NASA TECHNICAL MEMORANDUM

NASA TM X-62,273

NASA TM X-62,273

(NASA-TM-X-62273) WIND TUNNEL TESTS OF AN F-8 AIRPLANE MODEL EQUIPPED WITH AN OBLIQUE WING (NASA) 72 p HC $5.75

N73-32974

CSCL 01C

Unclas

G3/02 19807

WIND TUNNEL TESTS OF AN F-8 AIRPLANE MODEL EQUIPPED WITH AN OBLIQUE WING

By Lawrence A. Graham, Robert T. Jones and James L. Summers

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June 1973

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SUMMARY

An experimental investigation was conducted in the Ames 11- by 11-Foot Transonic Wind Tunnel to study the lift, drag and stability characteristics of a [illegible]07-scale model of an operational airplane fitted with an oblique wing. The model wing was of elliptical planform with an unswept aspect ratio of 12.7 and a thickness of 10 percent. All other external geometric features of the model were scaled to the basic full size operational airplane with the engine inlet faired closed.

Longitudinal and lateral-directional stability data were obtained with the wing at sweep angles of 0°, 45° and 60°. Test Mach numbers ranged from 0.6 to 1.4. Angles of attack were between -4° and 8° at zero sideslip. Angles of sideslip were between ± 4 degrees for two angles of attack depending upon the wing configuration. Tests were conducted at a Reynolds number of 6 million per foot except for a few runs when balance capacity limited the Reynolds number to 4 million per foot.

The static longitudinal data show this configuration to be generally stable within the lift range of the investigation, although a trend toward instability appears in localized regions of the data. The data indicate that lateral-directional-stability characteristics for this configuration are generally good.

INTRODUCTION

Recent experimental results obtained in the NASA-Ames 11- by 11-Foot Transonic Wind Tunnel have clearly indicated the potential of the oblique-wing concept toward achieving maximum aerodynamic efficiency of a wing over a wide speed range (references 1 and 2). In view of these results, the application of this concept in the design of complete airplane configurations should provide the same potential, and additional advantages to other items such as speed, noise and power required for landing and take off, sonic boom, etc. as discussed in reference 3. To further study the potential of the oblique-wing concept a limited investigation has been made in the Ames 11- by 11-Foot Transonic Wind Tunnel of the lift, drag, and stability characteristics of a 0.087-scale model of an operational airplane fitted with an oblique wing. The model wing was of elliptical planform with an elliptic axis ratio of 10:1, an unswept aspect ratio of 12.7, and a thickness of 10 percent. The airfoil section of the wing was an NACA 3610-02,40. All other external geometric features of the model were scaled to the basic full scale operational airplane. The engine inlet was closed with a fairing beginning at the model nose to prevent airflow through the ducts within the model.

A complete set of results are provided in this report with essentially no analysis.

NOMENCLATURE

The axis systems and sign convertions are shown in figure 1. Lift and drag are presented in the stability-axis coordinate system and all other forces and moments are presented in the body-axis coordinate system. Because the data were computer plotted the corresponding plot symbol, where used, is given together with the conventional symbol.

Symbol	Plot Symbol	Definition
b		wing span
c		wing chord
c_{root}		wing root chord
C_D	CD	drag coefficient, drag/qS
C_ℓ	CBL	rolling-moment coefficient, rolling moment/qSb
C_{ℓ_β}		rolling-moment coefficient slope
C_L	CL	lift coefficient, lift/qS
C_m	CLM	pitching-moment coefficient, pitching moment/qSc_{root}
C_n	CYN	yawing-moment coefficient, yawing moment/qSb

C_{n_β}		yawing-moment coefficient slope
C_Y	CY	side-force coefficient, side force/qS
C_{Y_β}		side-force coefficient slope
H		maximum vertical distance from wing reference plane to wing base line at 0.4c
(L/D)	L/D	lift-drag ratio
M	MACH	free-stream Mach number
q		free-stream dynamic pressure
Re	RN/L	unit Reynolds number, million per foot
S		wing area
t		wing thickness
x		Cartesian coordinate
Y-Up		maximum distance from wing base line to wing upper surface measured perpendicular to the wing base line
Y-Lo		maximum distance from wing base line to wing lower surface measured perpendicular to the wing base line
Z-Up		vertical distance from wing chord to wing upper surface
Z-Lo		vertical distance from wing chord to wing lower surface
z		Cartesian coordinate
α	ALPHA	angle of attack
β	BETA	angle of sideslip
Λ	LAMBDA	angle between a perpendicular to the body longitudinal axis and the 0.25 chord line of the wing measured in a horizontal plane

Subscripts

max		maximum value

Configuration Code

W_3	W3	wing
F_o	FO	flaps, undeflected
B_1	B1	body
T	T	tail

TEST FACILITY

The tests were conducted in the Ames 11- by 11-Foot Transonic Wind Tunnel which is a variable density, closed return, continuous flow type. This tunnel has an adjustable nozzle (two flexible walls) and a slotted test section to permit transonic testing over a Mach number range continuously variable from 0.4 to 1.4.

MODEL DESCRIPTION

The model consisted of an elliptical planform wing mounted on top of the fuselage of a 0.087-scale model of an operational fighter-type airplane as shown in figure 2. Pertinent dimensions of the wing are shown in tables 1 and 2 and in figure 2. A photograph of the model mounted in the wind tunnel is shown in figure 2(e). The wing was pivoted in the horizontal plane about the 0.4 root-chord point to obtain angles of 0^o, 45^o and 60^o. The wing had an elliptical planform with an elliptic axis ratio of 10:1 (unswept aspect ratio of 12.7) and a straight 25-percent chord line. The wing section was a NACA 3610-02,40 perpendicular to the unswept chord line. The horizontal and vertical tail surfaces had NACA 65A006 airfoil sections and a 45^o swept quarter-chord line. The horizontal tail was set at 2 1/2 degree incidence relative to the body center line. All external geometric features of the model, other than the wing, were 0.087-scale of the full size operational fighter-type airplane except that the engine inlet was faired closed as shown in figure 2(a). Model body contours are shown in figure 2(b).

TESTING AND PROCEDURE

The model was sting supported through the base of the model body shown in figure 2(a) and force and moment data were obtained from an internally mounted six-component strain-gage balance. The moment center was located longitudinally at the wing pivot point ($0.4c_{root}$) and 0.174 inch above the model center line (fig. 2(a)). Tests were conducted at a Reynolds number of 6 million per foot except for a few runs where balance capacity limited the Reynolds number to 4 million per foot. Angle of attack ranged between -4 to 8 degrees at zero sideslip. Angles of sideslip were between ±4 degrees for two angles of attack depending upon the wing configuration: one angle of attack at or slightly below $(L/D)_{max}$ (as determined from longitudinal data) and one angle of attack slightly above $(L/D)_{max}$. Six component force and moment data were obtained for the wing at sweep angles of 0^o, 45^o and 60^o.

The measured balance data were adjusted to a condition corresponding to free-stream static pressure on the model base. The Mach number range for each sweep angle tested is shown in table 3.

A complete index of the data figures is given in table 4.

RESULTS AND DISCUSSION

Effect of Wing Sweep Angle on Maximum Lift-to-Drag Ratio

The maximum lift-to-drag ratios for the wing at $\Lambda = 0^o$, 45^o and 60^o are shown in figure 3. For $\Lambda = 0^o$ the highest $(L/D)_{max}$ value obtained was 20 at a Mach number of 0.60. At $M = 0.70$ the $(L/D)_{max}$ has decreased slightly (from 20 to 19.8) and drops sharply to 9.0 at $M = 0.80$. This drop in $(L/D)_{max}$ indicates that for $\Lambda = 0^o$ the wing leading edge Mach number is approaching the critical Mach number at 0.70 and is supercritical at $M = 0.80$ as discussed in reference 3. Increasing the wing sweep angle at the higher test Mach numbers retards the loss in $(L/D)_{max}$ with increasing Mach number as shown in figure 3. For example, the unswept wing ($\Lambda = 0^o$) shows an abrupt loss in $(L/D)_{max}$ between $M = 0.70$ and 0.80 (from $(L/D_{max} = 19.8$ to $(L/D)_{max} = 9.0$ respectively). Pivoting the wing from $\Lambda = 0^o$ to $\Lambda = 45^o$ at $M = 0.80$ increases $(L/D)_{max}$ from 9.0 to 13.8. The same effect is seen in the data for $\Lambda = 45^o$ and 60^o; between $M = 0.98$ and 1.05 for $\Lambda = 45^o$, $(L/D)_{max}$ decreases from 11.75 to 6.75; between $M = 1.05$ and 1.30 for $\Lambda = 60^o$, $(L/D)_{max}$ changes from 6.75 to 5.3.

CONCLUDING REMARKS

The static longitudinal stability data show this configuration to be generally stable within the lift range of the investigation. What would be considered a trend toward instability (pitch-up) for a symmetrical configuration appears in localized regions of the data (for example at M = 0.98, $\Lambda = 45^\circ$, (figure 4, page 7) and a lift coefficient of 0.35). With the wing in a swept position the downstream tip tends to stall before other portions of the wing. This tip flow behavior is similar to the tip-stall of a symmetrically swept-back wing and causes the same well known pitch-up tendency of the swept-back wing. However, with the oblique wing in the swept position and only one tip stalling, a spanwise shift in center-of-pressure accompanies the longitudinal c.p. shift and both rolling and pitching moments are involved. An example of this can be seen in the corresponding lateral-directional data for the conditions above (figure 5, page 29). A comprehensive examination of the data indicate that lateral-directional stability characteristics for this configuration are generally good. That is, C_{n_β} and C_{Y_β} are of the proper sign; C_{l_β} is negative at $\Lambda = 0^\circ$ and 60° and, although sometimes positive at $\Lambda = 45^\circ$, is of low magnitude and this, in conjunction with the stable trend of C_{n_β}, indicates an overall stable configuration.

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June 18, 1973

REFERENCES

1. Graham, Lawrence A.; Jones, Robert T.; and Boltz, Frederick W.: An Experimental Investigation of an Oblique-Wing and Body Combination at Mach Numbers Between 0.60 and 1.40. NASA TM X-62,207, December 1972.

2. Graham, Lawrence A.; Jones, R. T.; and Boltz, Frederick W.: An Experimental Investigation of Three Oblique-Wing and Body Combinations at Mach Numbers Between 0.60 and 1.40. NASA TM X-62,256, May 1973.

3. Jones, R. T.: New Design Goals and a New Shape for the SST. Astronautics and Aeronautics, December 1972.

TABLE 1. - MODEL GEOMETRY

Wing	
Planform	10:1 ellipse about c/4
Span (reference)	60.00 in
Area (reference)	278.00 in^2
Root chord	6.00 in
Aspect ratio	12.7
Maximum t/c	0.10
Incidence	0°
0.25c sweep	0°
Section	NACA 3610-02,40
Maximum thickness location, percent chord	40
Leading-edge nose radius, percent chord	2
Horizontal tail	
Planform	trapezoidal
Span	18.96 in
Area	51.70 in^2
Root chord	9.37 in
Tip chord	1.40 in
Aspect ratio	6.95
Maximum t/c	0.06
Incidence	-2.5°
0.25c sweep	45°
Section	NACA 65A006
Vertical tail	
Planform	trapezoidal
Span	12.57 in
Area	108.10 in^2
Root chord	13.70 in
Tip chord	3.50 in
Aspect ratio	1.46
Maximum t/c	0.06
0.25c sweep	52.5°
Section	NACA 65A006

TABLE 2. - WING DIMENSIONAL DATA*

Semi-span	Chord	Y-Up	Y-Lo	H
.000	6.000	.465	.179	.000
1.000	5.997	.465	.179	.000
2.000	5.987	.464	.178	.000
3.000	5.970	.463	.178	.000
4.000	5.946	.461	.177	.000
5.000	5.915	.458	.176	.000
6.000	5.879	.456	.175	.000
7.000	5.834	.452	.174	.000
8.000	5.783	.448	.172	.000
9.000	5.724	.444	.171	.000
10.000	5.657	.438	.169	.010
10.986	5.583	.433	.166	.018
11.850	5.512	.427	.164	.025
12.635	5.442	.422	.162	.030
13.356	5.373	.416	.160	.034
14.024	5.304	.411	.158	.038
14.645	5.237	.406	.156	.041
15.226	5.170	.401	.154	.043
15.772	5.104	.396	.152	.045
16.286	5.039	.390	.150	.046
16.772	4.975	.385	.148	.046
17.233	4.911	.381	.146	.047
17.671	4.849	.376	.145	.047
18.087	4.787	.371	.143	.048
18.483	4.726	.366	.141	.049
18.862	4.666	.362	.139	.049
19.224	4.606	.357	.137	.051
19.570	4.548	.352	.136	.052
19.902	4.490	.348	.134	.053
20.220	4.432	.343	.132	.055
20.977	4.289	.332	.128	.060
21.533	4.178	.324	.125	.066
22.046	4.069	.315	.121	.071
22.523	3.963	.307	.118	.076
22.966	3.860	.299	.115	.081
23.379	3.760	.291	.112	.086
23.763	3.662	.284	.109	.091
24.123	3.567	.276	.106	.096
24.459	3.474	.269	.104	.101

* All dimensions are inches

TABLE 2. - WING DIMENSIONAL DATA - Concluded.

