02.1	.0333	-.0048	-0.390
02.1	.0333	-.0048	-0.430
04.7	.0324	-.0034	-0.920
04.7	.0324	-.0034	-1.000
06.4	.0327	-.0040	-0.550
06.4	.0327	-.0039	-0.540

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot{\alpha}}}$
M = 1.80			
δ_L = 0° δ_U = 0°			
-05.0	.0297	-.0048	-0.070
-05.0	.0297	-.0041	-0.090
-02.5	.0300	-.0045	-0.050
-02.5	.0300	-.0045	-0.050
00.0	.0295	-.0037	-0.320
00.0	.0295	-.0038	-0.340
02.7	.0292	-.0032	-0.400
02.7	.0292	-.0032	-0.400
05.4	.0286	-.0023	-0.660
05.4	.0287	-.0023	-0.640
08.2	.0284	-.0018	-0.560
08.2	.0284	-.0019	-0.560
11.0	.0283	-.0018	-0.620
11.0	.0283	-.0018	-0.620
13.6	.0286	-.0022	-0.410
13.6	.0286	-.0022	-0.440
δ_L = 15° δ_U = 0°			
-05.9	.0302	-.0046	-0.210
-05.9	.0302	-.0046	-0.200
-03.4	.0303	-.0049	-0.210
-03.4	.0303	-.0049	-0.220
-00.9	.0304	-.0050	-0.300
-00.9	.0304	-.0050	-0.310
01.5	.0301	-.0044	-0.400
01.5	.0301	-.0045	-0.500
M = 2.20			
δ_L = 0° δ_U = 0°			
-05.2	.0265	-.0041	-0.070
-05.2	.0265	-.0041	-0.080
-02.7	.0267	-.0044	-0.120
-02.7	.0267	-.0044	-0.090
-00.1	.0267	-.0045	-0.140
-00.1	.0267	-.0045	-0.110
02.4	.0266	-.0042	-0.220
02.4	.0266	-.0042	-0.200
04.9	.0263	-.0037	-0.180
04.9	.0263	-.0037	-0.170
07.7	.0257	-.0025	-0.280
07.7	.0257	-.0025	-0.360
10.6	.0250	-.0012	-0.660
10.6	.0250	-.0012	-0.570
13.3	.0253	-.0018	-0.270
13.3	.0254	-.0019	-0.290
δ_L = 15° δ_U = 0°			
-06.1	.0270	-.0048	-0.260
-06.1	.0270	-.0048	-0.270
-03.6	.0271	-.0051	-0.230
-03.6	.0271	-.0051	-0.230
-01.1	.0273	-.0054	-0.210
-01.1	.0273	-.0054	-0.200
01.3	.0273	-.0055	0.020
01.3	.0273	-.0054	-0.080

[1] Model subject to buffeting

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TABLE I.- PITCHING DERIVATIVES - Continued

(a) With flap control - Concluded

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot{\alpha}}}$
M = 2.50			
$\delta_L = 0°$ $\delta_U = 0°$			
-05.0	.0248	-.0043	-0.341
-05.0	.0249	-.0045	-0.456
-02.3	.0247	-.0042	-0.126
-02.3	.0246	-.0040	-0.143
00.3	.0246	-.0039	-0.059
00.3	.0247	-.0041	-0.094
03.0	.0245	-.0037	-0.159
03.0	.0245	-.0036	-0.175
05.7	.0245	-.0036	-0.128
05.7	.0245	-.0037	-0.139
08.4	.0242	-.0029	-0.230
08.4	.0242	-.0028	-0.191
11.3	.0238	-.0017	-0.500
11.3	.0237	-.0016	-0.514
13.9	.0236	-.0012	-0.608
13.9	.0235	-.0011	-0.595
$\delta_L = 15°$ $\delta_U = 0°$			
-05.6	.0245	-.0045	-0.203
-05.6	.0245	-.0046	-0.268
-02.9	.0246	-.0048	-0.197
-02.9	.0246	-.0048	-0.250
-00.3	.0246	-.0050	-0.234
-00.3	.0246	-.0049	-0.240
02.2	.0246	-.0049	-0.231
02.2	.0246	-.0049	-0.268
04.8	.0246	-.0049	-0.202
04.8	.0246	-.0050	-0.203
07.5	.0245	-.0045	-0.151
M = 3.00			
$\delta_L = 0°$ $\delta_U = 0°$			
-05.1	.0226	-.0042	-0.298
-05.1	.0225	-.0039	-0.377
-02.4	.0225	-.0037	-0.125
-02.4	.0224	-.0034	-0.168
00.3	.0225	-.0038	-0.043
00.3	.0224	-.0036	-0.125
03.0	.0224	-.0034	-0.127
03.0	.0223	-.0033	-0.147
05.8	.0223	-.0032	-0.114
05.8	.0224	-.0036	-0.114
08.5	.0223	-.0031	-0.169
08.5	.0222	-.0029	-0.193
11.4	.0221	-.0026	-0.343
11.4	.0220	-.0024	-0.393
13.9	.0220	-.0022	-0.401
13.9	.0220	-.0022	-0.385
$\delta_L = 15°$ $\delta_U = 0°$			
-05.6	.0225	-.0043	-0.182
-05.6	.0225	-.0044	-0.256
-02.9	.0225	-.0045	-0.151
-02.9	.0225	-.0045	-0.210
-00.2	.0225	-.0046	-0.208
-00.2	.0225	-.0046	-0.243
02.4	.0225	-.0046	-0.197
02.4	.0225	-.0046	-0.252
05.1	.0225	-.0046	-0.240
05.1	.0225	-.0046	-0.262
07.8	.0225	-.0045	-0.152
07.8	.0225	-.0044	-0.196
10.5	.0224	-.0041	-0.226
10.5	.0224	-.0042	-0.354
M = 3.50			
$\delta_L = 0°$ $\delta_U = 0°$			
-05.3	.0210	-.0035	-0.344
-05.3	.0212	-.0041	-0.416
-02.4	.0208	-.0027	-0.193
-02.4	.0209	-.0032	-0.223
00.3	.0209	-.0031	-0.117
00.3	.0209	-.0029	-0.179
03.1	.0209	-.0031	-0.154
03.1	.0210	-.0034	-0.165
05.8	.0210	-.0036	-0.144
05.8	.0208	-.0029	-0.207
08.7	.0208	-.0028	-0.157
08.7	.0209	-.0031	-0.165
11.5	.0208	-.0028	-0.123
11.5	.0208	-.0030	-0.216
14.0	.0208	-.0028	-0.268
14.0	.0207	-.0025	-0.265
$\delta_L = 15°$ $\delta_U = 0°$			
-05.6	.0212	-.0042	-0.165
-05.6	.0213	-.0044	-0.254
-02.8	.0212	-.0041	-0.210
-02.9	.0212	-.0042	-0.228
-00.1	.0212	-.0043	-0.180
-00.1	.0212	-.0042	-0.238
02.5	.0212	-.0044	-0.186
02.5	.0212	-.0043	-0.232
05.3	.0212	-.0043	-0.237
05.3	.0212	-.0043	-0.274
08.1	.0212	-.0043	-0.223
08.1	.0211	-.0042	-0.194
10.8	.0211	-.0041	-0.245
10.8	.0211	-.0041	-0.245
13.3	.0210	-.0038	-0.135
13.3	.0210	-.0037	-0.327

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot{\alpha}}}$

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TABLE I.- PITCHING DERIVATIVES - Continued

(b) Flap controls removed

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot\alpha}}$
[1]M = 0.70			
-04.7	.0650	-.0006	0.015
-04.7	.0651	-.0006	-0.011
-01.7	.0655	-.0011	-0.091
-01.7	.0654	-.0011	-0.128
01.3	.0655	-.0011	-0.145
01.3	.0656	-.0011	-0.224
04.2	.0653	-.0006	-0.165
04.2	.0653	-.0006	-0.104
07.3	.0642	-.0000	-0.253
07.3	.0642	-.0000	-0.241
10.3	.0652	-.0006	-0.064
10.3	.0650	-.0006	-0.082
13.3	.0640	.0004	-0.192
13.3	.0639	.0004	-0.126
16.1	.0650	-.0006	0.128
16.1	.0650	-.0006	0.199
[1]M = 0.80			
-04.6	.0581	-.0010	-0.226
-04.6	.0582	-.0010	-0.186
-01.6	.0586	-.0014	-0.202
-01.6	.0586	-.0014	-0.099
01.3	.0567	.0004	-0.303
01.3	.0572	-.0000	-0.224
04.3	.0563	.0008	-0.136
04.3	.0563	.0008	-0.193
[1]M = 0.90			
-04.6	.0525	-.0009	-0.181
-04.6	.0533	-.0018	-0.276
-01.6	.0528	-.0013	-0.255
-01.6	.0524	-.0009	-0.235
01.3	.0507	.0008	-0.292
01.3	.0512	.0002	-0.217
04.5	.0506	.0008	-1.294
04.5	.0498	.0017	-1.223
[1]M = 0.95			
-04.5	.0511	-.0022	-0.142
-04.5	.0511	-.0022	-0.129
-01.6	.0509	-.0020	-0.324
-01.6	.0506	-.0017	-0.323
01.3	.0491	-.0000	-0.327
01.3	.0486	.0004	-0.126
04.4	.0484	.0007	-0.500
04.4	.0486	.0004	-0.504
13.5	.0525	-.0036	-0.094
13.5	.0520	-.0031	-0.085
[1]M = 1.00			
01.4	.0476	-.0008	-0.386
01.4	.0472	-.0004	-0.473
04.5	.0461	.0007	-0.992
04.5	.0465	.0004	-0.926
10.4	.0490	-.0024	-0.184
10.4	.0486	-.0019	-0.038
13.3	.0488	-.0021	-0.072
13.3	.0490	-.0024	-0.113
[1]M = 1.05			
01.4	.0455	-.0006	-0.689
01.4	.0454	-.0004	-0.693
04.6	.0457	-.0008	-0.666
04.6	.0460	-.0012	-0.538
07.5	.0443	.0007	-0.634
07.5	.0447	.0003	-0.360
10.3	.0475	-.0027	0.022
10.3	.0473	-.0025	0.042
13.2	.0473	-.0025	-0.097
13.2	.0469	-.0023	-0.152
15.7	.0470	-.0023	0.147
15.7	.0474	-.0027	0.161
[1]M = 1.10			
01.5	.0427	.0007	-0.869
01.5	.0443	-.0012	-0.825
04.6	.0455	-.0027	0.090
04.6	.0457	-.0027	-0.091
07.4	.0431	.0001	-0.170
07.4	.0437	-.0004	-0.253
10.3	.0459	-.0029	0.058
10.3	.0459	-.0029	-0.027
13.1	.0456	-.0024	-0.071
13.1	.0459	-.0029	-0.111
15.6	.0458	-.0027	-0.091
15.6	.0459	-.0029	-0.054
[1]M = 1.20			
04.3	.0419	-.0019	-0.142
04.3	.0419	-.0019	-0.087
07.3	.0409	-.0008	-0.333
07.3	.0408	-.0006	-0.423
10.2	.0420	-.0019	-0.253
10.2	.0416	-.0015	-0.295
13.0	.0420	-.0019	-0.072
13.0	.0420	-.0019	-0.076
15.5	.0431	-.0032	0.663
15.5	.0435	-.0037	0.335
[1]M = 1.38			
-04.6	.0375	-.0015	-0.416
-04.6	.0379	-.0021	-0.329
-01.7	.0376	-.0017	-0.354
-01.7	.0375	-.0015	-0.203
01.1	.0384	-.0027	-0.065
01.1	.0383	-.0027	-0.027
04.0	.0382	-.0024	-0.113
04.0	.0380	-.0022	-0.159
06.9	.0374	-.0015	-0.209
06.9	.0377	-.0019	-0.263
09.8	.0369	-.0009	-0.501
09.8	.0372	-.0013	-0.501
12.7	.0376	-.0018	-0.193
12.7	.0375	-.0017	-0.194
15.3	.0379	-.0022	-0.191
15.3	.0378	-.0020	-0.189

[1]Model subject to buffeting

[redacted]