Semi-span	Chord	Y-Up	Y-Lo	H
24.773	3.384	.262	.101	.106
25.068	3.296	.255	.098	.111
25.344	3.210	.249	.096	.116
25.604	3.127	.242	.093	.121
25.848	3.046	.236	.091	.126
26.077	2.966	.230	.088	.131
26.293	2.889	.224	.086	.137
26.495	2.814	.218	.084	.142
26.686	2.741	.212	.082	.146
26.866	2.670	.207	.080	.150
27.036	2.600	.197	.076	.156
27.196	2.533	.187	.072	.160
27.347	2.467	.178	.068	.164
27.489	2.403	.169	.065	.167
27.624	2.340	.161	.062	.17[illegible]
27.751	2.279	.153	.059	[illegible]
27.870	2.220	.145	.056	[illegible]
27.984	2.163	.139	.053	.17[illegible]
28.091	2.106	.129	.050	.182
28.345	1.965	.116	.045	.189
28.524	1.859	.105	.041	.193
28.684	1.758	.096	.037	.198
28.825	1.662	.088	.034	.202
28.952	1.572	.081	.031	.205
29.064	1.487	.075	.029	.208
29.164	1.406	.069	.026	.211
29.254	1.330	.064	.024	.213
29.333	1.258	.059	.023	.216
29.405	1.190	.055	.021	.218
29.468	1.125	.051	.020	.220
29.529	1.064	.047	.018	.221
29.600	.977	.043	.017	.223
29.700	.846	.038	.014	.226
29.800	.692	.031	.012	.229
29.900	.489	.022	.008	.232
30.000	.000	.000	.000	.235

TABLE 3. - TEST CO..DITIONS

Configuration	Λ	Re/10^6 per ft.	Mach Numbers 0.60	0.70	0.80	0.95	0.98	1.05	1.10	1.20	1.30	1.40	Schedule α	β
W_3 F_o B_1T	0	6.0	x	x	x								-4 +5	0
	45	6.0		x	x	x	x	x					-4 + 6	0
	60	6.0 / 4.0			x	x	x	x	x	x	x	x	-4 +8	0
	0	6.0	x	x	x								0	-4 +5
	0	6.0	x	x	x								3	-4 +4
	45	6.0		x	x	x	x	x					2	-4 +4
	45	6.0		x	x	x	x	x					4	-4 +4
	60	6.0			x	x	x	x	x	x			3	-4 +4
W_3F_o B_1T	60	6.0			x	x	x	x	x	x			5	-4 +4

TABLE 4. - INDEX OF DATA FIGURES

Note:
1. Positive directions of force coefficients, moment coefficients, and angles are indicated by arrows

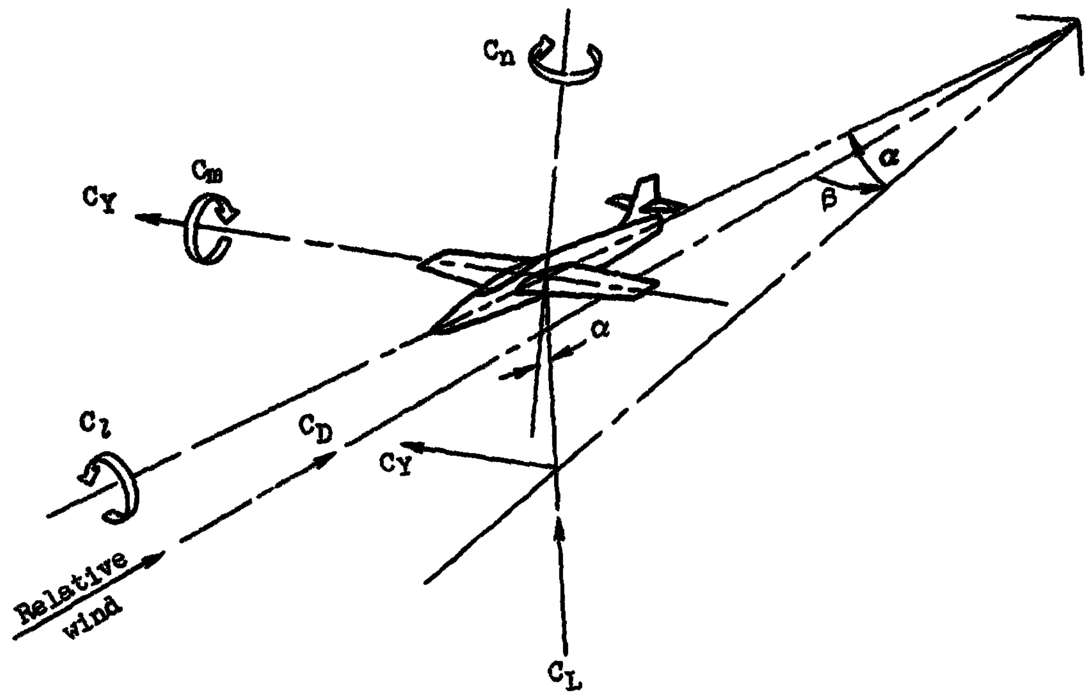
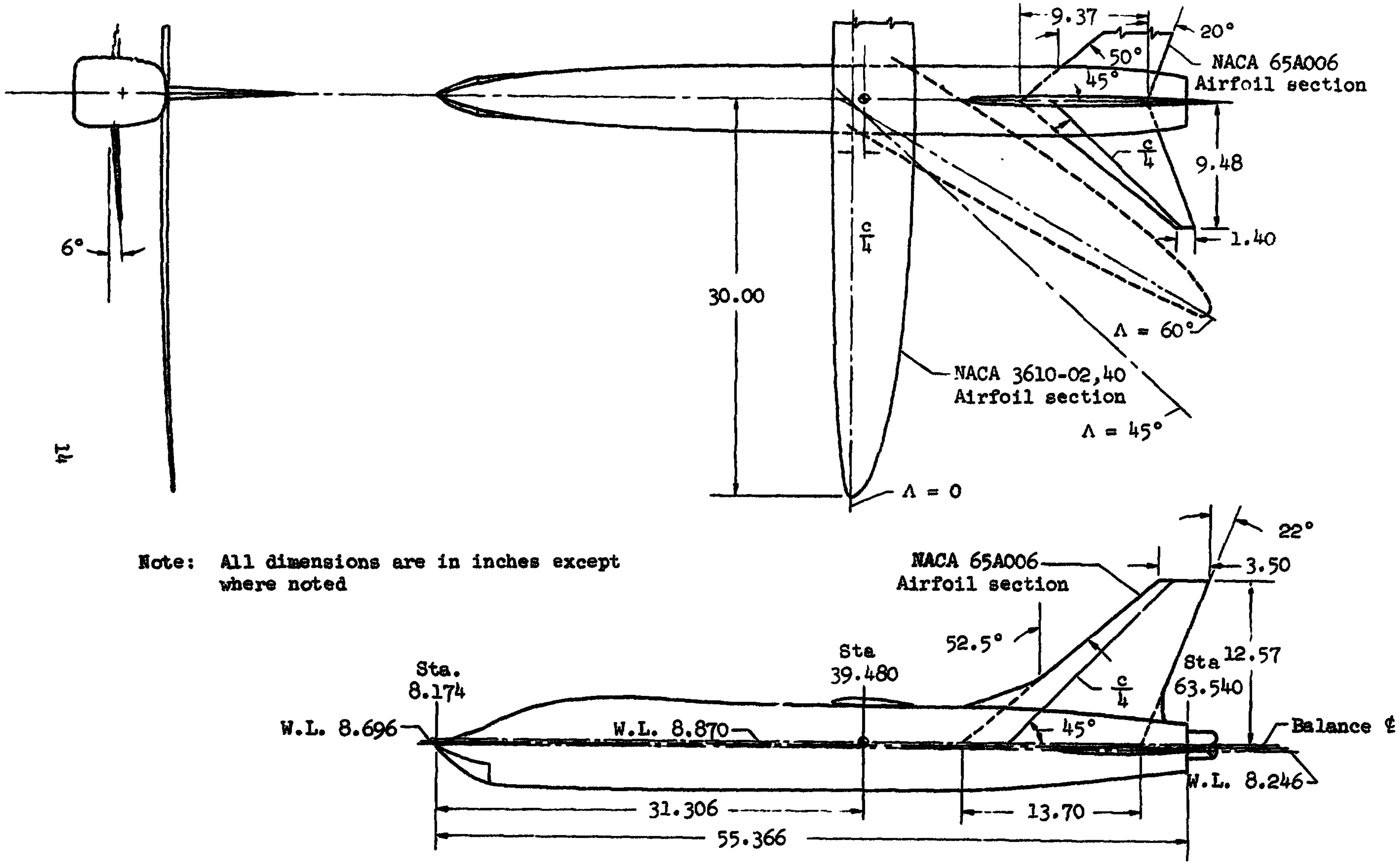


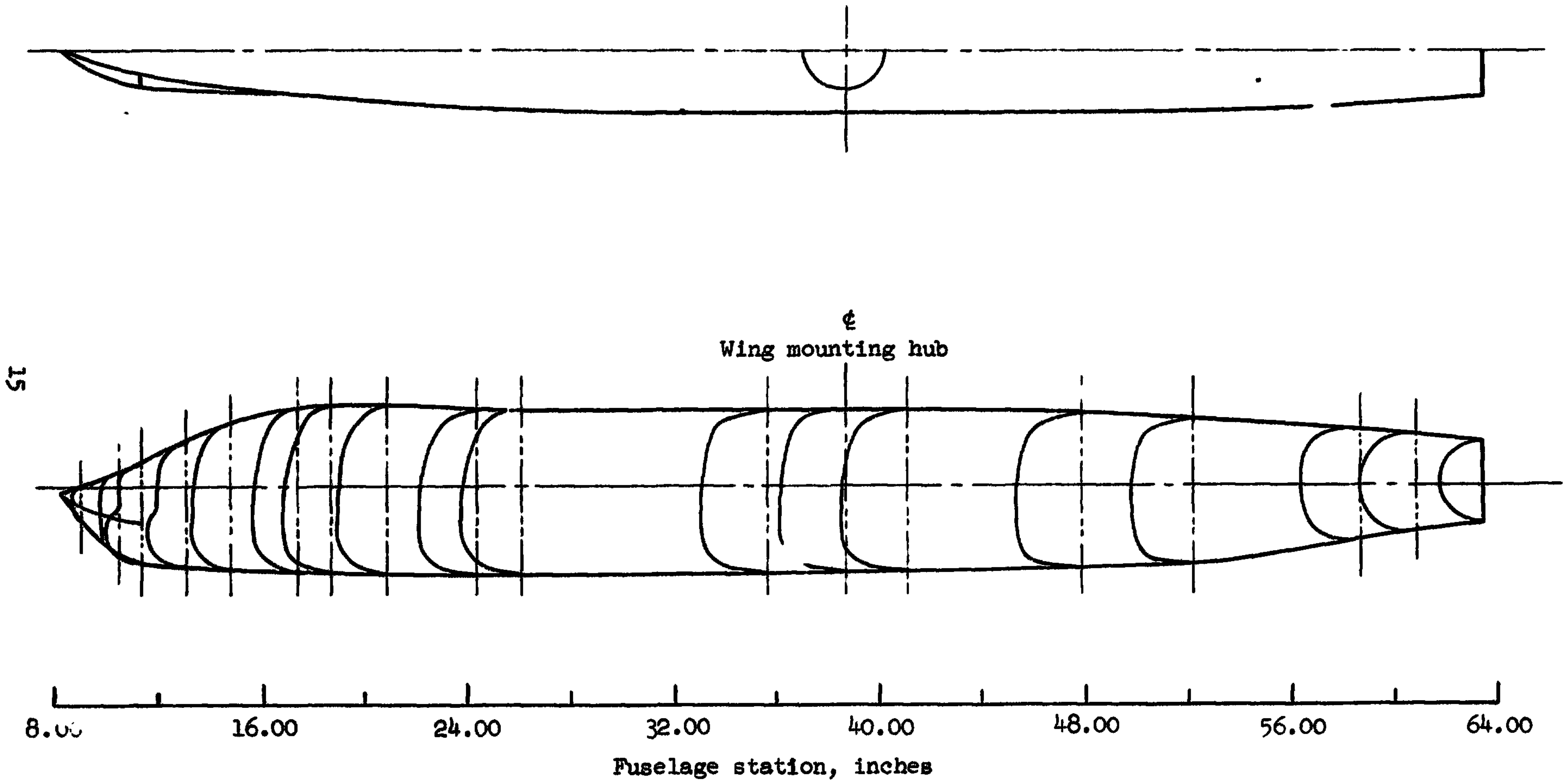
Figure 1.- Axis systems.