TABLE I.- PITCHING DERIVATIVES - Concluded

(b) Flap controls removed - Concluded

α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot{\alpha}}}$	α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot{\alpha}}}$	α, deg	k	C_{m_α}	$C_{m_q}+C_{m_{\dot{\alpha}}}$
M = 1.55				M = 2.50							
-05.1	.0341	-.0005	-0.620	-05.4	.0265	-.0024	-0.211				
-05.1	.0341	-.0005	-0.600	-05.4	.0267	-.0028	-0.343				
-02.2	.0342	-.0006	-0.400	-02.5	.0265	-.0024	-0.170				
-02.2	.0342	-.0006	-0.410	-02.5	.0266	-.0026	-0.220				
00.7	.0346	-.0011	-0.310	00.2	.0265	-.0023	-0.196				
00.7	.0346	-.0011	-0.320	00.2	.0266	-.0024	-0.190				
03.6	.0347	-.0012	-0.260	03.0	.0266	-.0024	-0.153				
03.6	.0347	-.0012	-0.270	03.0	.0265	-.0024	-0.195				
06.5	.0347	-.0012	-0.270	05.9	.0265	-.0023	-0.232				
06.5	.0347	-.0012	-0.270	05.9	.0265	-.0022	-0.363				
09.4	.0348	-.0014	-0.250	08.7	.0263	-.0019	-0.208				
09.4	.0348	-.0014	-0.270	08.7	.0263	-.0019	-0.407				
12.3	.0346	-.0011	-0.500	11.6	.0260	-.0010	-0.374				
12.3	.0346	-.0011	-0.510	11.6	.0259	-.0009	-0.537				
14.9	.0350	-.0016	-0.230	14.3	.0257	-.0004	-0.507				
14.9	.0350	-.0016	-0.240	14.3	.0257	-.0004	-0.668				
M = 1.80				M = 3.00							
-05.5	.0322	-.0022	-0.130	-05.3	.0245	-.0024	-0.237				
-05.5	.0322	-.0022	-0.160	-05.3	.0246	-.0026	-0.347				
-02.7	.0320	-.0019	-0.100	-02.5	.0244	-.0022	-0.182				
-02.7	.0320	-.0019	-0.110	-02.5	.0245	-.0024	-0.247				
00.0	.0316	-.0014	-0.140	00.2	.0245	-.0024	-0.180				
00.0	.0316	-.0014	-0.140	00.2	.0245	-.0024	-0.209				
03.0	.0313	-.0010	-0.300	03.1	.0244	-.0022	-0.203				
03.0	.0313	-.0010	-0.290	03.1	.0244	-.0022	-0.240				
06.0	.0311	-.0006	-0.400	06.0	.0244	-.0022	-0.228				
06.0	.0311	-.0006	-0.410	06.0	.0244	-.0022	-0.246				
08.9	.0311	-.0007	-0.400	08.8	.0244	-.0021	-0.233				
08.9	.0311	-.0007	-0.380	08.8	.0244	-.0021	-0.240				
11.9	.0313	-.0009	-0.360	11.7	.0243	-.0020	-0.237				
11.9	.0313	-.0009	-0.350	11.7	.0243	-.0020	-0.254				
14.5	.0314	-.0011	-0.290	14.3	.0242	-.0015	-0.304				
14.5	.0314	-.0011	-0.300	14.3	.0241	-.0014	-0.323				
M = 2.20				M = 3.50							
-05.5	.0289	-.0024	-0.150	-05.4	.0233	-.0024	-0.196				
-05.5	.0289	-.0024	-0.140	-05.5	.0234	-.0031	-0.293				
-02.7	.0289	-.0025	-0.100	-02.6	.0232	-.0023	-0.195				
-02.7	.0289	-.0024	-0.130	-02.6	.0233	-.0027	-0.248				
00.0	.0289	-.0025	-0.130	00.2	.0232	-.0022	-0.195				
00.0	.0289	-.0025	-0.140	00.2	.0232	-.0023	-0.248				
02.7	.0288	-.0024	-0.170	03.1	.0231	-.0020	-0.208				
02.7	.0288	-.0024	-0.170	03.1	.0231	-.0022	-0.251				
05.5	.0285	-.0019	-0.250	06.0	.0231	-.0021	-0.180				
05.5	.0285	-.0019	-0.260	06.0	.0231	-.0021	-0.227				
08.3	.0280	-.0010	-0.430	08.9	.0231	-.0021	-0.337				
08.3	.0280	-.0010	-0.430	08.9	.0230	-.0020	-0.209				
11.0	.0277	-.0006	-0.480	11.8	.0230	-.0020	-0.204				
11.0	.0277	-.0006	-0.480	11.8	.0230	-.0020	-0.225				
13.5	.0277	-.0006	-0.460	14.3	.0230	-.0019	-0.203				
13.5	.0277	-.0006	-0.450	14.3	.0230	-.0020	-0.239				

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[redacted]

TABLE II.- YAWING DERIVATIVES

(a) With flap control

α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$
M = 0.70				
δ_L = 15° δ_U = 0°				
-06.0	.0528	.0012	-0.257	-0.069
-06.0	.0529	.0012	-0.148	-0.019
-03.0	.0529	.0012	-0.219	-0.026
-03.0	.0521	.0007	-0.168	-0.035
-00.0	.0532	.0015	-0.236	-0.063
-00.0	.0531	.0015	-0.252	-0.027
03.0	.0535	.0018	-0.210	-0.029
03.0	.0534	.0018	-0.194	-0.018
06.0	.0534	.0018	-0.150	-0.034
06.0	.0531	.0015	-0.114	0.073
09.0	.0541	.0024	-0.108	0.021
09.0	.0542	.0024	-0.107	0.032
12.0	.0551	.0031	0.006	0.008
12.0	.0550	.0031	-0.024	-0.039
14.7	.0558	.0037	-0.216	0.172
14.7	.0558	.0037	-0.248	0.142
M = 0.80				
δ_L = 15° δ_U = 0°				
-06.0	.0482	.0019	-0.197	-0.022
-06.0	.0473	.0011	-0.167	-0.005
-03.0	.0477	.0014	-0.209	0.027
-03.0	.0476	.0014	-0.174	-0.025
-00.0	.0483	.0020	-0.232	-0.028
-00.0	.0482	.0019	-0.202	0.012
03.0	.0482	.0020	-0.141	0.040
03.0	.0482	.0020	-0.127	0.061
05.9	.0497	.0031	0.000	0.000
05.9	.0497	.0031	-0.034	0.009
09.0	.0497	.0034	-0.081	0.120
09.0	.0499	.0034	-0.120	0.045
11.9	.0497	.0031	-0.304	0.225
11.9	.0498	.0031	-0.324	0.100
14.7	.0507	.0040	-0.090	0.195
14.7	.0507	.0041	-0.219	0.392
M = 0.90				
δ_L = 15° δ_U = 0°				
-06.0	.0426	.0010	-0.215	-0.013
-06.0	.0432	.0015	-0.097	0.043
-03.0	.0429	.0013	-0.208	0.001
-03.0	.0430	.0013	-0.226	-0.186
-00.0	.0437	.0021	-0.057	-0.008
-00.0	.0437	.0021	-0.185	0.015
03.0	.0446	.0029	0.240	-0.016
03.0	.0449	.0032	0.380	0.016
05.9	.0443	.0026	-0.364	-0.005
05.9	.0448	.0029	-0.386	0.058
09.0	.0454	.0035	-0.318	0.094
09.0	.0453	.0034	-0.333	0.085
12.0	.0453	.0035	-0.895	0.141
12.0	.0453	.0034	-1.036	-0.211
14.7	.0460	.0040	-1.186	-0.387

α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$
M = 0.95				
δ_L = 15° δ_U = 0°				
-06.0	.0410	.0012	-0.065	-0.024
-06.0	.0410	.0012	-0.121	0.000
-03.0	.0409	.0011	0.084	0.000
-03.0	.0419	.0020	0.073	-0.002
-00.0	.0421	.0022	-0.107	-0.005
-00.0	.0424	.0025	0.066	-0.051
03.0	.0429	.0030	0.383	0.043
03.0	.0432	.0033	0.425	0.036
06.0	.0430	.0030	-0.311	-0.024
06.0	.0428	.0029	-0.329	-0.098
09.0	.0434	.0033	-0.489	-0.363
09.0	.0436	.0036	-0.635	-0.406
10.9	.0430	.0030	-1.158	-0.651
10.9	.0436	.0036	-1.112	-0.523
M = 1.00				
δ_L = 15° δ_U = 0°				
-06.0	.0397	.0017	0.031	-0.019
-06.0	.0402	.0022	0.020	-0.157
-03.0	.0401	.0022	0.113	-0.046
-03.0	.0399	.0019	0.053	-0.014
-00.0	.0411	.0031	-0.009	-0.047
-00.0	.0410	.0030	0.206	0.026
02.9	.0417	.0037	0.282	-0.199
02.9	.0415	.0035	0.285	-0.050
05.9	.0413	.0033	-0.307	-0.105
05.9	.0416	.0035	-0.288	-0.209
09.0	.0423	.0041	-0.790	-0.780
09.0	.0420	.0038	-0.982	-0.113
09.9	.0425	.0044	-1.246	-0.363
09.9	.0422	.0041	-1.168	-0.231
M = 1.05				
δ_L = 15° δ_U = 0°				
-06.0	.0386	.0021	0.261	0.016
-06.0	.0388	.0024	0.257	0.011
-03.0	.0386	.0021	0.095	-0.008
-03.0	.0382	.0019	-0.010	0.023
-00.0	.0400	.0036	0.340	0.006
-00.0	.0398	.0033	0.171	-0.000
03.0	.0411	.0046	0.736	0.053
03.0	.0412	.0047	0.815	0.035
06.0	.0399	.0034	-0.463	-0.341
06.0	.0402	.0037	-0.618	-0.595
08.9	.0408	.0043	-1.400	-0.204
08.9	.0414	.0049	-1.228	-0.671
10.0	.0410	.0046	-1.731	-0.279
10.0	.0412	.0047	-1.847	-0.320

TABLE II.- YAWING DERIVATIVES - Continued

(a) With flap control - Continued

α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$
M = 1.10				
$\delta_L = 15°$ $\delta_U = 0°$				
-06.0	.0371	.0021	0.653	0.038
-06.0	.0368	.0017	0.786	0.067
-03.0	.0373	.0022	0.146	-0.028
-03.0	.0376	.0025	0.161	-0.019
-00.0	.0390	.0039	0.146	0.119
-00.0	.0385	.0035	0.271	0.037
03.0	.0411	.0060	1.438	0.049
03.0	.0407	.0057	1.453	0.043
05.9	.0381	.0031	-0.776	-0.668
06.0	.0386	.0036	-0.788	-0.955
07.9	.0401	.0051	-1.215	-0.466
07.9	.0396	.0046	-1.185	-0.422
M = 1.20				
$\delta_L = 15°$ $\delta_U = 0°$				
-06.0	.0349	.0022	0.536	-0.506
-06.0	.0341	.0015	0.620	-0.763
-03.0	.0350	.0024	0.271	-0.042
-03.0	.0352	.0026	0.316	-0.107
-00.0	.0375	.0050	1.115	0.053
-00.0	.0378	.0053	1.129	0.075
02.9	.0360	.0034	-0.247	-0.148
02.9	.0362	.0036	-0.347	-0.320
06.0	.0373	.0047	-1.314	-0.446
06.0	.0366	.0040	-1.293	-0.567
M = 1.38				
$\delta_L = 15°$ $\delta_U = 0°$				
-06.0	.0309	.0016	-0.458	-0.017
-06.0	.0312	.0019	-0.420	-0.236
-03.0	.0318	.0026	-0.283	-0.284
-03.0	.0317	.0025	-0.275	-0.301
-00.0	.0323	.0032	-0.282	-0.289
-00.0	.0322	.0031	-0.345	-0.329
02.9	.0333	.0044	-0.991	-0.137
03.0	.0333	.0044	-0.858	-0.295
03.9	.0333	.0042	-1.318	-0.330

α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$
M = 1.55				
$\delta_L = 0°$ $\delta_U = 0°$				
-06.0	.0299	.0031	-0.170	-0.199
-06.0	.0299	.0031	-0.200	-0.145
-03.0	.0297	.0029	-0.230	-0.180
-03.0	.0297	.0029	-0.230	-0.141
-00.0	.0298	.0031	-0.190	-0.153
-00.0	.0298	.0032	-0.200	-0.372
03.0	.0301	.0035	-0.100	-0.362
03.0	.0301	.0035	-0.090	-0.290
06.0	.0299	.0033	-0.230	-0.427
06.0	.0299	.0033	-0.200	-0.402
09.0	.0301	.0035	-0.210	-0.353
09.0	.0301	.0035	-0.210	-0.373
12.0	.0306	.0041	-0.120	0.089
12.0	.0308	.0043	-0.180	-0.004
14.6	.0306	.0041	-0.170	0.020
14.6	.0308	.0043	-0.210	-0.035
M = 1.80				
$\delta_L = 0°$ $\delta_U = 0°$				
-06.0	.0273	.0036	-0.160	-0.288
-06.0	.0273	.0036	-0.170	-0.294
-03.0	.0274	.0036	-0.170	-0.220
-03.0	.0274	.0036	-0.160	-0.229
-00.0	.0274	.0036	-0.200	-0.186
-00.0	.0274	.0036	-0.160	-0.284
03.0	.0275	.0038	-0.180	-0.396
03.0	.0275	.0038	-0.190	-0.255
06.0	.0274	.0036	-0.240	-0.333
06.0	.0274	.0037	-0.250	-0.394
09.0	.0281	.0046	-0.220	-0.454
09.0	.0283	.0049	-0.230	-0.354
12.0	.0279	.0043	-0.180	-0.061
12.0	.0283	.0049	-0.220	-0.195
14.6	.0283	.0048	-0.260	-0.074
14.6	.0285	.0051	-0.280	-0.127
M = 2.20				
$\delta_L = 0°$ $\delta_U = 0°$				
-06.0	.0247	.0041	-0.120	-0.123
-06.0	.0247	.0041	-0.110	-0.152
-03.0	.0248	.0042	-0.100	-0.186
-03.0	.0248	.0042	-0.110	-0.174
-00.0	.0249	.0043	-0.100	-0.254
-00.0	.0249	.0044	-0.120	-0.198
03.0	.0249	.0044	-0.110	-0.358
03.0	.0249	.0044	-0.110	-0.350
06.0	.0248	.0043	-0.120	-0.290
06.0	.0248	.0043	-0.120	-0.288
09.0	.0248	.0042	-0.110	-0.251
09.0	.0248	.0042	-0.120	-0.166
11.9	.0248	.0042	-0.110	-0.288
12.0	.0248	.0043	-0.130	-0.141
14.6	.0249	.0044	-0.140	-0.153
14.6	.0251	.0046	-0.130	-0.227

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TABLE II.- YAWING DERIVATIVES - Continued