Note: All dimensions are in inches except where noted

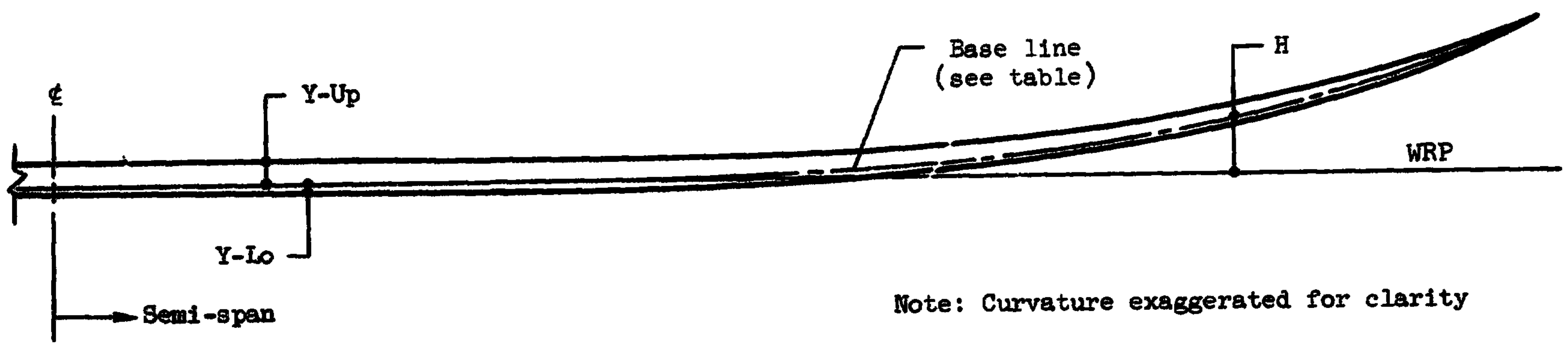
(a) Three-view

Figure 2. - Oblique-wing/body model details and photograph.



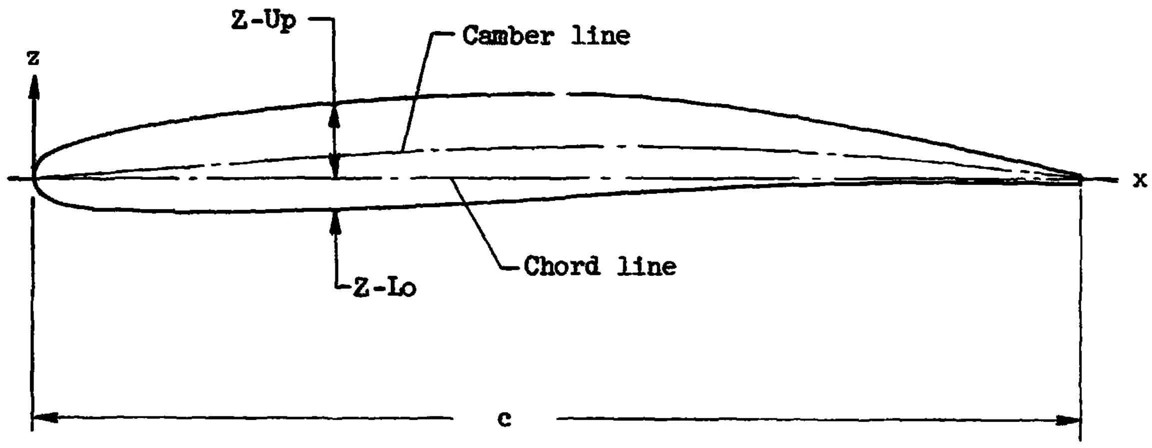
(b) Fuselage contours

Figure 2.- Continued.



(c) Wing curvature

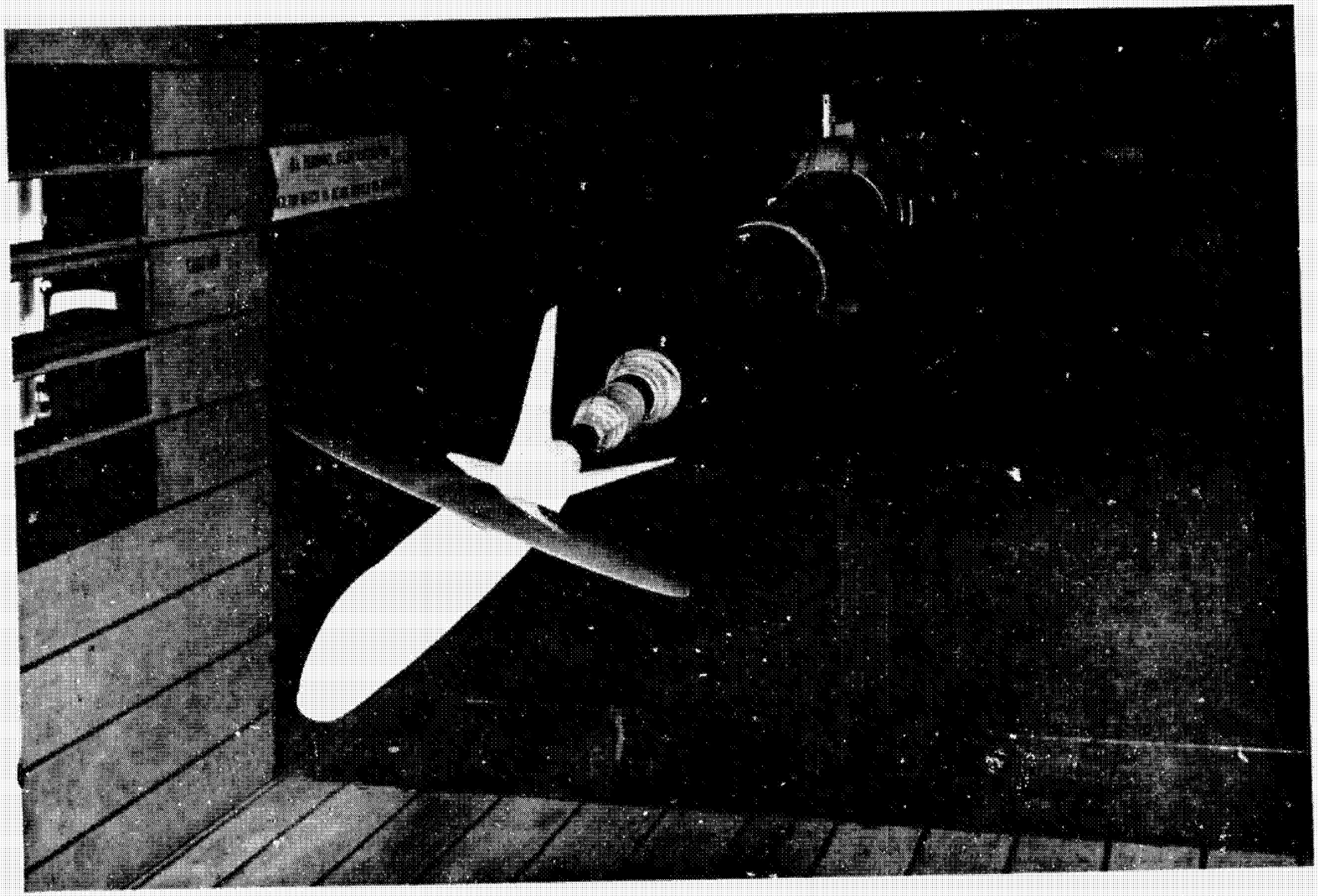
Figure 2.- Continued.



$\frac{x}{c}$	$\frac{t}{c}$	$\frac{\text{Camber}}{c}$	$\frac{\text{Z-Up}}{c}$	$\frac{\text{Z-Lo}}{c}$
.001	.01203	.00008	.00609	-.00594
.010	.03394	.00078	.01775	-.01619
.025	.04849	.00195	.02619	-.02230
.050	.06119	.00389	.03449	-.02671
.075	.06891	.00582	.04027	-.02864
.100	.07446	.00772	.04495	-.02951
.150	.08250	.01144	.05269	-.02981
.200	.08852	.01498	.05924	-.02928
.300	.09689	.02129	.06974	-.02715
.400	.10000	.02621	.07621	-.02379
.500	.09647	.02925	.07749	-.01899
.600	.08560	.02995	.07275	-.01285
.700	.06796	.02785	.06182	-.00613
.800	.04568	.0224[illegible]	.04531	-.00038
.900	.02255	.01334	.02461	.00207
1.000	.00400	.00000	.00200	-.00200

(d) Wing section drawing and tabulated airfoil section data for wing number 1, W_1

Figure 2.- Continued.



(e) Photograph of the model in the Ames 11- by 11-Foot Transonic Wind Tunnel, $\Lambda = 45^\circ$

Figure 2. - Concluded.

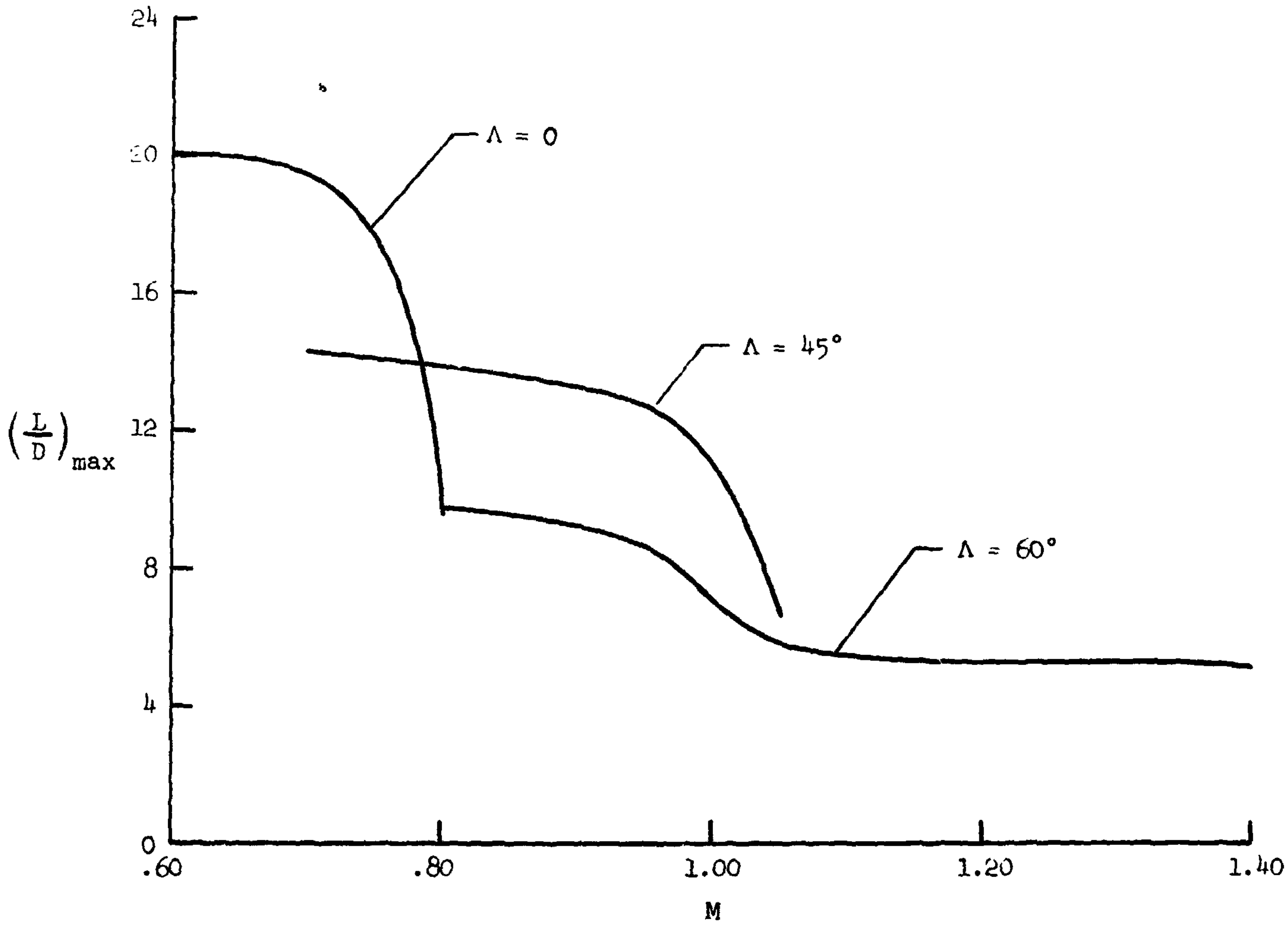


Figure 3.- Variation of maximum lift-to-drag ratio with Mach number for three wing sweep angles.