(a) With flap control - Concluded

α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$	α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$
M = 2.50									
$\delta_L = 0°$ $\delta_U = 0°$									
-05.7	.0232	.0039	0.106	0.085					
-05.7	.0234	.0045	0.022	0.035					
-02.7	.0228	.0033	0.190	0.171					
-02.7	.0230	.0037	0.087	0.089					
00.2	.0230	.0036	0.106	0.172					
00.2	.0231	.0039	0.017	0.111					
03.2	.0232	.0041	0.060	0.005					
03.2	.0235	.0047	-0.180	-0.051					
06.2	.0232	.0042	0.029	-0.282					
06.2	.0237	.0051	-0.204	-0.336					
12.2	.0230	.0038	-0.041	-0.832					
M = 3.00									
$\delta_L = 0°$ $\delta_U = 0°$									
-05.7	.0208	.0044	-0.065	0.065					
-05.7	.0208	.0044	-0.063	0.041					
-02.7	.0209	.0044	-0.106	-0.019					
-02.7	.0209	.0044	-0.106	0.034					
00.2	.0208	.0044	-0.122	-0.022					
00.2	.0208	.0043	-0.123	-0.027					
03.2	.0209	.0045	-0.108	-0.084					
03.2	.0209	.0045	-0.114	-0.043					
06.2	.0209	.0046	-0.118	-0.255					
06.2	.0209	.0046	-0.127	-0.235					
09.2	.0209	.0046	-0.113	-0.198					
09.2	.0209	.0045	-0.106	-0.049					
12.2	.0209	.0045	-0.187	-0.747					
12.2	.0209	.0045	-0.119	-0.162					
14.8	.0209	.0045	-0.082	-0.049					
14.8	.0209	.0045	-0.090	-0.098					
M = 3.50									
$\delta_L = 0°$ $\delta_U = 0°$									
-05.7	.0197	.0044	-0.124	0.071					
-05.7	.0197	.0044	-0.118	0.280					
-02.7	.0197	.0045	-0.106	-0.044					
-02.7	.0197	.0044	-0.110	0.023					
00.2	.0197	.0045	-0.128	0.153					
00.2	.0196	.0044	-0.132	0.138					
03.2	.0196	.0045	-0.124	0.136					
03.2	.0196	.0045	-0.118	0.099					
06.2	.0196	.0045	-0.136	-0.147					
06.2	.0196	.0045	-0.123	0.023					
09.2	.0196	.0046	-0.099	0.104					
09.2	.0196	.0046	-0.096	0.160					
12.2	.0196	.0045	-0.098	0.078					
12.2	.0196	.0045	-0.104	0.116					
14.8	.0196	.0045	-0.096	-0.072					
14.8	.0196	.0045	-0.104	-0.043					

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TABLE II.- YAWING DERIVATIVES - Continued

(b) Flap controls removed

α, deg	k	C_{n_β}	C_{n_r} $-C_{n_\beta}\cos\alpha$	C_{l_r} $-C_{l_\beta}\cos\alpha$	α, deg	k	C_{n_β}	C_{n_r} $-C_{n_\beta}\cos\alpha$	C_{l_r} $-C_{l_\beta}\cos\alpha$
M = 0.70					M = 0.95				
-06.0	.0577	.0015	-0.098	-0.001	-06.0	.0449	.0015	-0.001	-0.049
-06.0	.0572	.0012	-0.135	-0.034	-06.0	.0449	.0015	-0.076	0.043
-03.0	.0572	.0012	-0.038	0.060	-03.0	.0449	.0015	0.083	0.085
-03.0	.0573	.0012	-0.261	-0.005	-03.0	.0449	.0015	0.081	0.039
-00.0	.0575	.0012	-0.199	-0.036	-00.0	.0449	.0015	0.023	0.053
-00.0	.0570	.0009	-0.179	-0.029	-00.0	.0457	.0021	0.028	0.002
03.0	.0578	.0015	-0.199	-0.004	03.0	.0463	.0026	0.312	0.033
03.0	.0578	.0015	-0.187	0.000	03.0	.0466	.0029	0.290	0.046
06.0	.0574	.0012	-0.148	0.179	05.9	.0469	.0032	0.245	-0.002
06.0	.0577	.0015	-0.158	0.185	05.9	.0470	.0032	0.224	-0.087
08.9	.0576	.0015	-0.108	0.052	09.0	.0463	.0026	-0.328	-0.014
08.9	.0581	.0018	-0.082	0.045	09.0	.0463	.0026	-0.321	0.050
12.0	.0591	.0025	-0.082	-0.032	11.9	.0460	.0024	-0.297	-0.036
12.0	.0591	.0025	-0.113	-0.004	11.9	.0460	.0023	-0.251	0.074
14.7	.0596	.0028	0.016	0.409	14.7	.0467	.0029	-0.474	0.394
14.7	.0597	.0029	-0.005	0.438	14.7	.0464	.0026	-0.480	0.461
M = 0.80					M = 1.00				
-06.0	.0523	.0017	-0.193	-0.027	-06.0	.0435	.0020	-0.050	0.083
-06.0	.0523	.0017	-0.195	-0.002	-06.0	.0438	.0023	0.020	0.068
-03.0	.0519	.0014	-0.220	0.002	-03.0	.0436	.0020	0.074	0.088
-03.0	.0519	.0014	-0.203	-0.042	-03.0	.0436	.0020	0.116	0.075
-00.0	.0523	.0017	-0.247	-0.041	-00.0	.0442	.0026	0.259	0.092
-00.0	.0519	.0014	-0.216	0.013	-00.0	.0446	.0029	0.198	0.059
03.0	.0522	.0017	-0.199	0.047	03.0	.0452	.0035	0.486	0.073
03.0	.0521	.0017	-0.115	0.038	03.0	.0453	.0035	0.486	0.073
05.9	.0529	.0023	-0.084	0.017	06.0	.0449	.0031	0.010	0.080
05.9	.0535	.0026	-0.112	0.004	06.0	.0448	.0031	0.019	0.066
09.0	.0534	.0026	-0.181	-0.050	08.9	.0443	.0026	-0.269	0.039
09.0	.0537	.0029	-0.190	-0.082	08.9	.0442	.0026	-0.335	0.055
12.0	.0535	.0026	-0.273	0.294	11.9	.0446	.0028	-0.271	0.058
12.0	.0534	.0026	-0.273	0.309	11.9	.0446	.0028	-0.288	0.105
14.7	.0536	.0026	-0.089	0.577	14.7	.0450	.0031	-0.598	0.539
14.7	.0534	.0026	-0.141	0.122	14.7	.0449	.0031	-0.577	0.532
M = 0.90					M = 1.05				
-06.0	.0471	.0016	-0.056	-0.036	-06.0	.0419	.0020	-0.021	0.028
-06.0	.0472	.0016	-0.150	-0.045	-06.0	.0419	.0020	0.039	0.084
-03.0	.0478	.0021	-0.117	0.013	-03.0	.0420	.0022	0.201	0.087
-03.0	.0478	.0021	-0.125	-0.062	-03.0	.0421	.0022	0.192	0.090
-00.0	.0479	.0021	-0.173	-0.037	-00.0	.0433	.0034	0.491	0.124
-00.0	.0479	.0021	-0.231	-0.037	-00.0	.0434	.0034	0.451	0.131
03.0	.0482	.0024	0.158	-0.053	02.9	.0434	.0034	0.269	0.032
03.0	.0482	.0024	0.121	-0.033	02.9	.0433	.0033	0.204	0.094
05.9	.0485	.0027	0.198	-0.032	05.9	.0427	.0028	-0.178	-0.024
05.9	.0485	.0027	0.122	-0.029	05.9	.0427	.0028	-0.167	0.029
08.9	.0485	.0027	-0.359	-0.000	08.9	.0424	.0025	-0.274	0.024
08.9	.0485	.0027	-0.287	-0.013	08.9	.0424	.0025	-0.274	0.012
12.0	.0482	.0024	-0.300	0.042	11.9	.0428	.0028	-0.291	0.055
12.0	.0479	.0021	-0.275	0.083	11.9	.0427	.0028	-0.310	0.028
14.7	.0486	.0027	-0.267	0.546	14.7	.0431	.0031	-0.537	-0.124
14.7	.0486	.0027	-0.321	0.492	14.7	.0434	.0034	-0.581	-0.338

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[redacted]

TABLE II.- YAWING DERIVATIVES - Continued

(b) Flap controls removed - Continued

α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$
M = 1.10				
-06.0	.0399	.0016	0.007	0.071
-06.0	.0399	.0016	-0.016	0.045
-03.0	.0405	.0022	0.202	0.066
-03.0	.0408	.0024	0.154	0.121
-00.0	.0423	.0039	0.795	0.129
-00.0	.0420	.0036	0.762	0.125
03.0	.0423	.0038	0.266	0.060
03.0	.0416	.0033	0.206	0.071
05.9	.0410	.0027	-0.234	-0.018
05.9	.0410	.0027	-0.206	-0.031
09.0	.0411	.0027	-0.219	0.070
09.0	.0411	.0027	-0.217	0.025
12.0	.0408	.0024	-0.257	0.019
12.0	.0408	.0024	-0.295	0.026
14.7	.0417	.0033	-0.426	-0.179
14.7	.0415	.0030	-0.511	-0.308
M = 1.20				
-06.0	.0375	.0018	-0.004	-0.087
-06.0	.0374	.0018	0.243	-0.105
-03.0	.0388	.0031	1.393	0.107
-03.0	.0398	.0037	1.278	-0.001
-00.0	.0392	.0034	0.679	-0.056
-00.0	.0388	.0034	0.237	-0.109
03.0	.0382	.0026	-0.272	-0.055
03.0	.0384	.0026	-0.228	-0.037
05.9	.0381	.0024	-0.364	0.068
05.9	.0381	.0024	-0.378	0.056
08.9	.0383	.0026	-0.241	0.027
08.9	.0383	.0026	-0.239	0.022
11.9	.0389	.0032	-0.399	-0.147
11.9	.0389	.0032	-0.459	-0.260
14.7	.0389	.0032	-0.895	-0.731
14.7	.0390	.0032	-0.937	-0.922
M = 1.38				
-06.0	.0339	.0020	-0.273	-0.240
-06.0	.0337	.0017	-0.179	-0.214
-03.0	.0350	.0030	-0.009	-0.120
-03.0	.0350	.0030	0.004	-0.077
-00.0	.0345	.0025	-0.235	-0.127
-00.0	.0345	.0025	-0.229	-0.115
03.0	.0345	.0025	-0.365	-0.134
03.0	.0342	.0022	-0.369	-0.105
06.0	.0345	.0025	-0.374	-0.088
06.0	.0345	.0025	-0.367	-0.102
08.9	.0350	.0030	-0.635	-0.468
08.9	.0352	.0033	-0.775	-0.720
12.0	.0355	.0068	-1.331	-0.155
12.0	.0358	.0071	-1.255	-0.164
14.0	.0351	.0033	-1.786	-0.094

α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$
M = 1.55				
-06.0	.0323	.0028	-0.170	-0.143
-06.0	.0324	.0028	-0.180	-0.178
-03.0	.0322	.0027	-0.230	-0.181
-03.0	.0322	.0027	-0.230	-0.120
-00.0	.0320	.0025	-0.270	-0.190
-00.0	.0320	.0025	-0.280	-0.207
03.0	.0319	.0025	-0.320	-0.290
03.0	.0319	.0025	-0.300	-0.307
06.0	.0322	.0028	-0.280	-0.342
06.0	.0322	.0028	-0.280	-0.347
09.0	.0322	.0028	-0.260	-0.216
09.0	.0322	.0028	-0.250	-0.238
12.0	.0325	.0031	-0.160	-0.234
12.0	.0325	.0031	-0.130	-0.240
14.6	.0326	.0032	-0.130	-0.109
14.6	.0326	.0032	-0.140	-0.061
M = 1.80				
-06.0	.0298	.0035	-0.120	-0.178
-06.0	.0298	.0035	-0.120	-0.182
-03.0	.0298	.0035	-0.100	-0.156
-03.0	.0298	.0035	-0.110	-0.129
-00.0	.0296	.0032	-0.240	-0.226
-00.0	.0296	.0032	-0.240	-0.208
03.0	.0295	.0031	-0.300	-0.306
03.0	.0295	.0031	-0.290	-0.294
06.0	.0296	.0032	-0.210	-0.314
06.0	.0296	.0032	-0.210	-0.303
09.0	.0295	.0031	-0.210	-0.228
09.0	.0295	.0031	-0.210	-0.264
11.9	.0295	.0031	-0.180	-0.121
12.0	.0295	.0031	-0.210	-0.110
14.6	.0295	.0031	-0.190	-0.097
14.6	.0295	.0031	-0.190	-0.069
M = 2.20				
-06.0	.0267	.0036	-0.150	-0.171
-06.0	.0267	.0036	-0.150	-0.190
-03.0	.0267	.0037	-0.160	-0.139
-03.0	.0267	.0037	-0.170	-0.107
-00.0	.0268	.0038	-0.160	-0.211
-00.0	.0268	.0038	-0.160	-0.185
02.9	.0269	.0040	-0.110	-0.292
02.9	.0269	.0040	-0.110	-0.256
06.0	.0269	.0040	-0.100	-0.253
06.0	.0269	.0040	-0.110	-0.170
09.0	.0268	.0039	-0.120	-0.220
09.0	.0268	.0039	-0.110	-0.170
12.0	.0267	.0037	-0.160	-0.144
12.0	.0267	.0037	-0.160	-0.200
14.6	.0266	.0036	-0.140	-0.162
14.6	.0266	.0036	-0.150	-0.160

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TABLE II.- YAWING DERIVATIVES - Continued

(b) Flap controls removed - Concluded

α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$	α, deg	k	C_{n_β}	C_{n_r} $-C_{n_{\dot\beta}}\cos\alpha$	C_{l_r} $-C_{l_{\dot\beta}}\cos\alpha$
M = 2.50									
-05.7	.0245	.0039	-0.180	-0.138					
-05.7	.0245	.0039	-0.183	-0.126					
-02.7	.0244	.0038	-0.244	-0.508					
-02.7	.0245	.0038	-0.239	-0.488					
00.2	.0245	.0039	-0.232	-0.251					
00.2	.0245	.0039	-0.226	-0.293					
03.2	.0245	.0040	-0.278	-0.521					
03.2	.0245	.0040	-0.245	-0.292					
06.2	.0246	.0041	-0.233	-0.607					
06.2	.0246	.0041	-0.212	-0.457					
09.2	.0247	.0042	-0.193	-0.325					
09.2	.0246	.0042	-0.170	-0.248					
12.2	.0246	.0041	-0.261	-0.879					
12.2	.0246	.0041	-0.227	-0.700					
14.8	.0245	.0039	-0.232	-0.450					
14.8	.0245	.0039	-0.237	-0.507					
M = 3.00									
-05.7	.0226	.0041	-0.218	-0.169					
-05.7	.0226	.0041	-0.204	-0.159					
-02.7	.0225	.0040	-0.265	-0.479					
-02.7	.0225	.0039	-0.270	-0.460					
00.2	.0225	.0040	-0.245	-0.271					
00.2	.0225	.0040	-0.248	-0.300					
03.2	.0226	.0042	-0.219	-0.242					
03.2	.0226	.0041	-0.221	-0.216					
06.2	.0226	.0042	-0.226	-0.509					
06.2	.0226	.0042	-0.233	-0.461					
09.2	.0226	.0043	-0.192	-0.197					
09.2	.0226	.0042	-0.181	-0.206					
12.2	.0226	.0042	-0.282	-0.943					
12.2	.0226	.0042	-0.230	-0.645					
14.8	.0226	.0041	-0.217	-0.506					
14.8	.0226	.0041	-0.209	-0.459					
M = 3.50									
-05.7	.0213	.0042	-0.241	-0.107					
-05.7	.0213	.0042	-0.227	-0.138					
-02.8	.0213	.0041	-0.242	-0.118					
-02.8	.0212	.0041	-0.243	-0.245					
00.2	.0213	.0041	-0.261	-0.224					
00.2	.0213	.0041	-0.246	-0.255					
03.2	.0213	.0042	-0.222	-0.162					
03.2	.0213	.0042	-0.232	-0.224					
06.2	.0213	.0043	-0.257	-0.553					
06.2	.0213	.0043	-0.229	-0.344					
09.2	.0213	.0042	-0.188	-0.079					
09.2	.0213	.0042	-0.197	-0.053					
12.2	.0212	.0042	-0.243	-0.563					
12.2	.0212	.0042	-0.210	-0.202					
14.8	.0212	.0041	-0.215	-0.305					
14.8	.0212	.0041	-0.219	-0.324					

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CONFIDENTIAL

TABLE II.- YAWING DERIVATIVES - Concluded

(c) β traverses

β, deg	k	C_{n_β}	C_{n_r} $-C_{n_\beta}\cos\alpha$	C_{l_r} $-C_{l_\beta}\cos\alpha$	β, deg	k	C_{n_β}	C_{n_r} $-C_{n_\beta}\cos\alpha$	C_{l_r} $-C_{l_\beta}\cos\alpha$
$M = 0.90$; $\alpha = 4°$									
$\delta_L = 15°$ $\delta_U = 0°$									
-06.0	.0446	.0027	-0.270	-0.560					
-06.0	.0446	.0026	-0.245	0.167					
-05.0	.0447	.0028	-0.262	0.010					
-05.0	.0448	.0028	-0.274	0.381					
-04.0	.0449	.0029	-0.303	-0.047					
-04.0	.0450	.0030	-0.132	-0.072					
-03.0	.0448	.0028	-0.275	-0.190					
-03.0	.0449	.0029	-0.265	-0.042					
-02.0	.0452	.0032	-0.027	-0.271					
-02.0	.0450	.0030	-0.043	-0.000					
-01.0	.0455	.0034	0.398	-0.143					
-01.0	.0455	.0034	0.422	-0.354					
00.0	.0458	.0037	0.669	0.081					
00.0	.0459	.0037	0.697	0.026					
02.0	.0449	.0029	0.019	-0.094					
02.0	.0449	.0029	-0.105	0.054					
04.0	.0447	.0027	-0.202	0.034					
04.0	.0449	.0028	-0.167	-0.049					
06.0	.0443	.0023	-0.194	-0.488					
06.0	.0448	.0027	-0.266	0.381					
$M = 1.20$; $\alpha = 0°$									
$\delta_L = 15°$ $\delta_U = 0°$									
-06.0	.0352	.0027	-0.164	-0.821					
-06.0	.0353	.0028	-0.325	-0.379					
-04.0	.0354	.0029	-0.166	-0.407					
-04.0	.0351	.0026	-0.256	-0.038					
-03.0	.0356	.0031	-0.158	-0.528					
-03.0	.0357	.0031	-0.031	-0.183					
-02.0	.0365	.0040	0.218	0.012					
-02.0	.0365	.0040	0.233	-0.120					
00.0	.0379	.0055	0.966	-0.019					
00.0	.0381	.0057	0.973	-0.039					
01.0	.0373	.0050	0.621	-0.051					
02.0	.0364	.0039	-0.120	-0.281					
02.0	.0361	.0035	0.091	-0.085					
04.0	.0353	.0027	-0.190	-0.291					
04.0	.0354	.0028	-0.157	-0.443					

[redacted]

TABLE III.- ROLLING DERIVATIVES

(a) With flap control

α, deg	k	$C_{l_p} + C_{l_{\dot\beta}} \sin\alpha$	$C_{n_p} + C_{n_{\dot\beta}} \sin\alpha$
M = 0.70			
δ_L = 15°		δ_U = 0°	
-06.0	.0361	-0.088	-0.257
-06.0	.0361	-0.033	-0.299
-03.0	.0363	-0.055	-0.160
-03.0	.0363	-0.030	-0.272
-00.0	.0366	-0.034	-0.137
-00.0	.0367	-0.017	-0.202
02.9	.0369	-0.033	-0.126
02.9	.0370	-0.026	-0.163
05.9	.0373	0.035	-0.143
05.9	.0373	0.012	-0.107
08.9	.0376	0.019	-0.156
08.9	.0376	-0.011	-0.177
11.9	.0383	0.023	-0.187
11.9	.0383	-0.016	-0.124
14.7	.0379	-0.070	-0.088
14.7	.0378	0.018	-0.206
M = 0.80			
δ_L = 15°		δ_U = 0°	
-06.0	.0323	-0.077	-0.070
-06.0	.0324	-0.007	-0.262
-03.0	.0327	-0.057	-0.168
-03.0	.0327	-0.077	-0.167
-00.0	.0329	-0.051	-0.126
-00.0	.0329	-0.038	-0.188
02.9	.0332	-0.049	-0.215
02.9	.0333	-0.033	-0.156
05.9	.0336	-0.046	-0.082
05.9	.0337	-0.051	-0.110
08.9	.0341	-0.106	-0.073
08.9	.0340	0.043	-0.199
11.9	.0341	-0.008	-0.103
11.9	.0341	0.011	-0.146
14.7	.0341	0.265	-0.219
14.7	.0336	0.563	-0.209
M = 0.90			
δ_L = 15°		δ_U = 0°	
-06.0	.0292	-0.151	-0.115
-06.0	.0292	-0.106	-0.160
-03.0	.0294	-0.068	-0.218
-03.0	.0295	-0.086	-0.147
-00.0	.0296	-0.070	-0.114
-00.0	.0297	-0.041	-0.175
02.9	.0299	-0.043	-0.123
02.9	.0300	-0.065	-0.198
05.9	.0304	-0.131	0.001
05.9	.0304	-0.105	-0.056
08.9	.0306	0.029	-0.070
08.9	.0307	-0.013	-0.113
11.9	.0307	-0.069	-0.166
11.9	.0304	-0.174	-0.029
14.7	.0310	-0.051	-0.042
14.7	.0311	-0.023	-0.110

α, deg	k	$C_{l_p} + C_{l_{\dot\beta}} \sin\alpha$	$C_{n_p} + C_{n_{\dot\beta}} \sin\alpha$
M = 0.95			
δ_L = 15°		δ_U = 0°	
-06.0	.0280	-0.045	-0.064
-06.0	.0281	-0.058	-0.133
-03.0	.0284	0.047	-0.004
-03.0	.0283	-0.036	-0.017
-00.0	.0286	-0.018	-0.013
-00.0	.0286	0.015	-0.004
02.9	.0290	0.009	0.058
02.9	.0290	-0.003	0.007
05.9	.0294	-0.057	-0.036
05.9	.0294	0.033	-0.064
08.9	.0298	0.018	-0.004
08.9	.0295	0.034	-0.039
11.9	.0295	0.076	0.059
11.9	.0294	0.151	-0.054
14.7	.0293	0.123	-0.149
14.7	.0291	0.036	-0.288
M = 1.00			
δ_L = 15°		δ_U = 0°	
-06.0	.0269	-0.059	0.114
-06.0	.0268	-0.028	-0.075
-03.0	.0270	-0.057	-0.056
-03.0	.0271	-0.008	-0.015
-00.0	.0273	-0.047	0.084
-00.0	.0274	0.000	-0.003
02.9	.0278	-0.026	0.035
02.9	.0277	-0.003	-0.104
05.9	.0282	-0.048	-0.123
05.9	.0281	-0.020	-0.168
08.9	.0282	0.025	-0.024
08.9	.0283	0.022	-0.088
11.9	.0279	-0.022	0.089
11.9	.0280	-0.019	0.019
14.7	.0282	0.047	0.052
14.7	.0280	0.109	0.035
M = 1.05			
δ_L = 15°		δ_U = 0°	
-06.0	.0259	-0.025	0.222
-06.0	.0259	-0.007	0.201
-03.0	.0259	-0.074	0.155
-03.0	.0260	-0.051	0.098
-00.0	.0262	-0.071	0.044
-00.0	.0261	-0.040	-0.013
02.9	.0267	-0.031	0.307
02.9	.0268	-0.004	0.255
05.9	.0271	-0.048	0.112
05.9	.0270	-0.036	0.118
08.9	.0272	0.027	-0.129
08.9	.0273	0.040	-0.082
11.9	.0273	-0.040	0.154
11.9	.0273	-0.023	0.123
14.7	.0271	0.047	0.081
14.7	.0271	-0.031	0.093

α, deg	k	$C_{l_p} + C_{l_{\dot\beta}} \sin\alpha$	$C_{n_p} + C_{n_{\dot\beta}} \sin\alpha$
M = 1.10			
δ_L = 15°		δ_U = 0°	
-06.0	.0249	-0.042	0.361
-06.0	.0249	-0.073	0.215
-03.0	.0250	-0.111	0.184
-03.0	.0250	-0.111	0.094
-00.0	.0252	-0.110	0.165
-00.0	.0252	-0.082	0.040
02.9	.0256	-0.082	0.255
02.9	.0256	-0.057	0.178
05.9	.0260	-0.055	0.170
05.9	.0260	-0.044	0.068
08.9	.0261	-0.063	0.167
08.9	.0261	-0.027	0.056
11.9	.0264	-0.010	0.123
11.9	.0265	-0.068	0.106
14.7	.0264	-0.029	0.137
14.7	.0262	0.025	0.097
M = 1.20			
δ_L = 15°		δ_U = 0°	
-06.0	.0232	-0.072	0.461
-06.0	.0232	-0.067	0.366
-03.0	.0233	-0.133	0.257
-03.0	.0232	-0.111	0.078
-00.0	.0233	-0.148	0.009
-00.0	.0232	-0.172	-0.157
02.9	.0238	-0.068	0.300
02.9	.0239	-0.048	0.267
05.9	.0242	0.008	0.185
05.9	.0242	-0.031	0.146
08.9	.0244	-0.043	0.232
08.9	.0244	-0.017	0.212
11.9	.0244	-0.063	0.331
11.9	.0243	-0.157	0.240
14.7	.0241	-0.173	0.280
14.7	.0241	-0.118	0.128
M = 1.55			
δ_L = 0°		δ_U = 0°	
-06.0	.0192	-0.100	-0.100
-06.0	.0192	-0.110	-0.081
-03.0	.0193	-0.060	-0.091
-03.0	.0193	-0.090	-0.074
-00.0	.0196	-0.100	-0.081
-00.0	.0195	-0.090	-0.082
03.0	.0198	-0.150	-0.079
03.0	.0198	-0.160	-0.053
05.9	.0201	-0.160	-0.037
05.9	.0201	-0.140	-0.047
09.0	.0201	-0.070	-0.043
09.0	.0202	-0.090	-0.044
12.0	.0203	-0.060	-0.002
12.0	.0203	-0.080	-0.014
14.6	.0207	0.030	-0.004
14.6	.0206	-0.050	-0.008

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[redacted]

TABLE III.- ROLLING DERIVATIVES - Continued

(a) With flap control - Concluded

α, deg	k	$C_{l_p} + C_{l_{\dot\beta}} \sin\alpha$	$C_{n_p} + C_{n_{\dot\beta}} \sin\alpha$
M = 1.80			
$\delta_L = 0°$		$\delta_U = 0°$	
-06.0	.0173	-0.130	-0.102
-06.0	.0173	-0.110	-0.111
-03.0	.0175	-0.160	-0.108
-03.0	.0175	-0.130	-0.114
-00.0	.0177	-0.160	-0.089
-00.0	.0177	-0.150	-0.094
02.9	.0179	-0.140	-0.101
02.9	.0179	-0.160	-0.098
06.0	.0181	-0.150	-0.089
06.0	.0181	-0.130	-0.079
08.9	.0182	-0.120	-0.061
08.9	.0182	-0.110	-0.076
12.0	.0184	-0.090	-0.048
12.0	.0184	-0.080	-0.045
14.6	.0194	-0.040	-0.034
14.6	.0185	-0.060	-0.013
M = 2.20			
$\delta_L = 0°$		$\delta_U = 0°$	
-06.0	.0155	-0.090	-0.088
-06.0	.0155	-0.050	-0.086
-03.0	.0157	-0.060	-0.057
-03.0	.0157	-0.070	-0.045
-00.0	.0158	-0.110	-0.014
-00.0	.0158	-0.070	-0.050
03.0	.0159	-0.130	-0.033
03.0	.0159	-0.130	-0.037
05.9	.0161	-0.130	-0.049
05.9	.0161	-0.110	-0.019
09.0	.0163	-0.040	-0.002
09.0	.0163	-0.030	-0.002
12.0	.0164	-0.070	0.010
12.0	.0164	-0.060	0.001
14.6	.0165	-0.040	0.021
14.6	.0165	-0.020	0.039
M = 3.00			
$\delta_L = 0°$		$\delta_U = 0°$	
-05.8	.0134	-0.126	0.178
-05.8	.0134	-0.127	0.192
-02.8	.0134	-0.252	0.202
-02.8	.0134	-0.249	0.208
00.1	.0136	-0.145	0.264
00.1	.0136	-0.154	0.275
03.1	.0136	-0.270	0.251
03.1	.0136	-0.271	0.199
06.1	.0137	-0.300	0.213
06.1	.0137	-0.288	0.247
12.1	.0138	-0.454	0.174
12.1	.0138	-0.451	0.154
14.8	.0139	-0.223	0.183
14.8	.0139	-0.216	0.162
M = 3.50			
$\delta_L = 0°$		$\delta_U = 0°$	
-05.8	.0128	-0.124	0.221
-05.8	.0128	-0.118	0.154
-02.8	.0128	-0.276	0.277
-02.8	.0128	-0.264	0.214
00.1	.0129	-0.369	0.201
00.1	.0128	-0.323	0.239
03.0	.0130	-0.287	0.313
03.0	.0129	-0.301	0.303
06.0	.0130	-0.289	0.292
06.0	.0130	-0.295	0.210
12.0	.0131	-0.539	0.168
12.0	.0130	-0.499	0.219
14.7	.0132	-0.264	0.205
14.7	.0132	-0.252	0.238