DATA

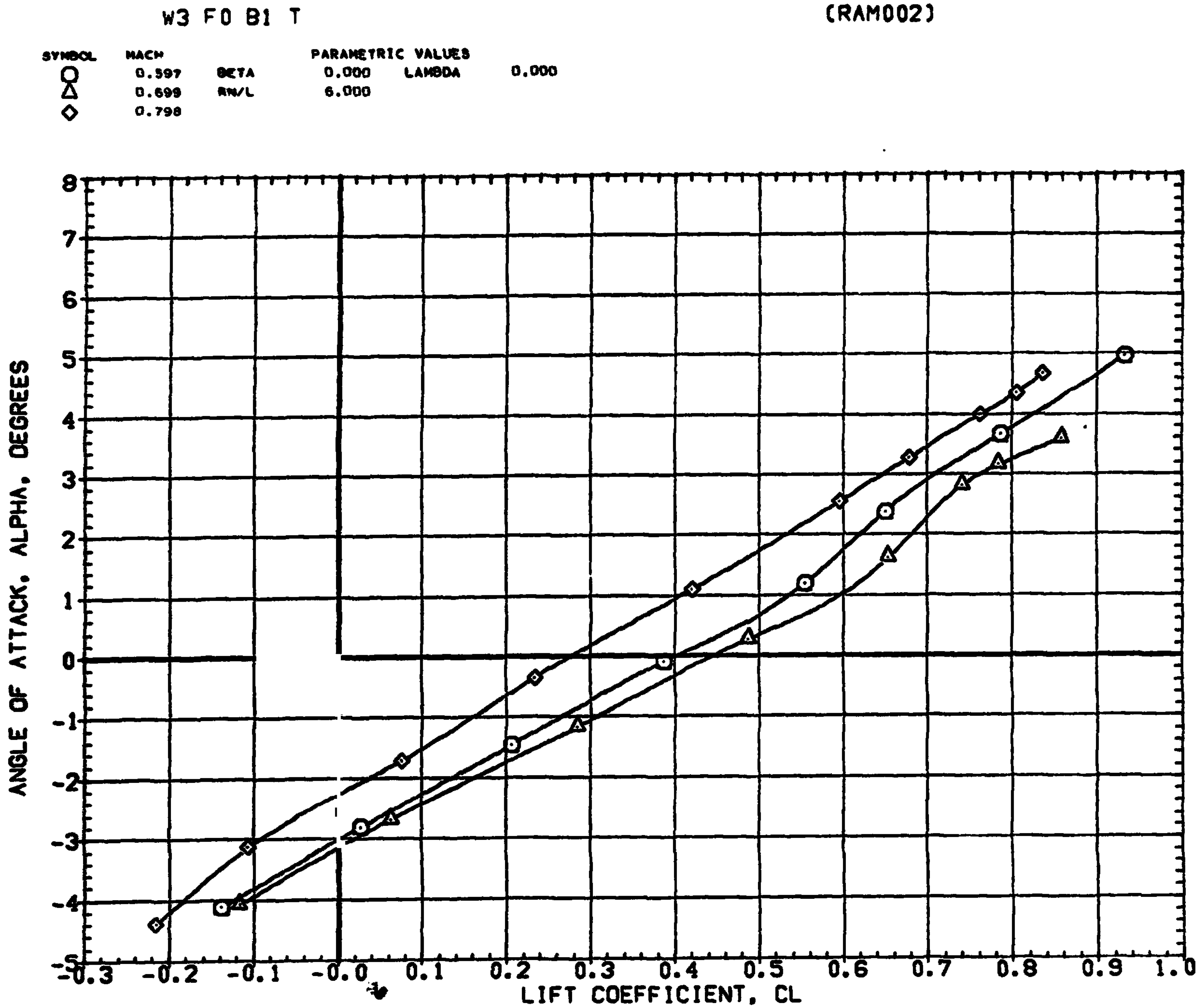


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

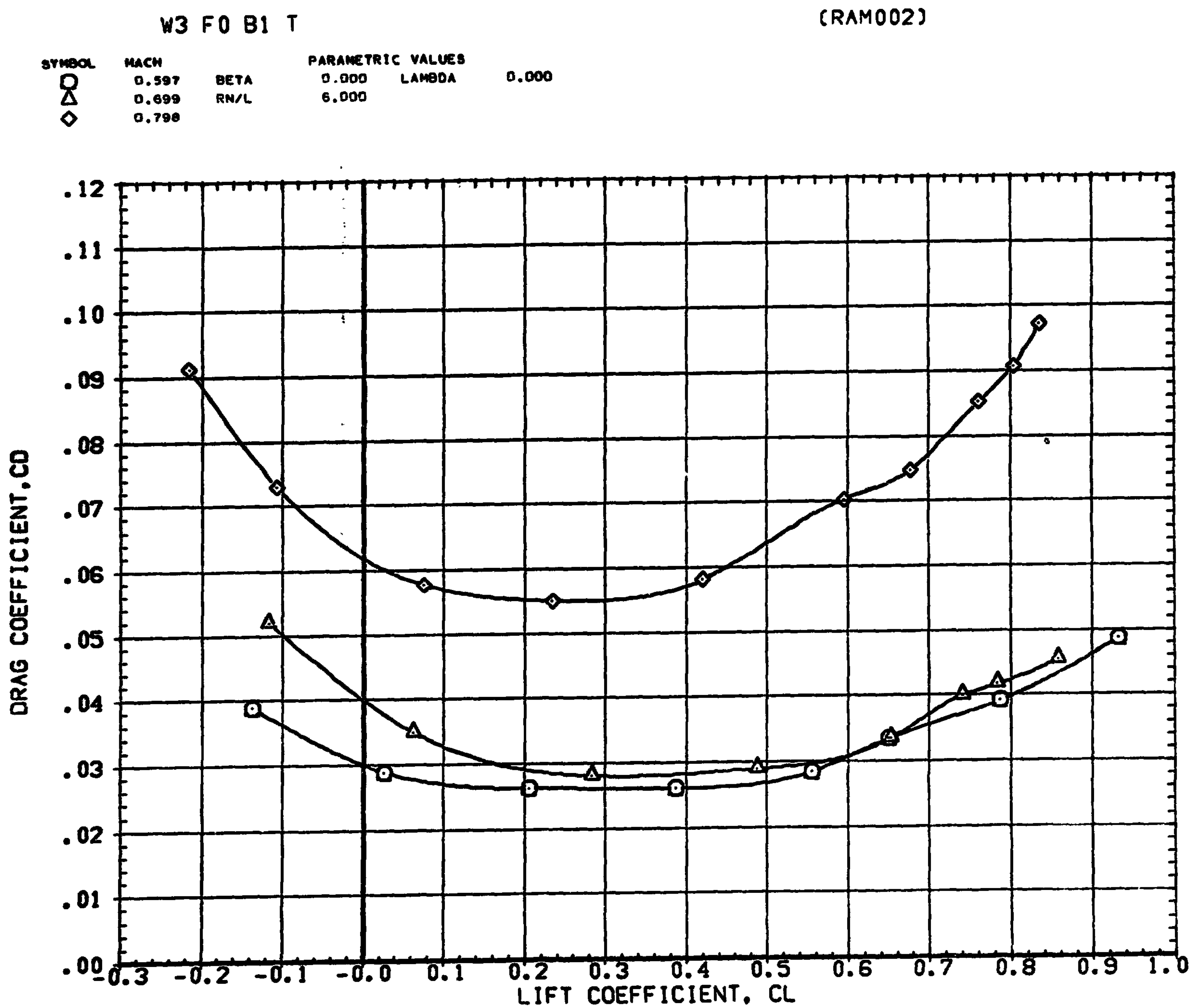


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

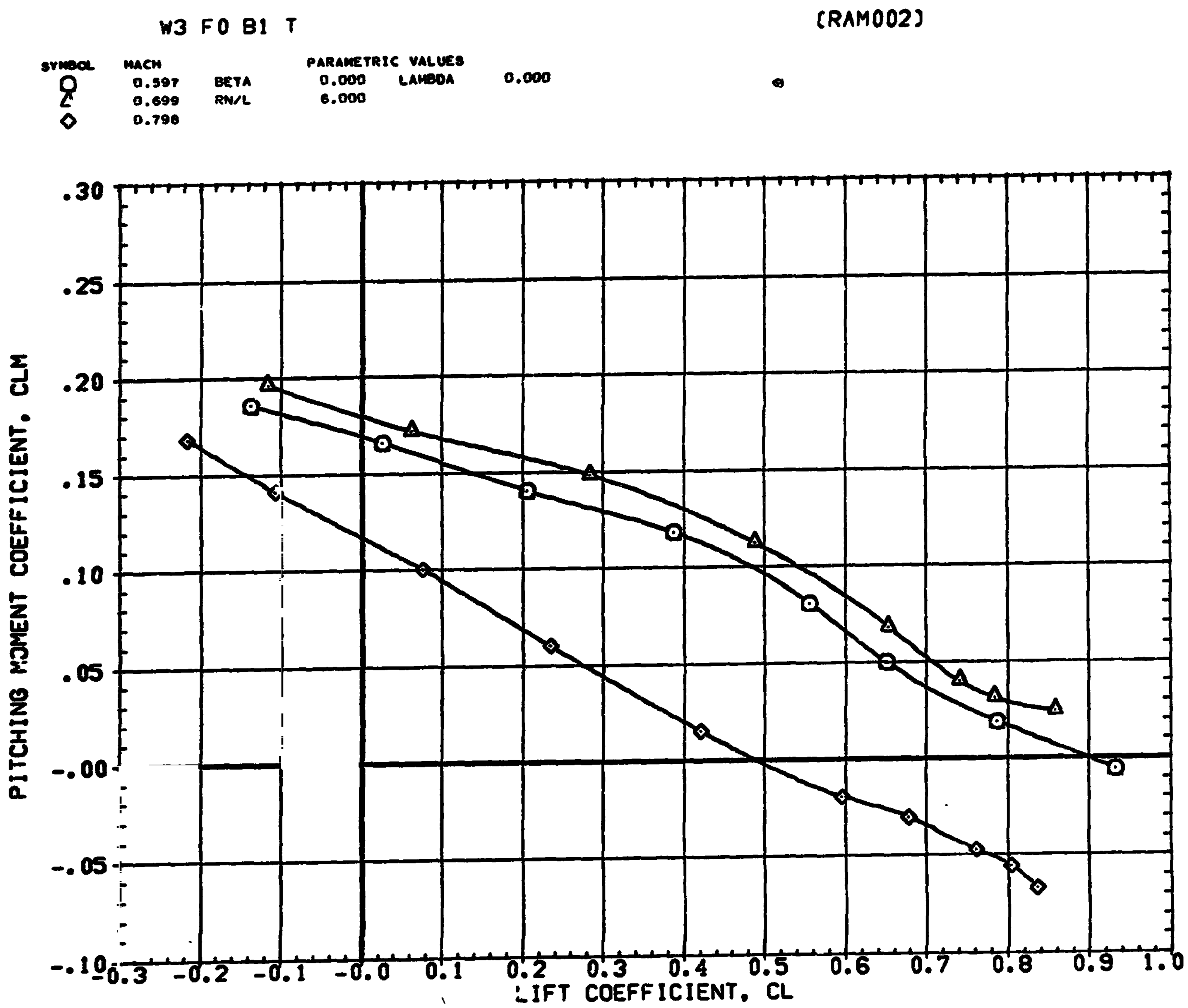


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

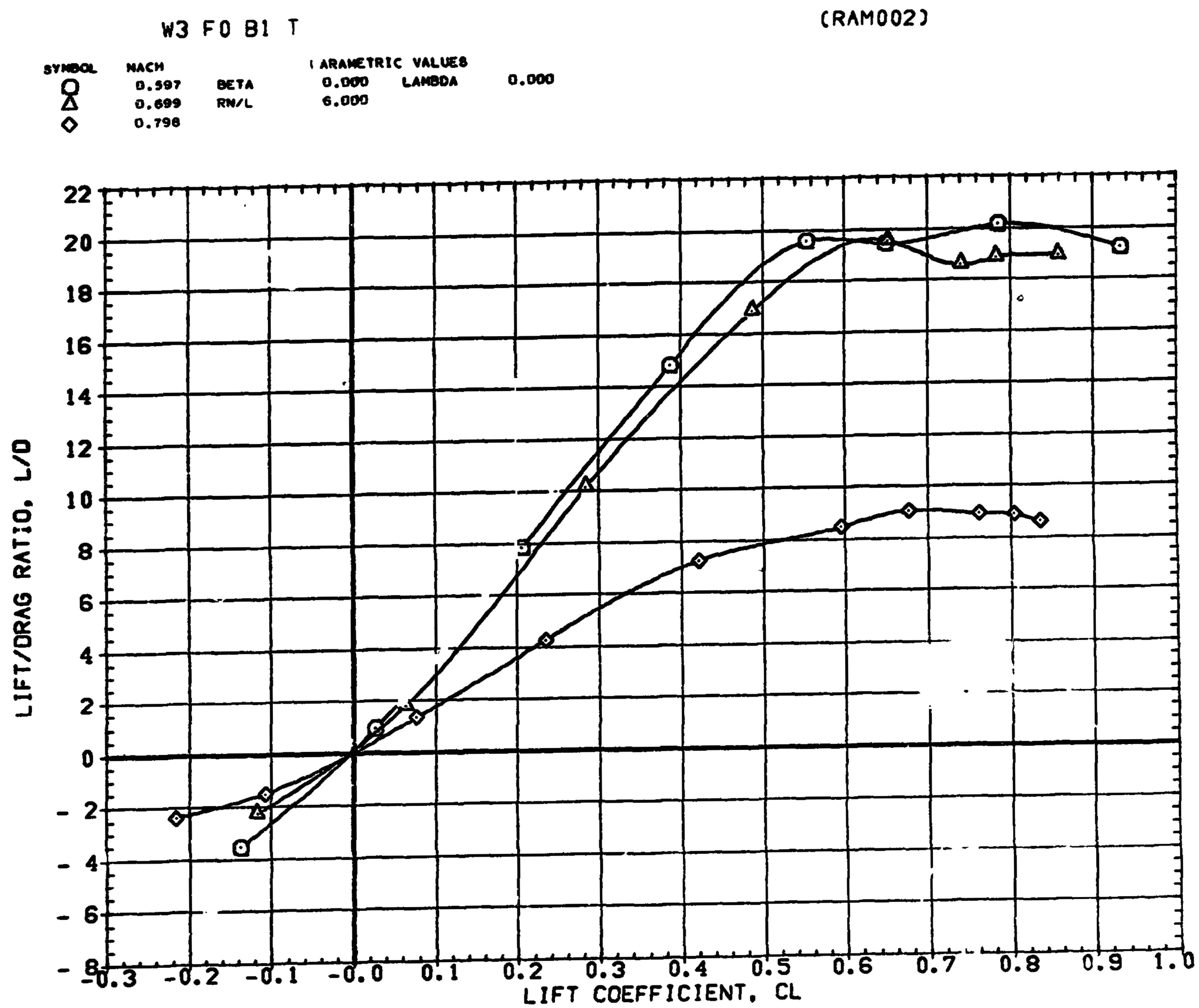


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