TABLE III.- ROLLING DERIVATIVES - Continued

(b) Flap controls removed

α, deg	k	$C_{l_p}+C_{l_{\dot{\beta}}}\sin\alpha$	$C_{n_p}+C_{n_{\dot{\beta}}}\sin\alpha$
M = 0.70			
-06.0	.0391	-0.042	-0.019
-06.0	.0389	-0.049	-0.001
-03.0	.0393	-0.059	0.007
-03.0	.0392	-0.040	0.030
-00.0	.0396	-0.008	0.007
-00.0	.0396	-0.027	-0.009
02.9	.0399	-0.028	0.024
02.9	.0398	-0.026	0.027
05.9	.0401	-0.049	0.035
05.9	.0401	-0.039	-0.026
08.9	.0406	-0.135	0.056
08.9	.0406	-0.070	-0.112
11.9	.0412	0.010	-0.020
11.9	.0411	-0.015	0.032
14.7	.0408	-0.049	0.039
14.7	.0408	-0.180	-0.069
M = 0.80			
-06.0	.0350	-0.079	-0.008
-06.0	.0349	-0.056	0.020
-03.0	.0353	-0.072	-0.031
-03.0	.0352	-0.094	0.002
-00.0	.0355	-0.057	-0.019
-00.0	.0356	-0.056	0.009
02.9	.0359	-0.069	-0.018
02.9	.0359	-0.043	0.022
06.0	.0361	-0.044	-0.020
06.0	.0360	-0.054	-0.007
08.9	.0365	-0.035	-0.028
08.9	.0366	-0.003	-0.045
11.9	.0368	-0.032	0.002
11.9	.0367	-0.028	0.031
13.4	.0366	-0.096	0.021
13.4	.0367	0.012	0.010
M = 0.90			
-06.0	.0314	-0.148	0.027
-06.0	.0314	-0.106	-0.003
-03.0	.0316	-0.084	0.043
-03.0	.0316	-0.069	0.003
-00.0	.0321	-0.058	0.010
-00.0	.0321	-0.069	0.017
02.9	.0323	-0.076	0.018
02.9	.0324	-0.071	0.028
05.9	.0327	-0.063	-0.010
05.9	.0327	-0.061	0.001
08.9	.0330	-0.046	-0.030
08.9	.0329	-0.086	-0.006
11.9	.0330	-0.060	-0.008
11.9	.0330	-0.004	0.014
14.7	.0329	-0.028	0.060
14.7	.0333	0.128	0.028

α, deg	k	$C_{l_p}+C_{l_{\dot{\beta}}}\sin\alpha$	$C_{n_p}+C_{n_{\dot{\beta}}}\sin\alpha$
M = 0.95			
-06.0	.0300	-0.158	-0.006
-06.0	.0300	-0.135	0.010
-03.0	.0303	-0.153	0.044
-03.0	.0303	-0.157	0.045
-00.0	.0305	-0.081	0.107
-00.0	.0306	-0.070	0.167
02.9	.0309	-0.088	0.036
02.9	.0309	-0.100	0.061
05.9	.0312	-0.091	0.009
05.9	.0311	-0.091	0.039
08.9	.0315	-0.118	0.048
08.9	.0314	-0.063	0.002
11.9	.0314	-0.042	0.064
11.9	.0314	-0.121	0.048
14.7	.0315	0.001	0.006
14.7	.0314	-0.066	0.012
M = 1.00			
-06.0	.0286	-0.210	0.077
-06.0	.0288	-0.175	0.036
-03.0	.0289	-0.171	0.074
-03.0	.0289	-0.165	0.007
00.0	.0293	-0.124	0.045
00.0	.0293	-0.126	0.054
02.9	.0296	-0.149	0.159
02.9	.0297	-0.071	0.132
05.9	.0299	-0.130	0.036
05.9	.0301	-0.129	0.053
08.9	.0302	-0.122	0.073
08.9	.0302	-0.080	0.041
11.9	.0303	-0.071	0.061
11.9	.0303	-0.045	0.059
14.7	.0303	-0.114	0.050
14.7	.0301	-0.284	0.163
M = 1.05			
-06.0	.0275	-0.196	0.087
-06.0	.0277	-0.140	0.068
-03.0	.0277	-0.159	0.065
-03.0	.0277	-0.155	0.089
-00.0	.0279	-0.173	0.083
-00.0	.0280	-0.171	0.059
02.9	.0286	-0.114	0.141
02.9	.0284	-0.099	0.163
05.9	.0288	-0.117	0.103
05.9	.0288	-0.133	0.083
08.9	.0291	-0.140	0.114
08.9	.0291	-0.108	0.071
11.9	.0292	-0.047	0.096
11.9	.0293	-0.146	0.105
14.7	.0292	-0.022	0.098
14.7	.0292	-0.059	0.128

α, deg	k	$C_{l_p}+C_{l_{\dot{\beta}}}\sin\alpha$	$C_{n_p}+C_{n_{\dot{\beta}}}\sin\alpha$
M = 1.10			
-06.0	.0267	-0.169	0.086
-06.0	.0267	-0.172	0.037
-03.0	.0278	-0.200	0.068
-03.0	.0267	-0.181	0.085
-00.0	.0268	-0.199	0.061
-00.0	.0269	-0.231	0.064
02.9	.0273	-0.183	0.159
02.9	.0273	-0.157	0.084
05.9	.0277	-0.170	0.162
05.9	.0277	-0.127	0.128
08.9	.0280	-0.111	0.114
08.9	.0279	-0.086	0.111
11.9	.0283	-0.099	0.099
11.9	.0282	-0.106	0.094
14.7	.0283	-0.042	0.130
14.7	.0282	-0.066	0.146
M = 1.20			
-06.0	.0248	-0.189	0.184
-06.0	.0248	-0.203	0.128
-03.0	.0248	-0.281	0.022
-03.0	.0248	-0.291	0.052
-00.0	.0251	-0.267	0.102
-00.0	.0251	-0.255	0.082
02.9	.0256	-0.208	0.146
02.9	.0255	-0.173	0.159
05.9	.0259	-0.161	0.124
05.9	.0258	-0.129	0.098
08.9	.0262	-0.136	0.122
08.9	.0261	-0.142	0.125
11.9	.0262	-0.120	0.142
11.9	.0262	-0.052	0.133
14.7	.0264	-0.145	0.149
14.7	.0263	-0.019	0.204
M = 1.38			
-06.0	.0221	-0.281	0.822
-06.0	.0221	-0.320	0.779
-03.0	.0224	-0.295	0.630
-03.0	.0224	-0.260	0.385
-00.0	.0227	-0.220	0.259
-00.0	.0226	-0.239	0.207
02.9	.0229	-0.263	0.140
02.9	.0230	-0.244	0.176
05.9	.0232	-0.248	0.156
05.9	.0231	-0.229	0.124
08.9	.0233	-0.200	0.174
08.9	.0233	-0.184	0.131
11.9	.0235	-0.153	0.170
11.9	.0235	-0.151	0.128
14.7	.0235	-0.227	0.193
14.7	.0235	-0.210	0.170

TABLE III.- ROLLING DERIVATIVES - Concluded

(b) Flap controls removed - Concluded

α, deg	k	$C_{l_p} + C_{l_{\dot{\beta}}} \sin\alpha$	$C_{n_p} + C_{n_{\dot{\beta}}} \sin\alpha$
M = 1.55			
-06.0	.0205	-0.140	-0.111
-06.0	.0205	-0.130	-0.093
-03.0	.0208	-0.070	-0.096
-03.0	.0208	-0.130	-0.103
-00.0	.0211	-0.170	-0.090
-00.0	.0211	-0.120	-0.058
03.0	.0213	-0.190	-0.069
03.0	.0213	-0.150	-0.084
06.0	.0215	-0.200	-0.082
06.0	.0215	-0.140	-0.091
09.0	.0217	-0.100	-0.048
09.0	.0217	-0.080	-0.063
12.0	.0219	-0.080	-0.066
12.0	.0219	-0.070	-0.116
14.6	.0221	-0.060	-0.091
14.6	.0221	-0.080	-0.075
M = 1.80			
-06.0	.0187	-0.120	-0.080
-06.0	.0186	-0.140	-0.101
-03.0	.0188	-0.110	-0.110
-03.0	.0188	-0.150	-0.057
-00.0	.0190	-0.160	-0.080
-00.0	.0190	-0.110	-0.102
03.0	.0191	-0.180	-0.080
03.0	.0191	-0.140	-0.100
06.0	.0193	-0.150	-0.064
06.0	.0193	-0.140	-0.083
09.0	.0195	-0.130	-0.137
09.0	.0195	-0.080	-0.082
12.0	.0197	-0.090	-0.064
12.0	.0197	-0.100	-0.065
14.6	.0199	-0.070	-0.057
14.6	.0199	-0.090	-0.074
M = 2.20			
-06.0	.0167	-0.060	-0.076
-06.0	.0167	-0.070	-0.106
-03.0	.0168	-0.070	-0.170
-03.0	.0168	-0.060	-0.096
-00.0	.0170	-0.060	-0.098
-00.0	.0170	-0.060	-0.111
03.0	.0171	-0.120	-0.101
03.0	.0171	-0.100	-0.110
06.0	.0173	-0.130	-0.126
06.0	.0173	-0.130	-0.084
09.0	.0175	-0.070	-0.063
09.0	.0175	-0.080	-0.085
11.9	.0176	-0.080	-0.073
11.9	.0176	-0.070	-0.091
14.6	.0177	-0.050	-0.100
14.6	.0177	-0.040	-0.087
M = 3.00			
-05.8	.0144	-0.150	0.341
-05.8	.0144	-0.142	0.204
-02.8	.0145	-0.153	0.327
-02.8	.0145	-0.153	0.262
00.1	.0146	-0.188	0.352
00.1	.0146	-0.168	0.326
03.1	.0146	-0.303	0.346
03.1	.0146	-0.299	0.341
06.1	.0147	-0.338	0.440
06.1	.0147	-0.322	0.420
12.1	.0148	-0.437	0.464
12.1	.0148	-0.466	0.433
14.8	.0150	-0.283	0.409
14.8	.0150	-0.249	0.480
M = 3.50			
-05.9	.0138	-0.206	0.305
-05.8	.0138	-0.211	0.389
-02.9	.0138	-0.396	0.340
-02.9	.0138	-0.359	0.356
00.1	.0139	-0.240	0.595
00.1	.0139	-0.306	0.500
03.1	.0139	-0.337	0.516
03.1	.0139	-0.321	0.458
06.1	.0139	-0.333	0.647
06.1	.0139	-0.346	0.519
12.1	.0140	-0.486	0.738
12.1	.0141	-0.473	0.618
14.7	.0142	-0.260	0.677
14.7	.0142	-0.257	0.620