W3 F0 B1 T (RAMOC)

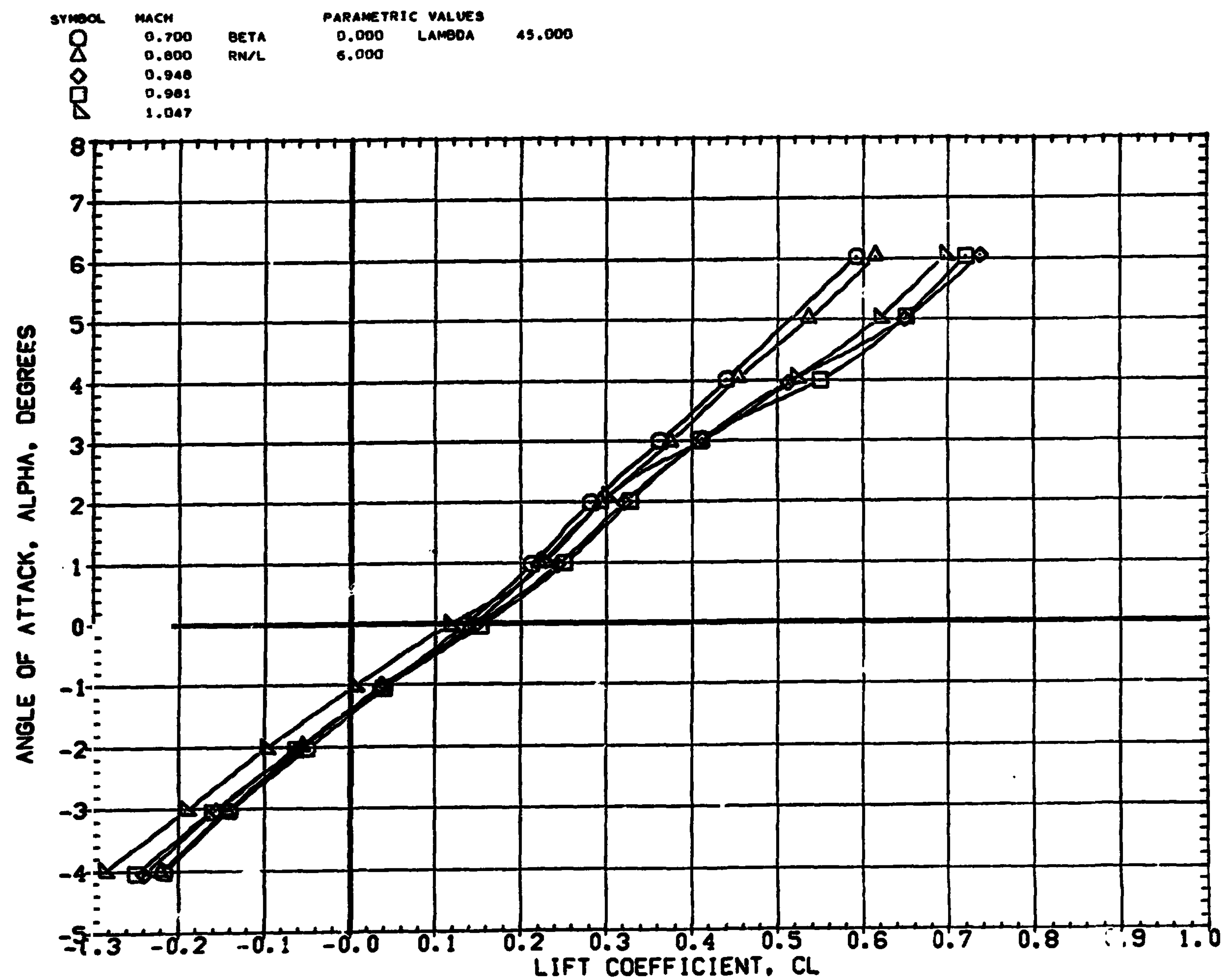


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

W3 F0 B1 T (RAM005)

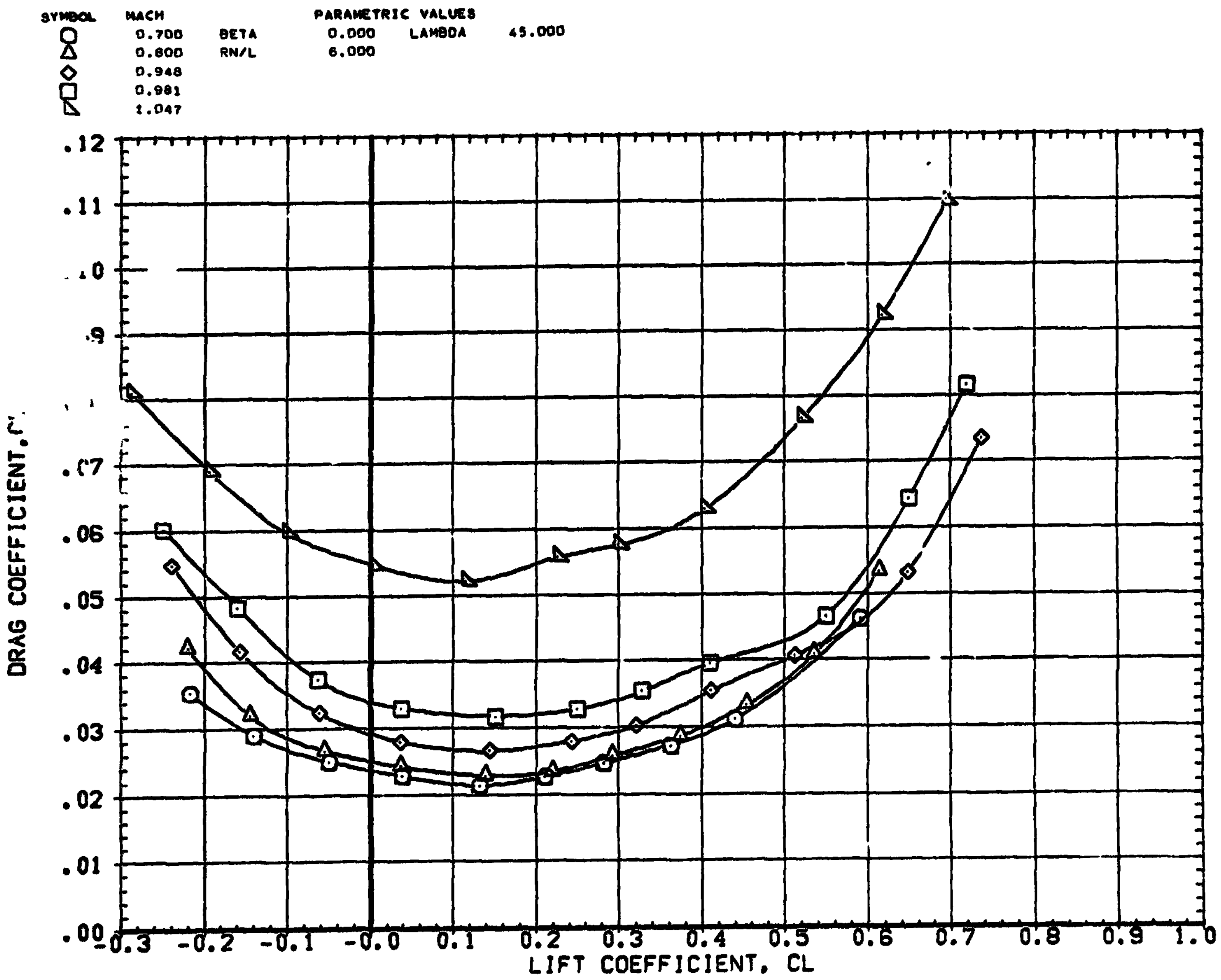


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

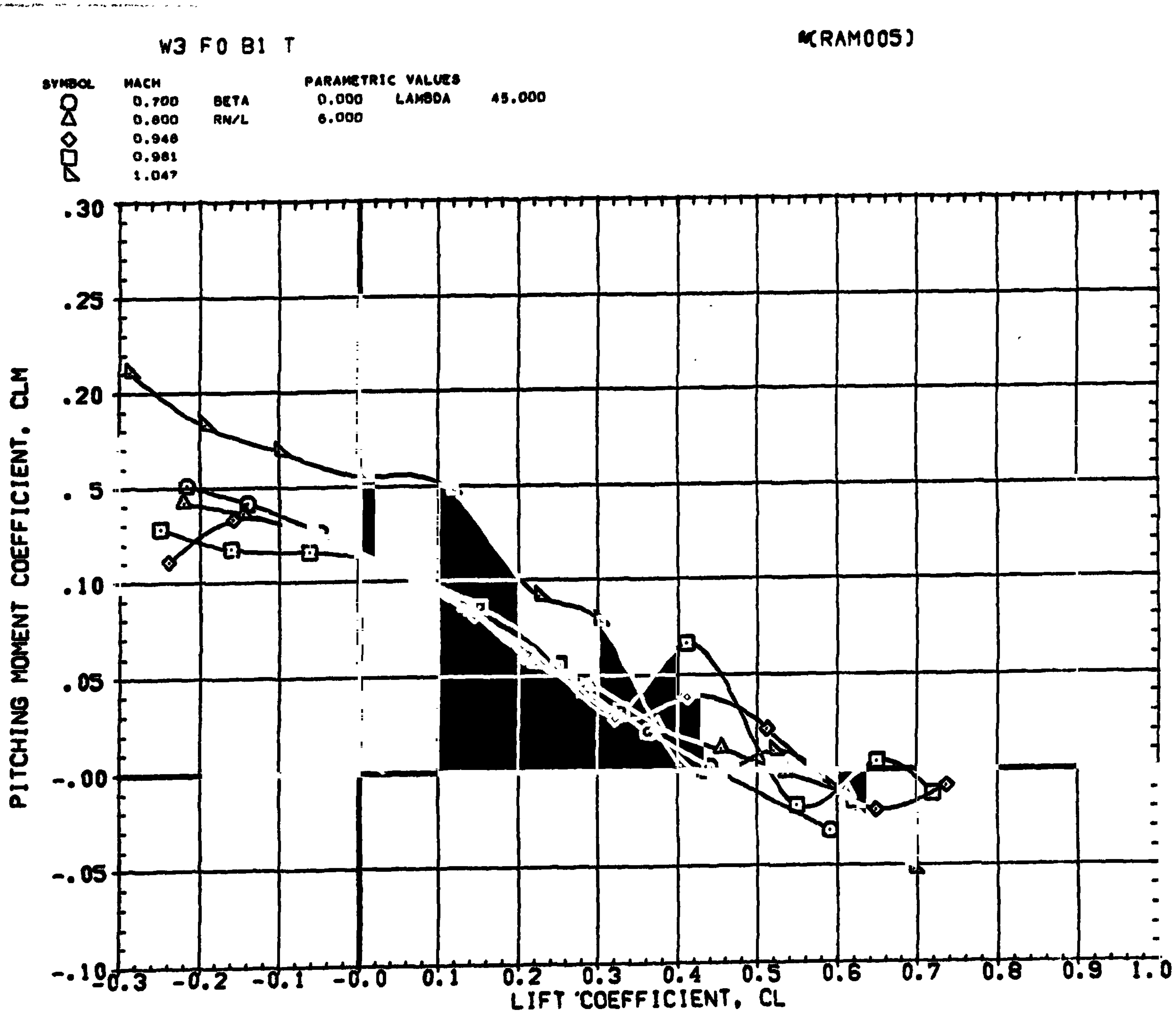


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

W3 F0 B1 T (RAM005)