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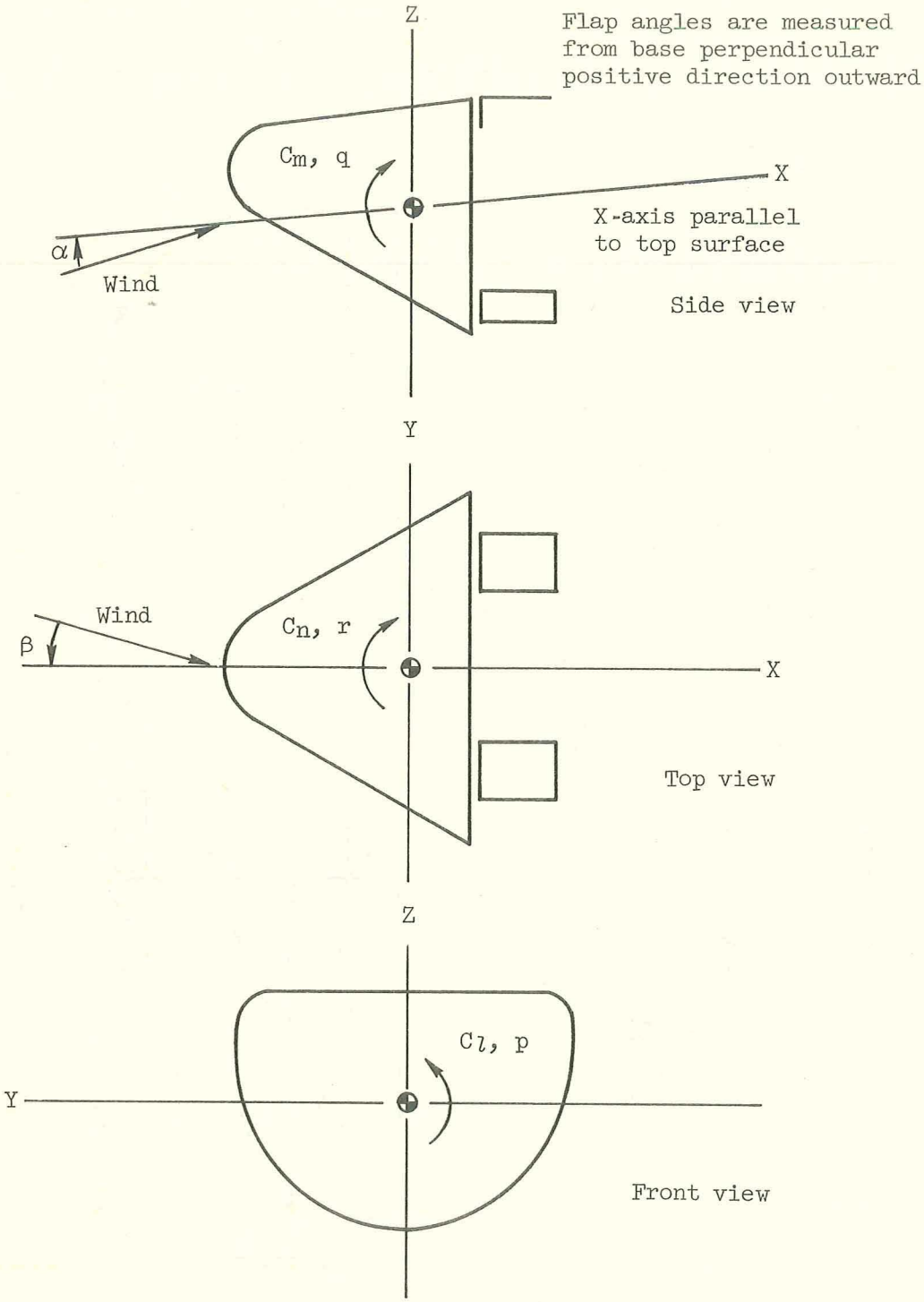

Figure 1.- The body system of axes. Arrows indicate positive direction of moments and angles.

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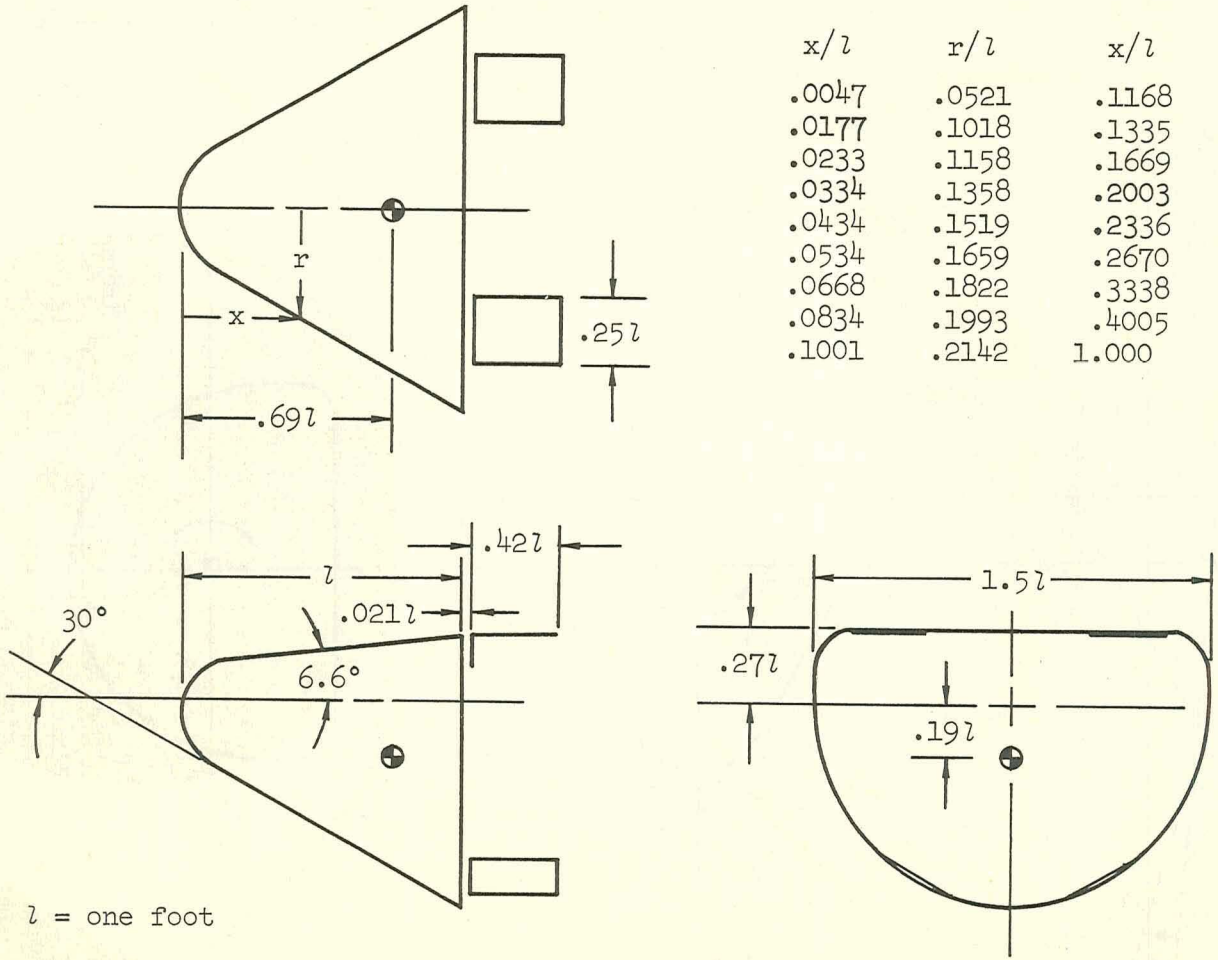

x/l	r/l	x/l	r/l
.0047	.0521	.1168	.2280
.0177	.1018	.1335	.2410
.0233	.1158	.1669	.2647
.0334	.1358	.2003	.2864
.0434	.1519	.2336	.3071
.0534	.1659	.2670	.3268
.0668	.1822	.3338	.3658
.0834	.1993	.4005	.4045
.1001	.2142	1.000	.7510

Figure 2.- Study configuration.

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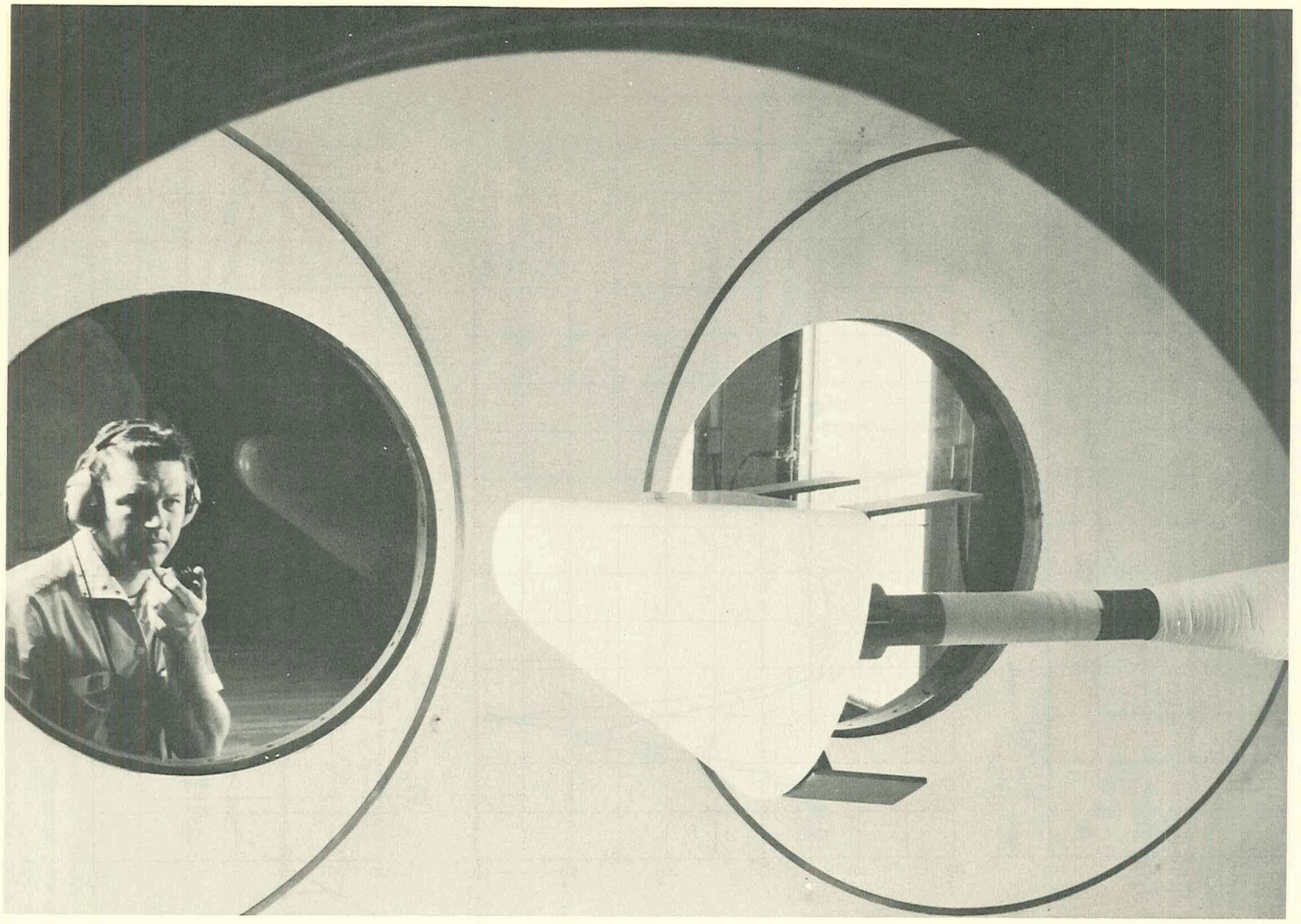

Figure 3.- Typical wind-tunnel installation in the 8- by 7-foot test section. A-24731

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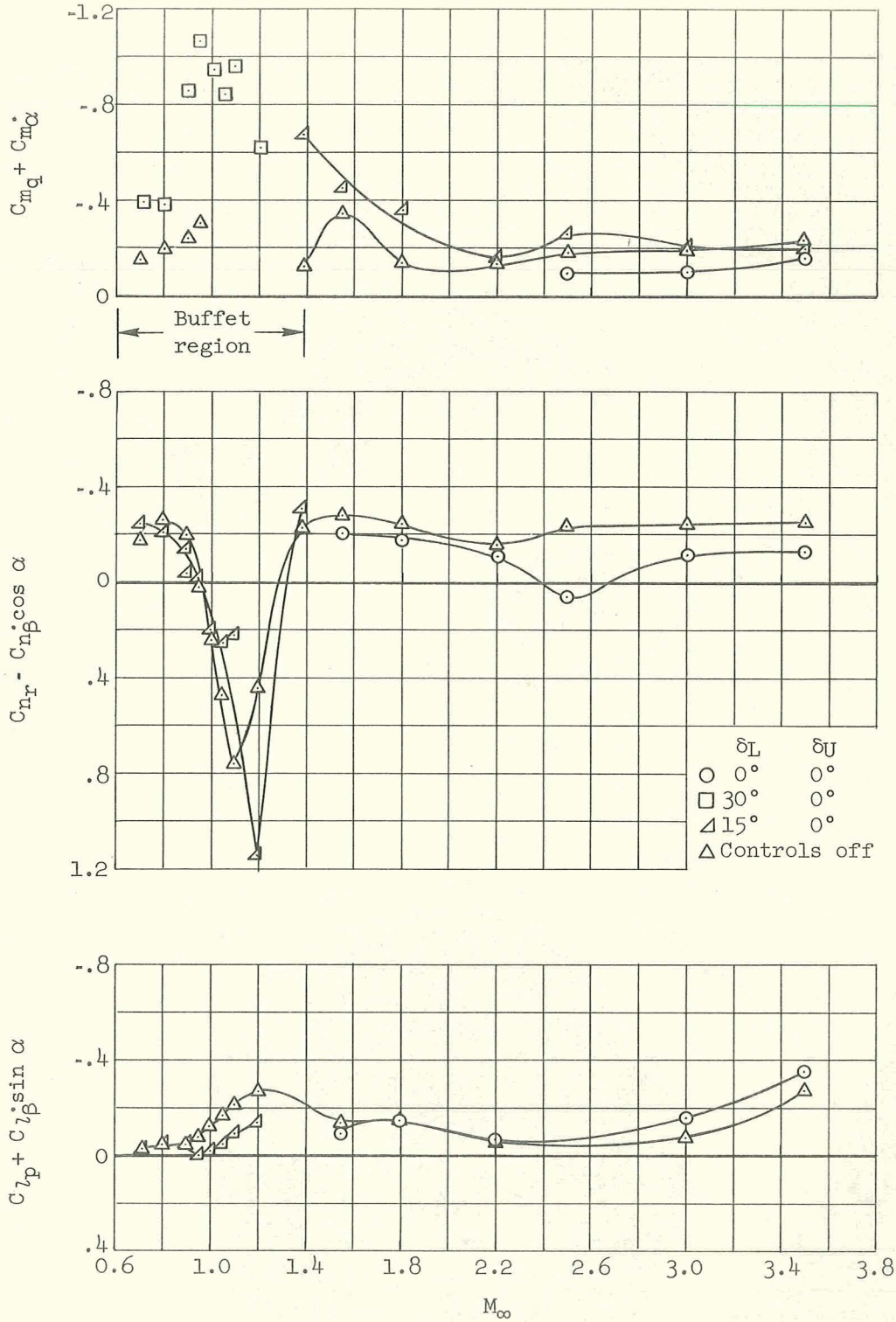

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Figure 4.- Variation with Mach number of the damping derivatives, $\alpha = 0^{\circ}$.