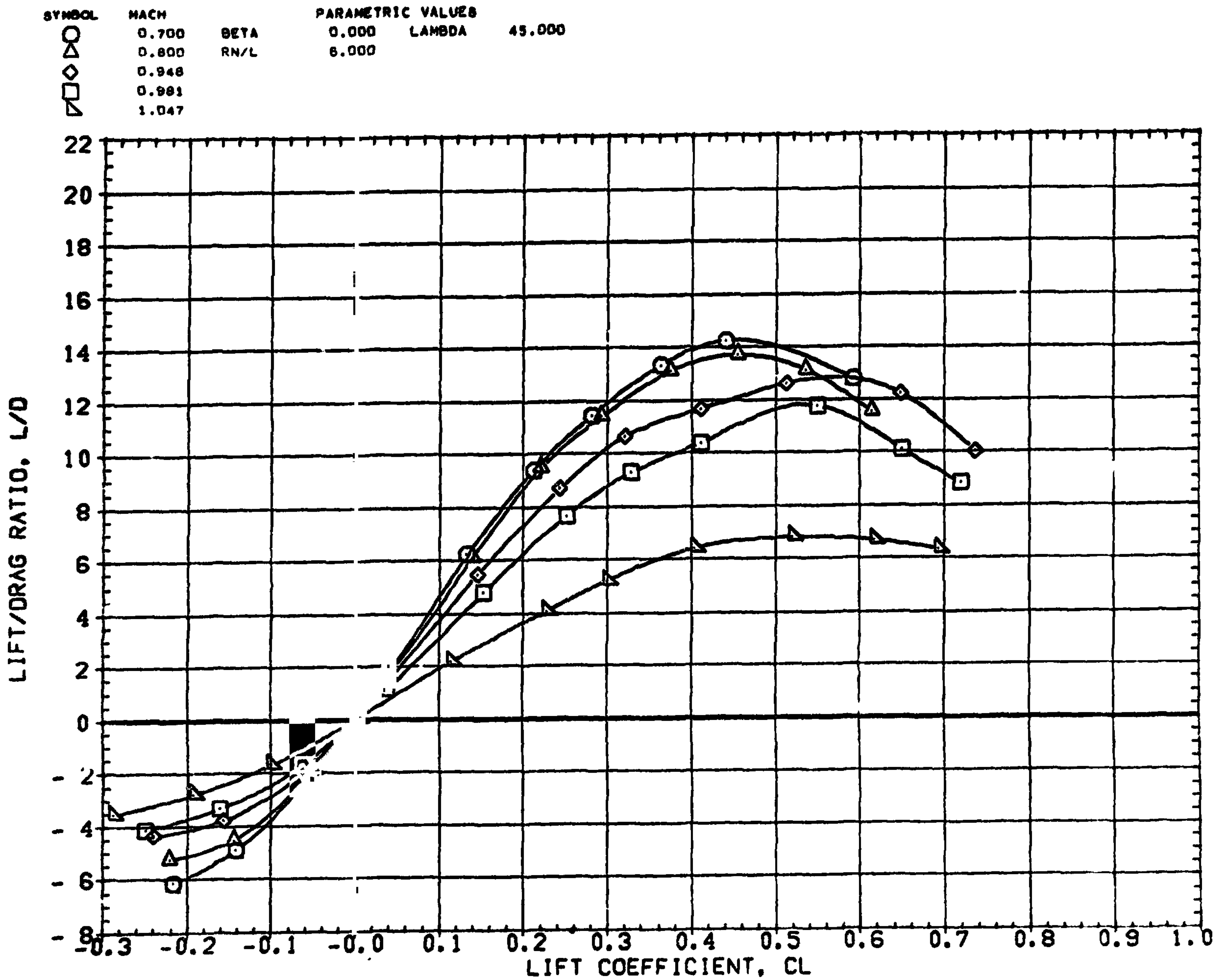


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

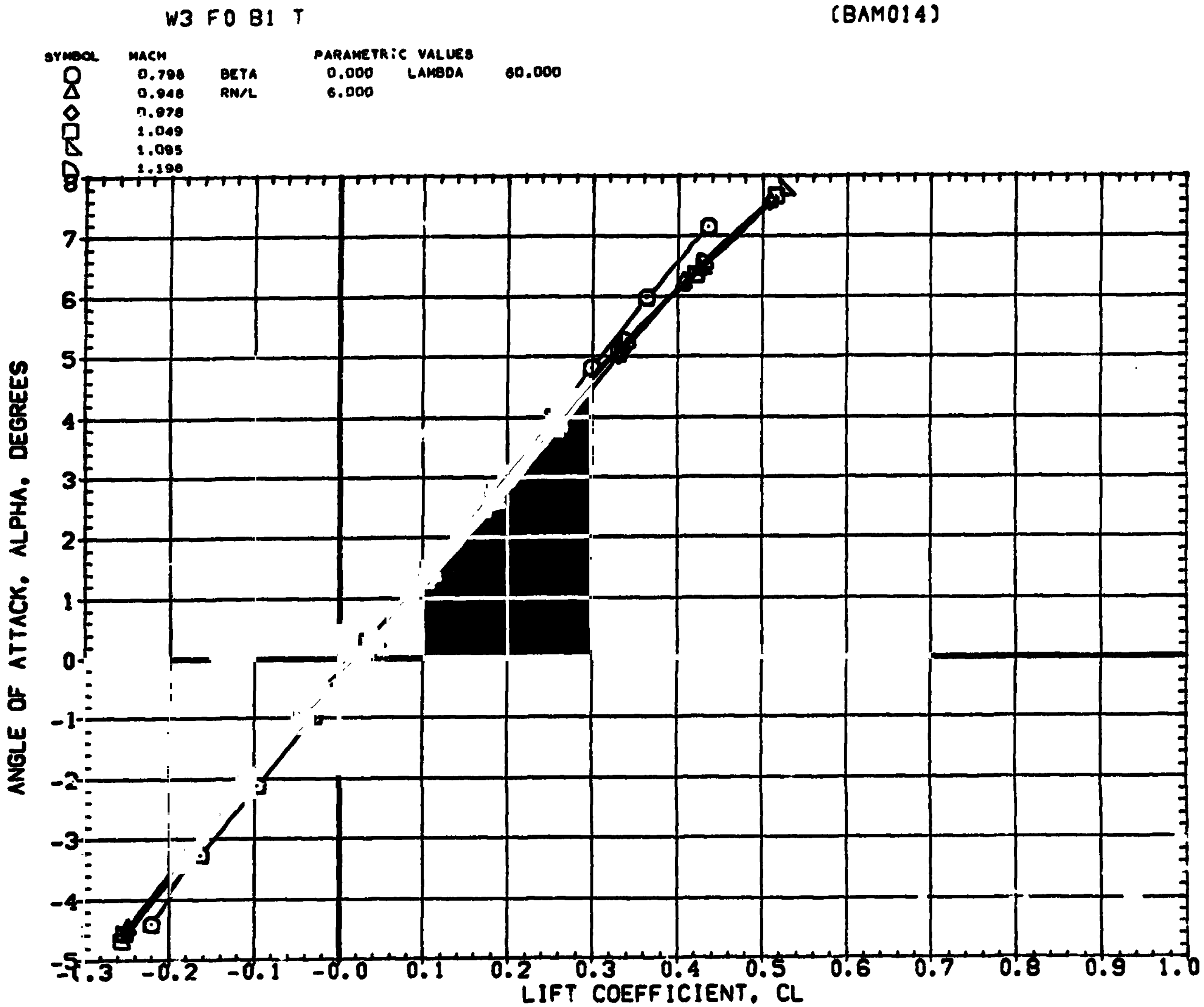


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

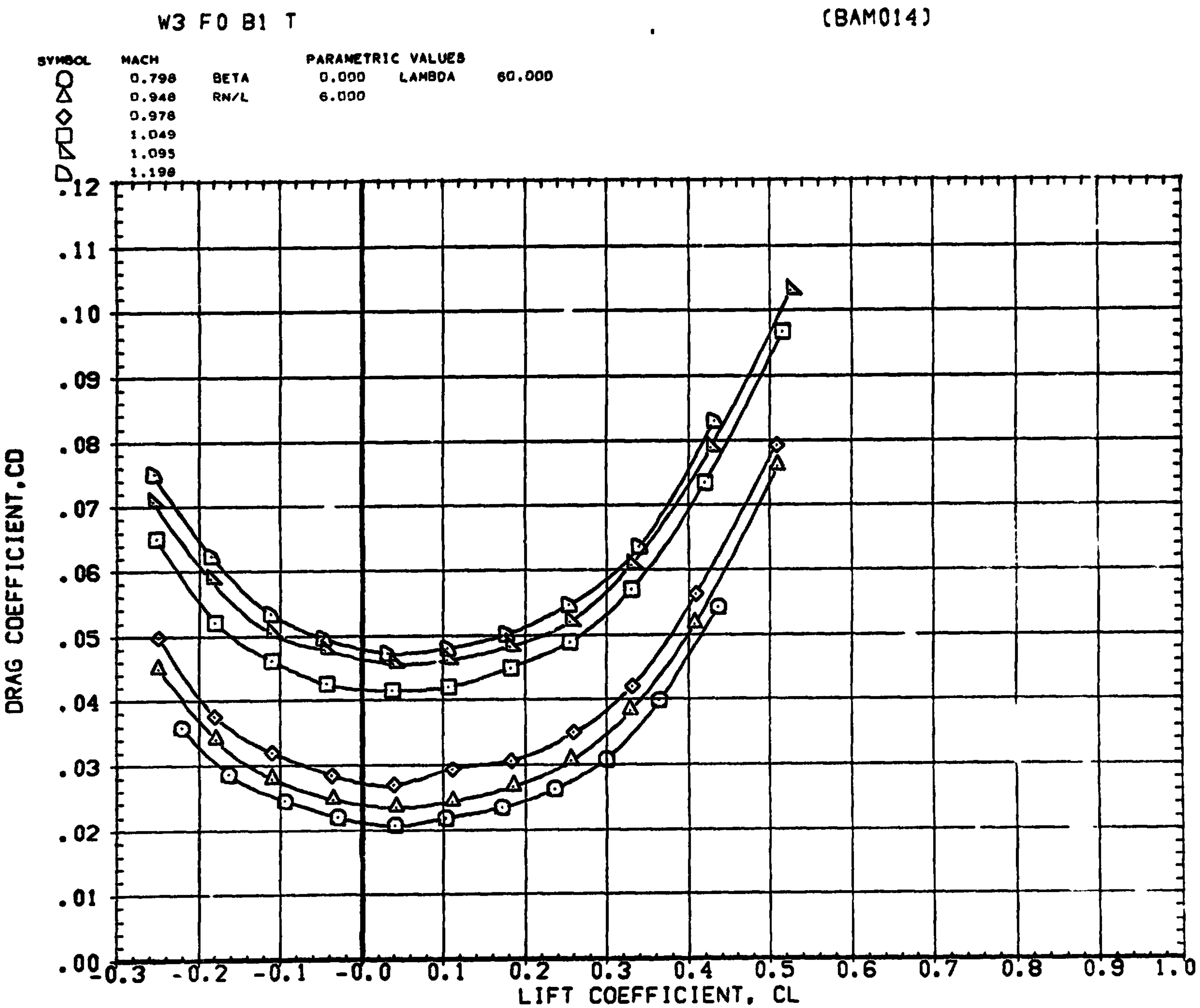


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

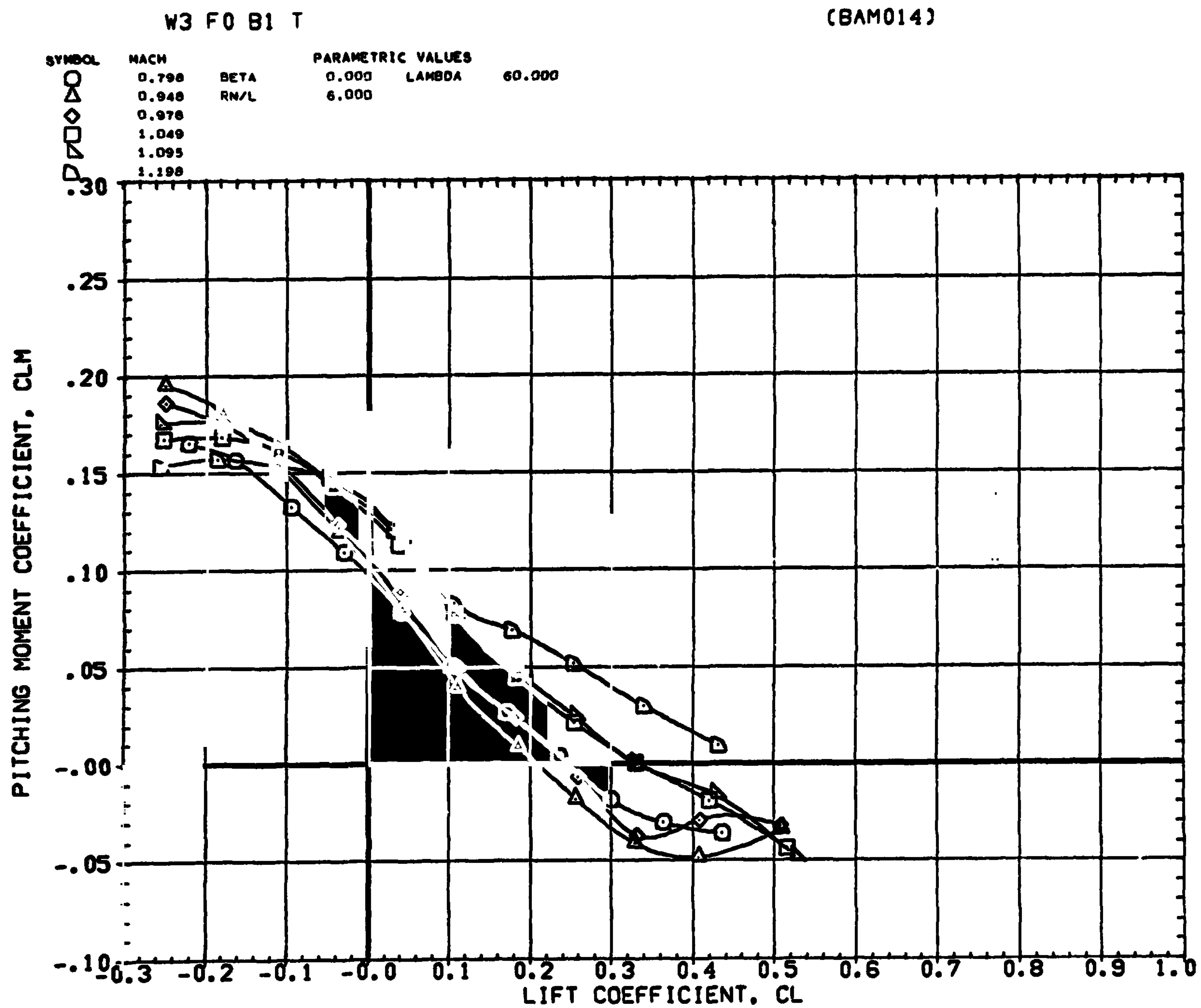


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