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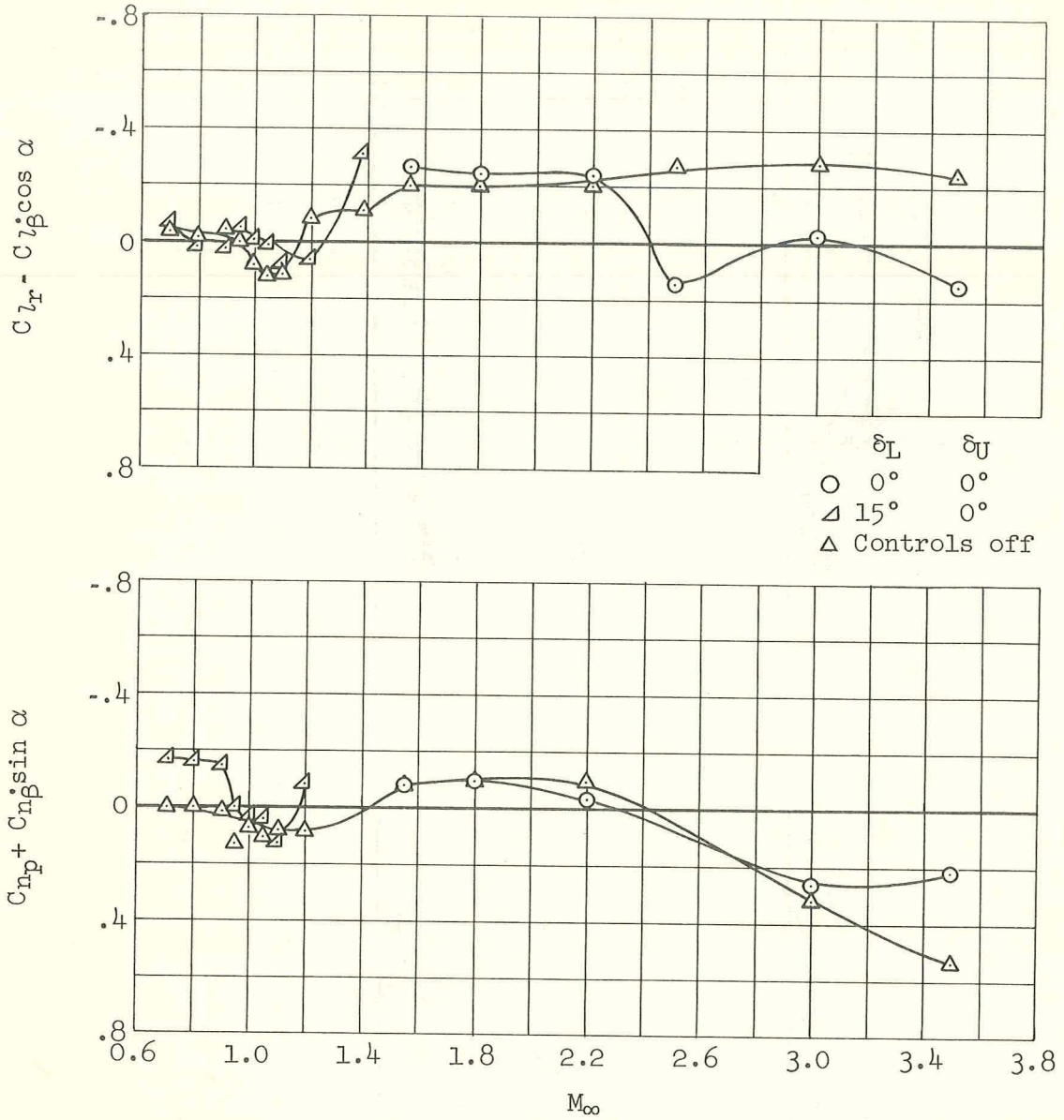

Figure 5.- Variation with Mach number of the cross derivatives, $\alpha = 0^\circ$.

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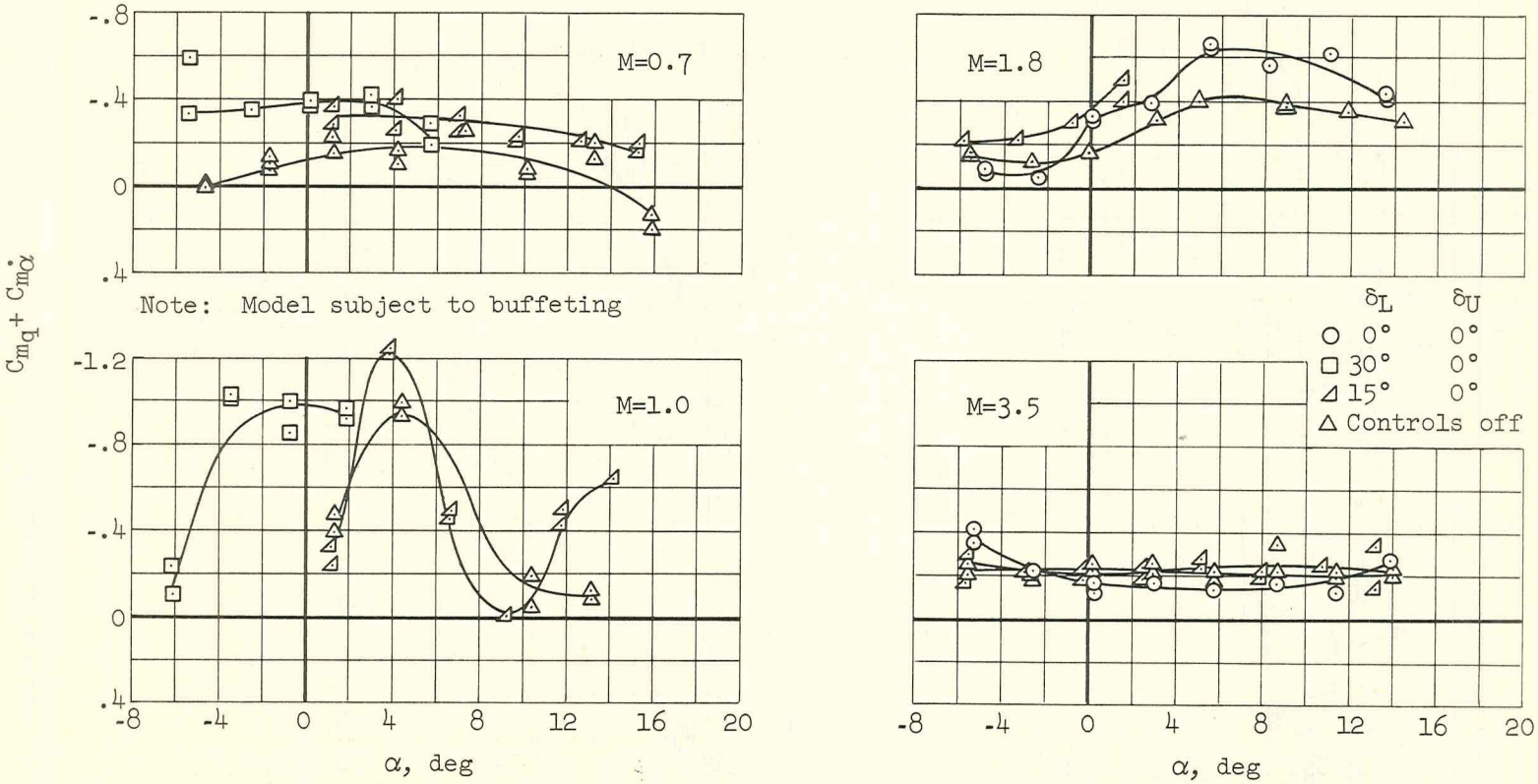

Figure 6.- Variation with angle of attack of the damping-in-pitch coefficient.

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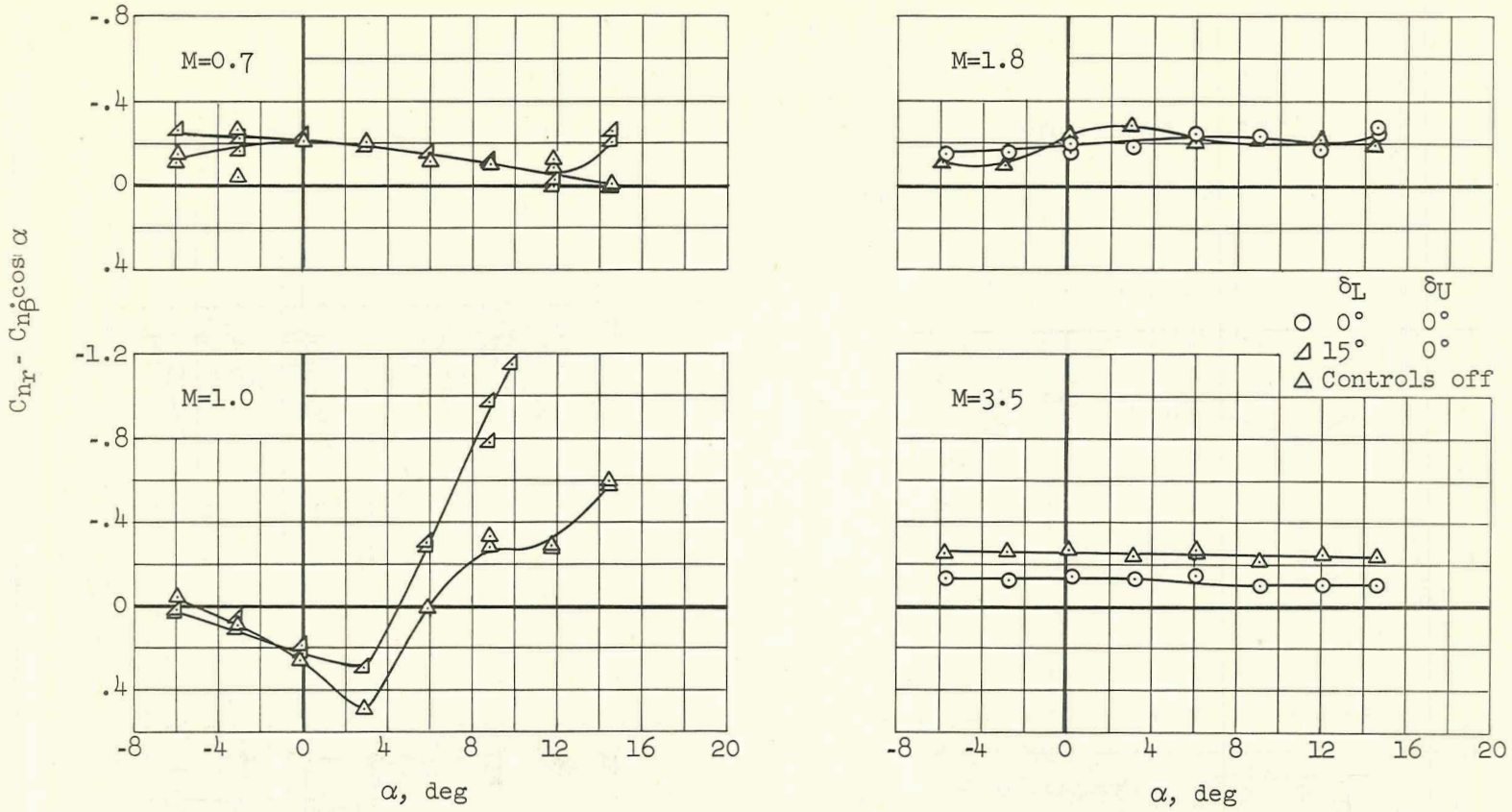

Figure 7.- Variation with angle of attack of the damping-in-yaw coefficient.