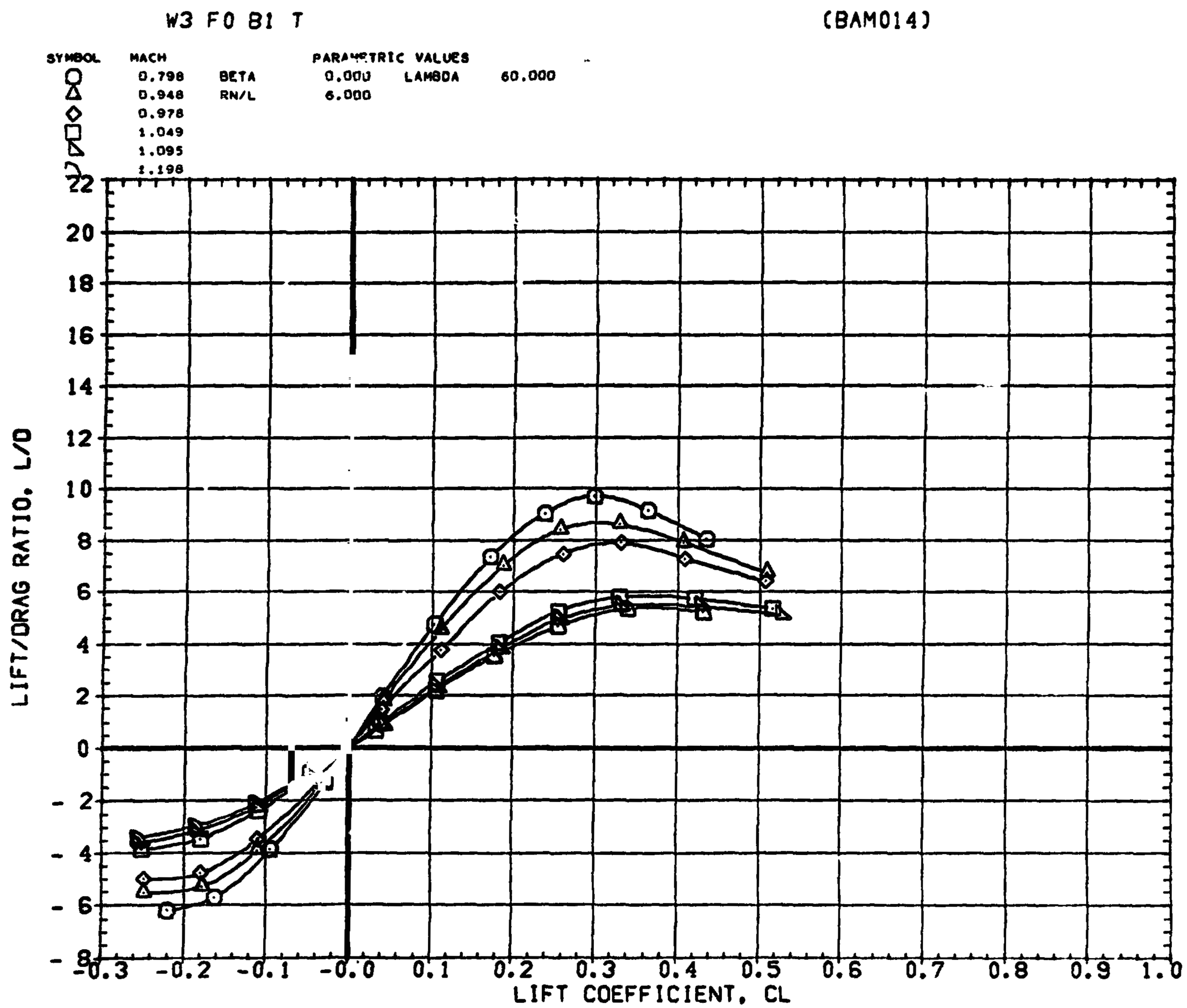


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

W3 F0 B1 T (RAM011)

SYMBOL	MACH	PARAMETRIC VALUES			
O	1.301	BETA	0.000	LAMBDA	60.000
Δ	1.402	RN/L	4.000		

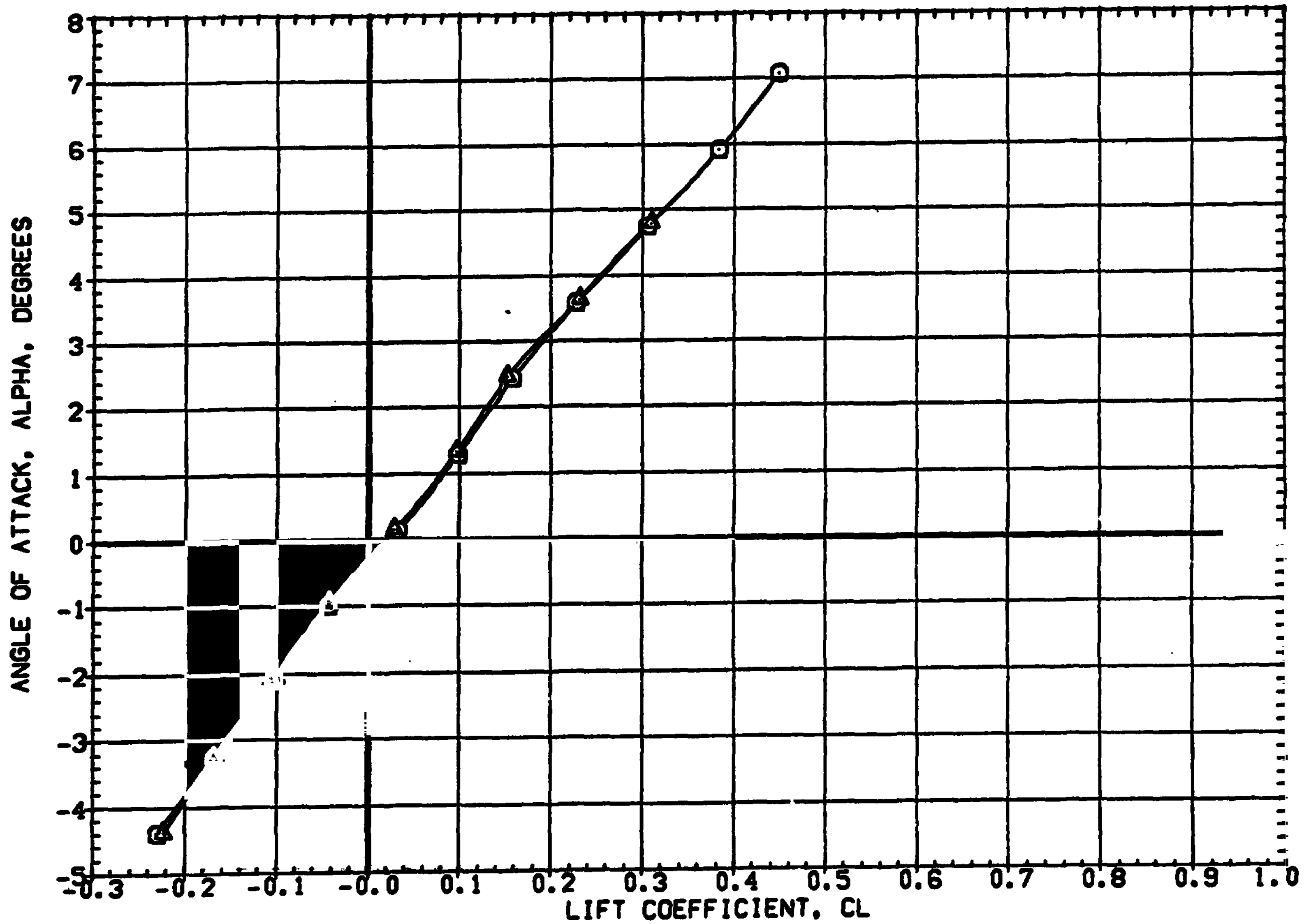


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

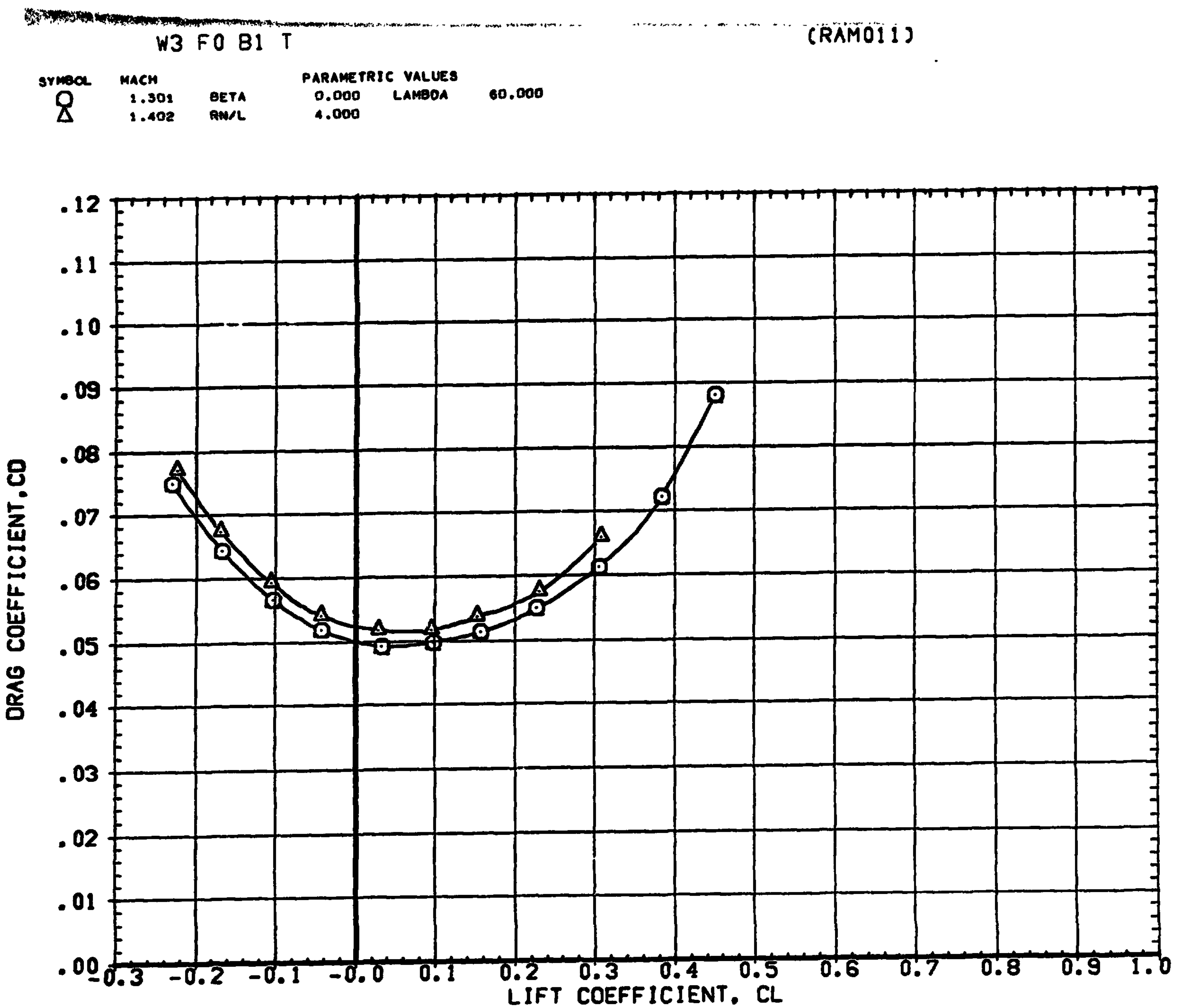


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

W3 F0 B1 T (RAM011)