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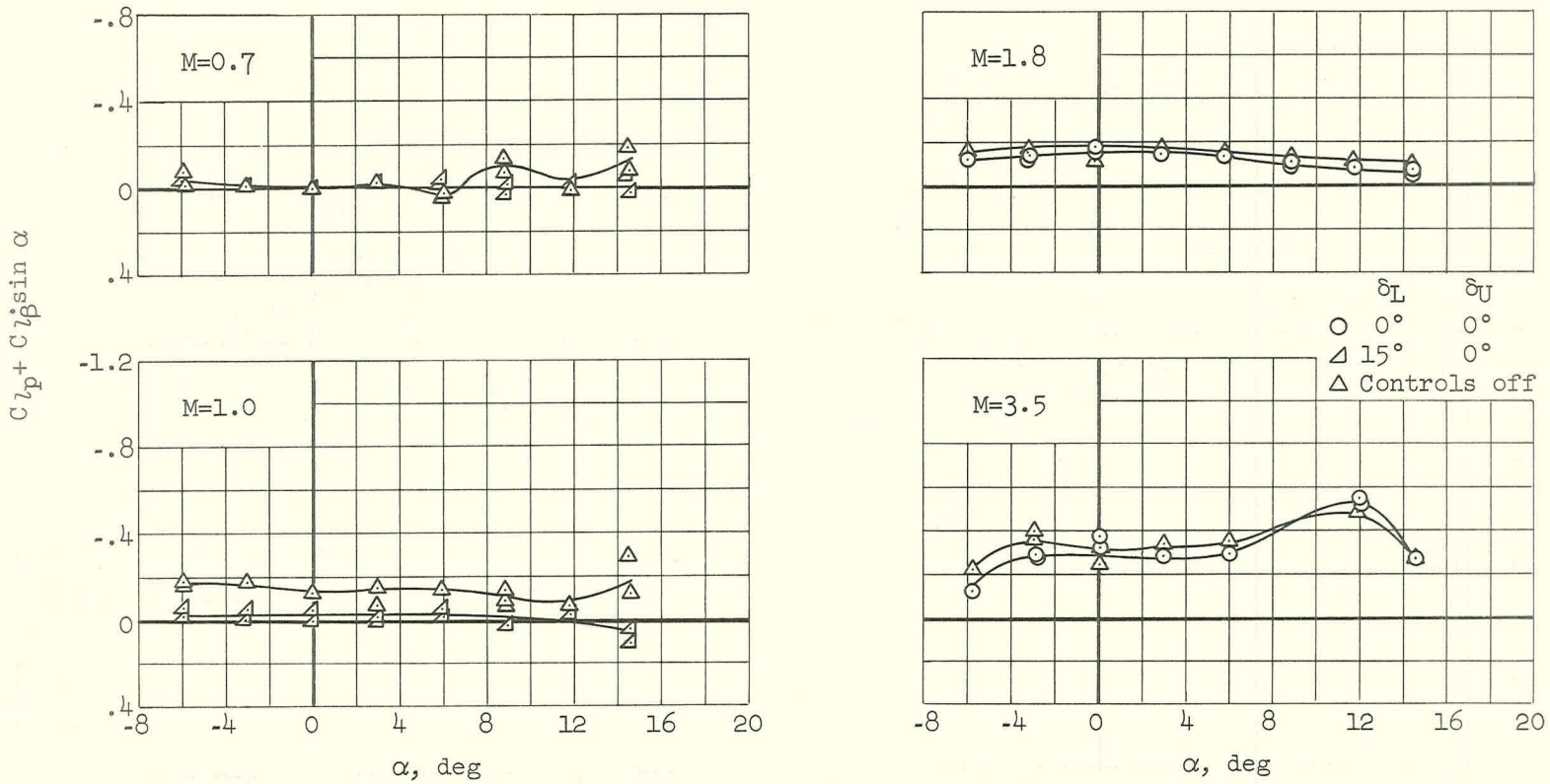

Figure 8.- Variation with angle of attack of the damping-in-roll coefficient.

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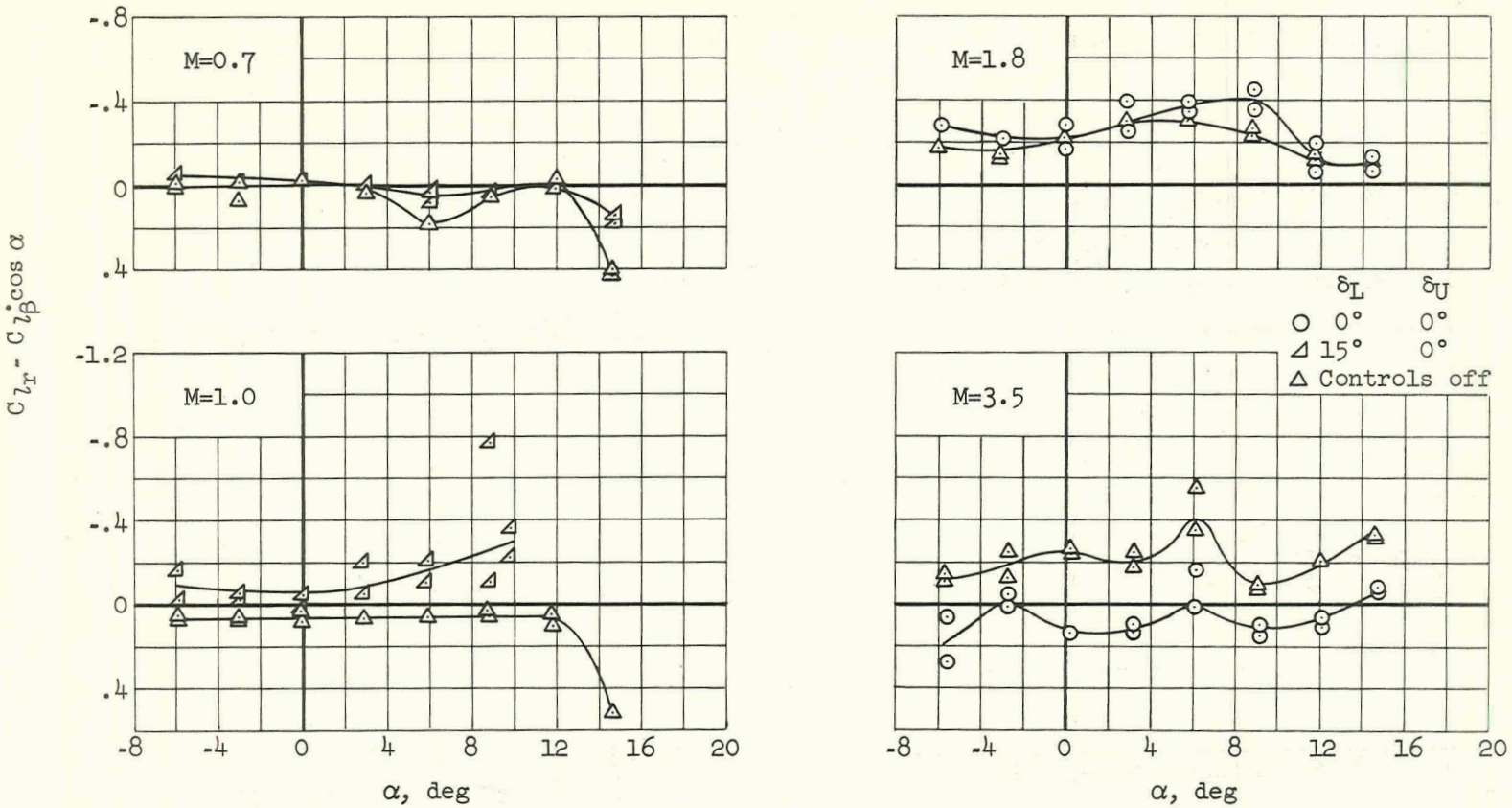

Figure 9.- Variation with angle of attack of the rolling moment due to yawing coefficient.

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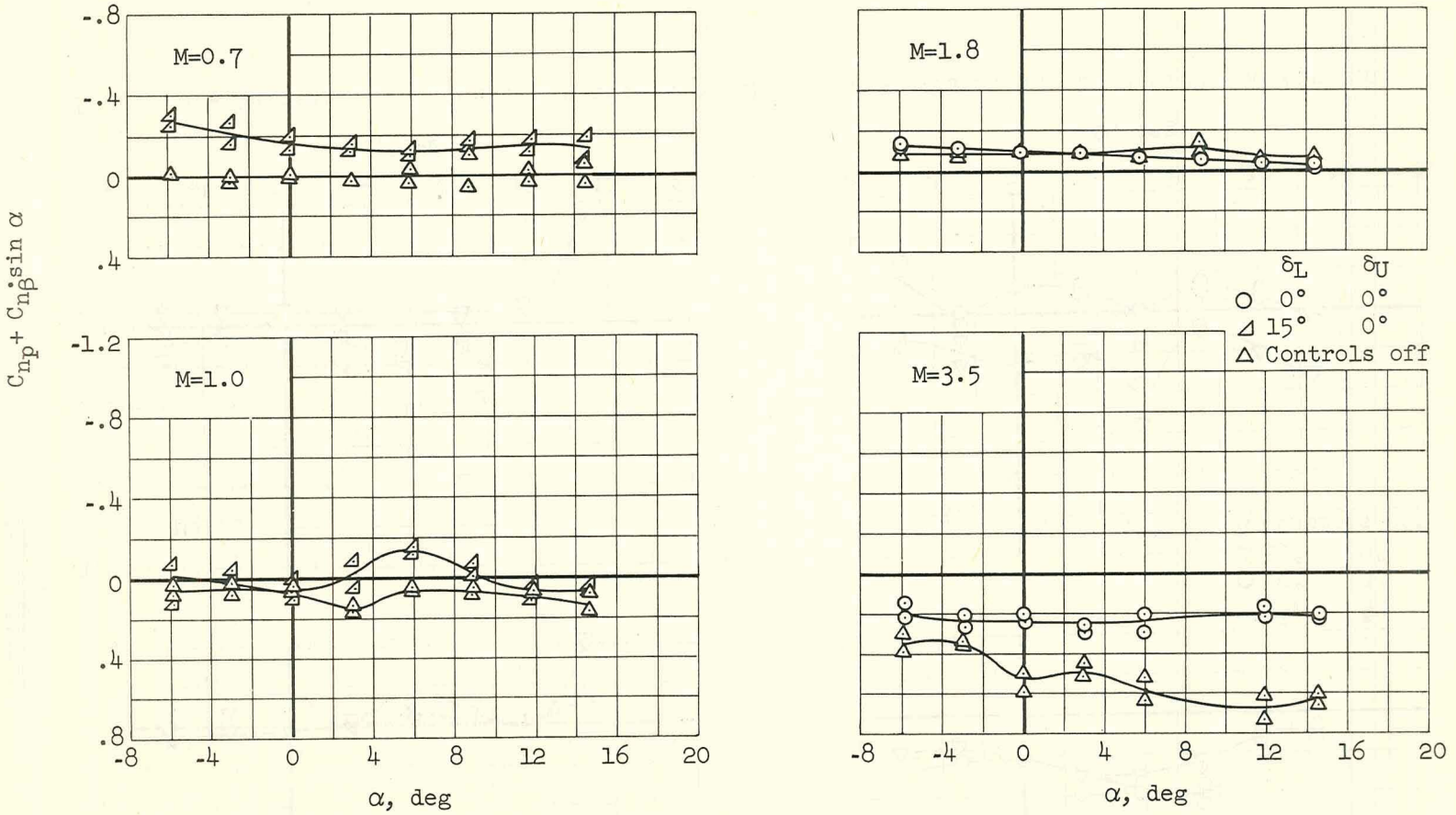

Figure 10.- Variation with angle of attack of the yawing moment due to rolling coefficient.

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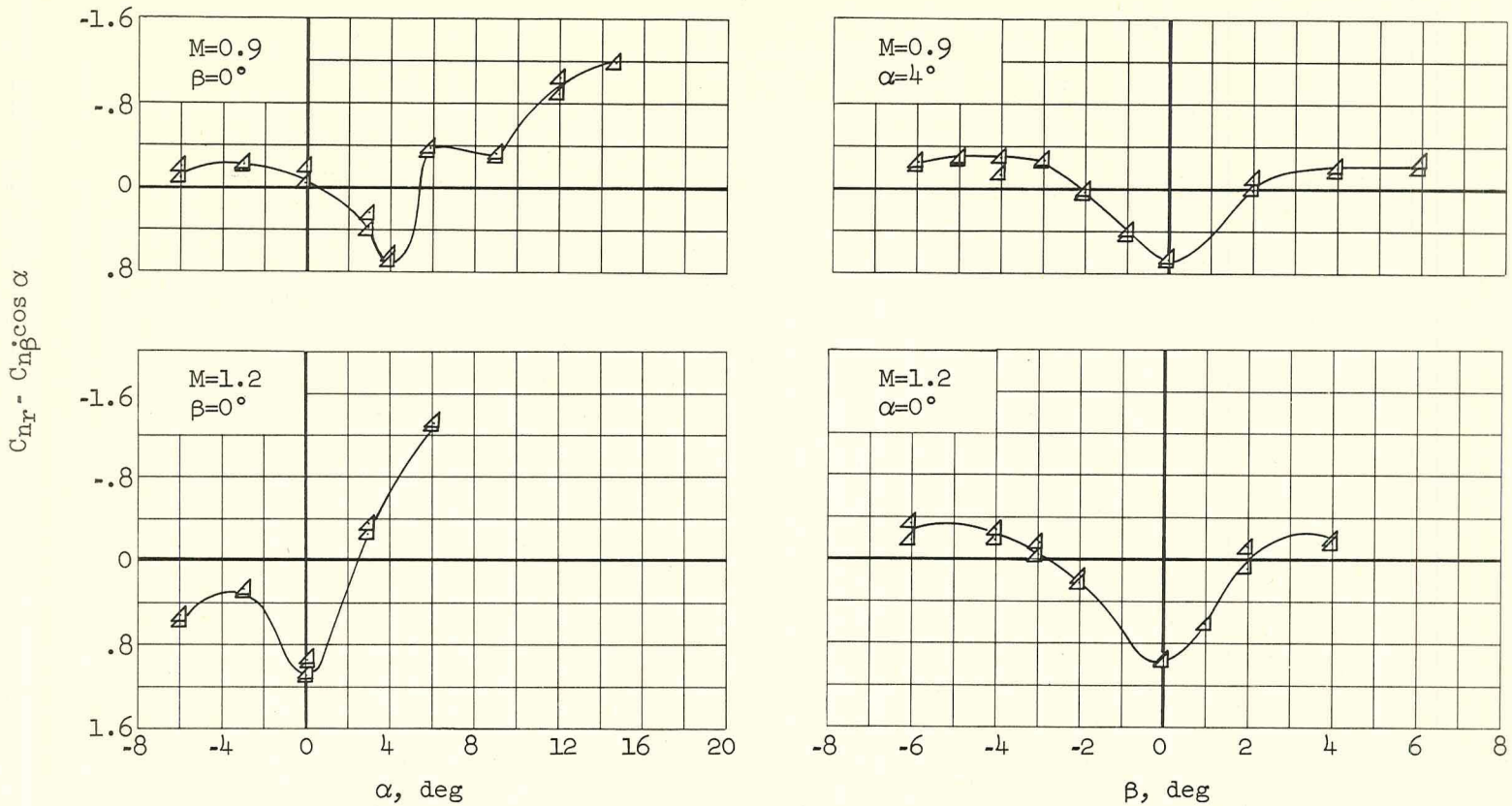

Figure 11.- Variation with angle of attack and sideslip of the damping-in-yaw coefficient; $\delta_L = 15^\circ$, $\delta_U = 0^\circ$.

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