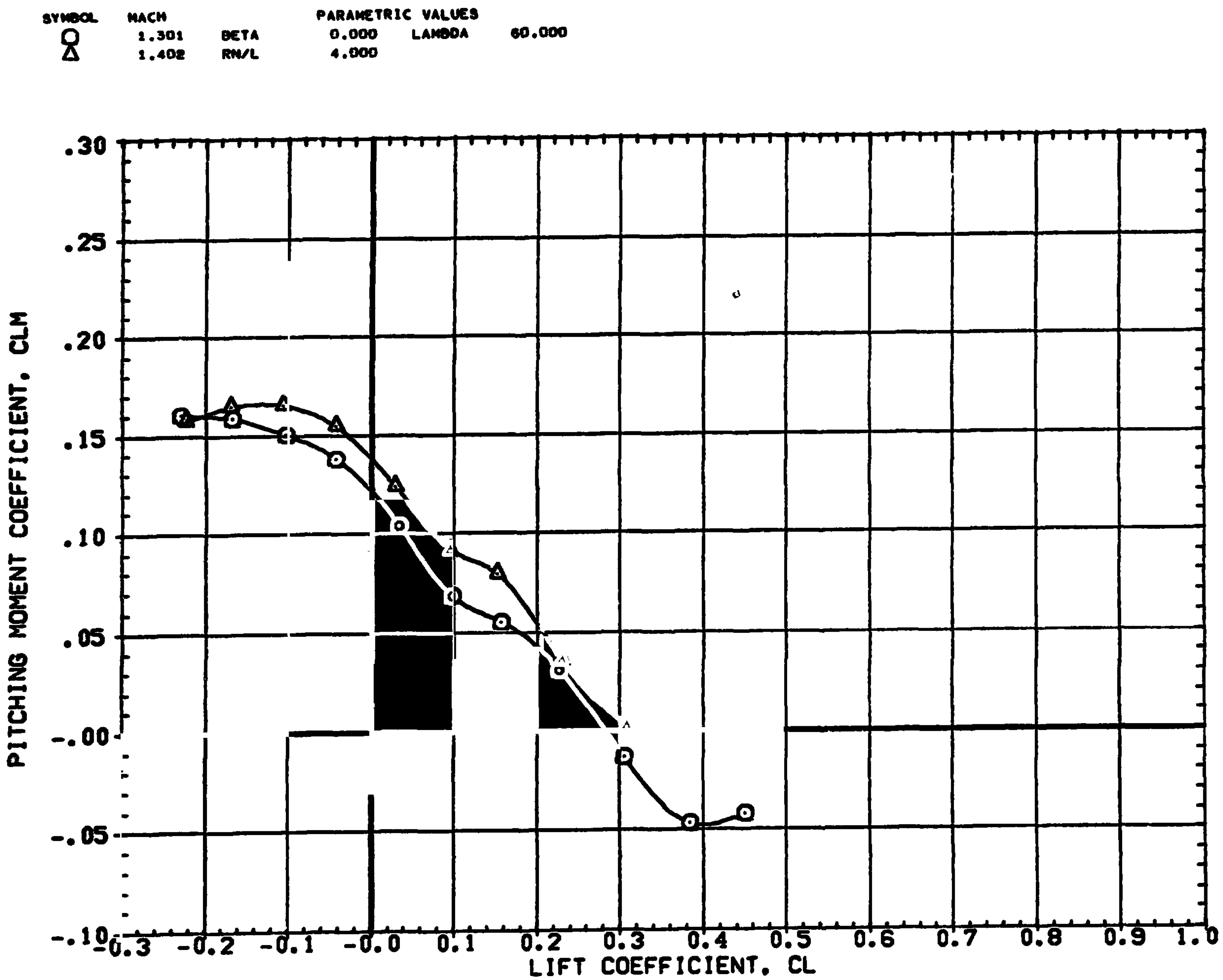


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

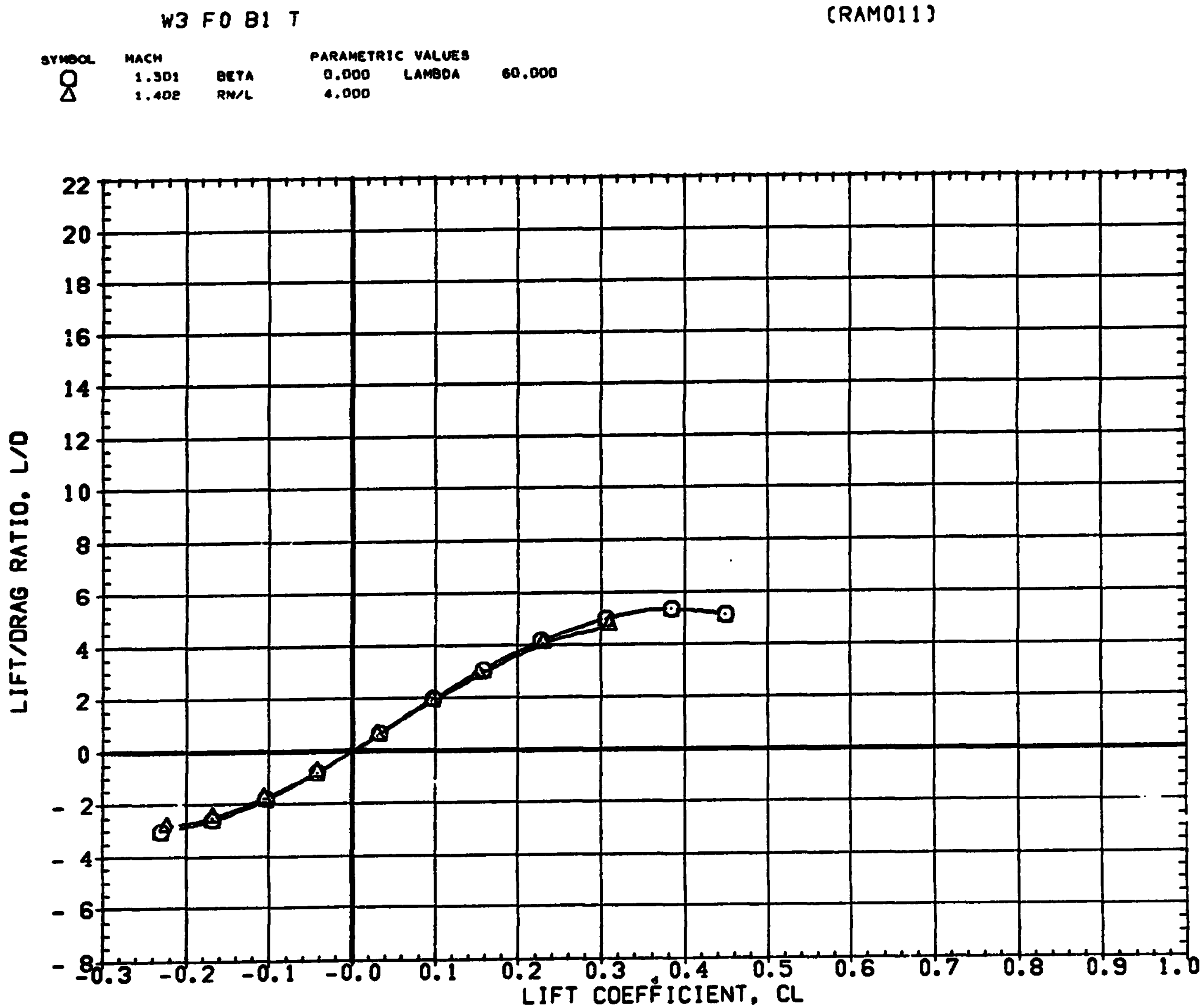


FIGURE 4. LONGITUDINAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

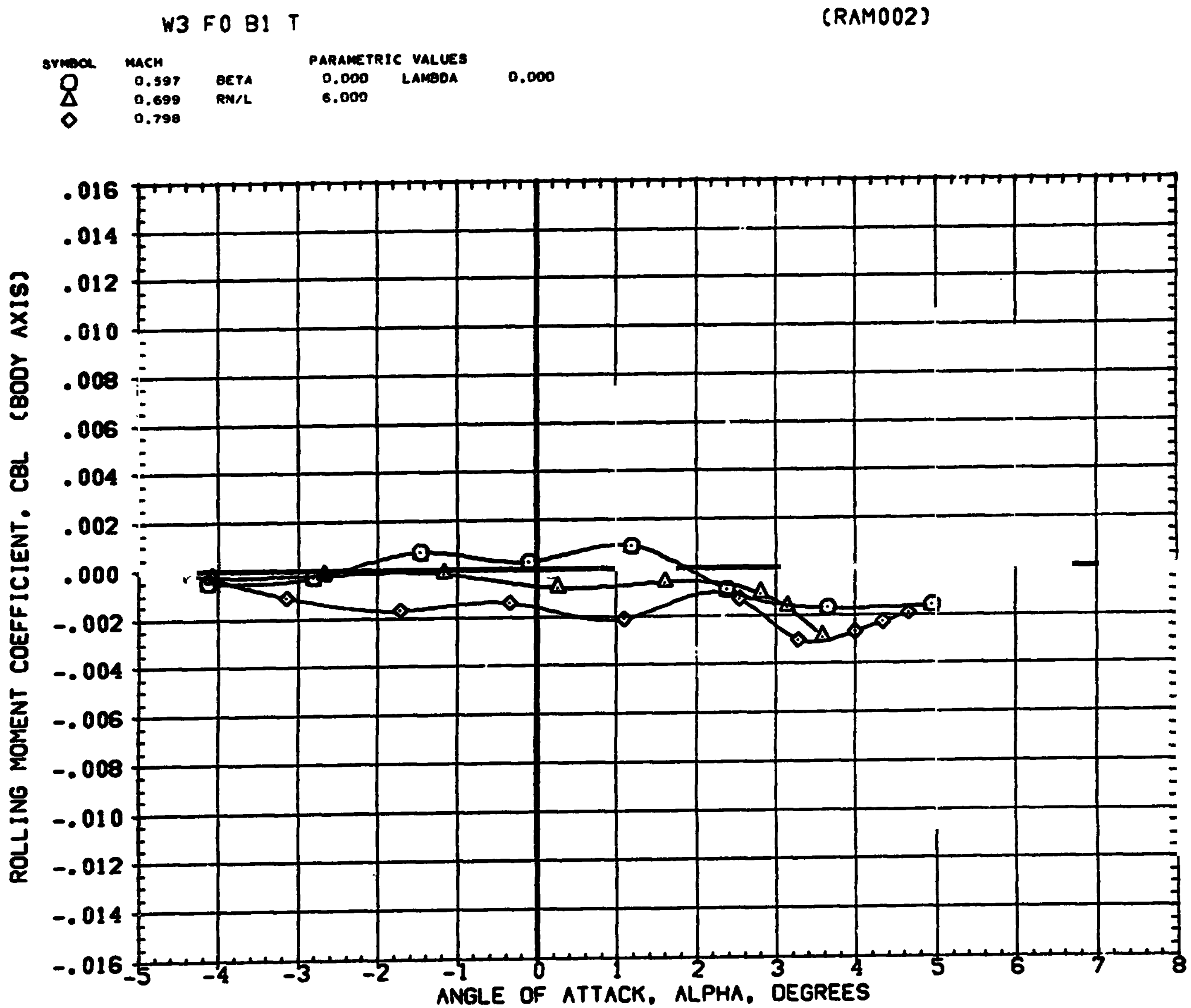


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

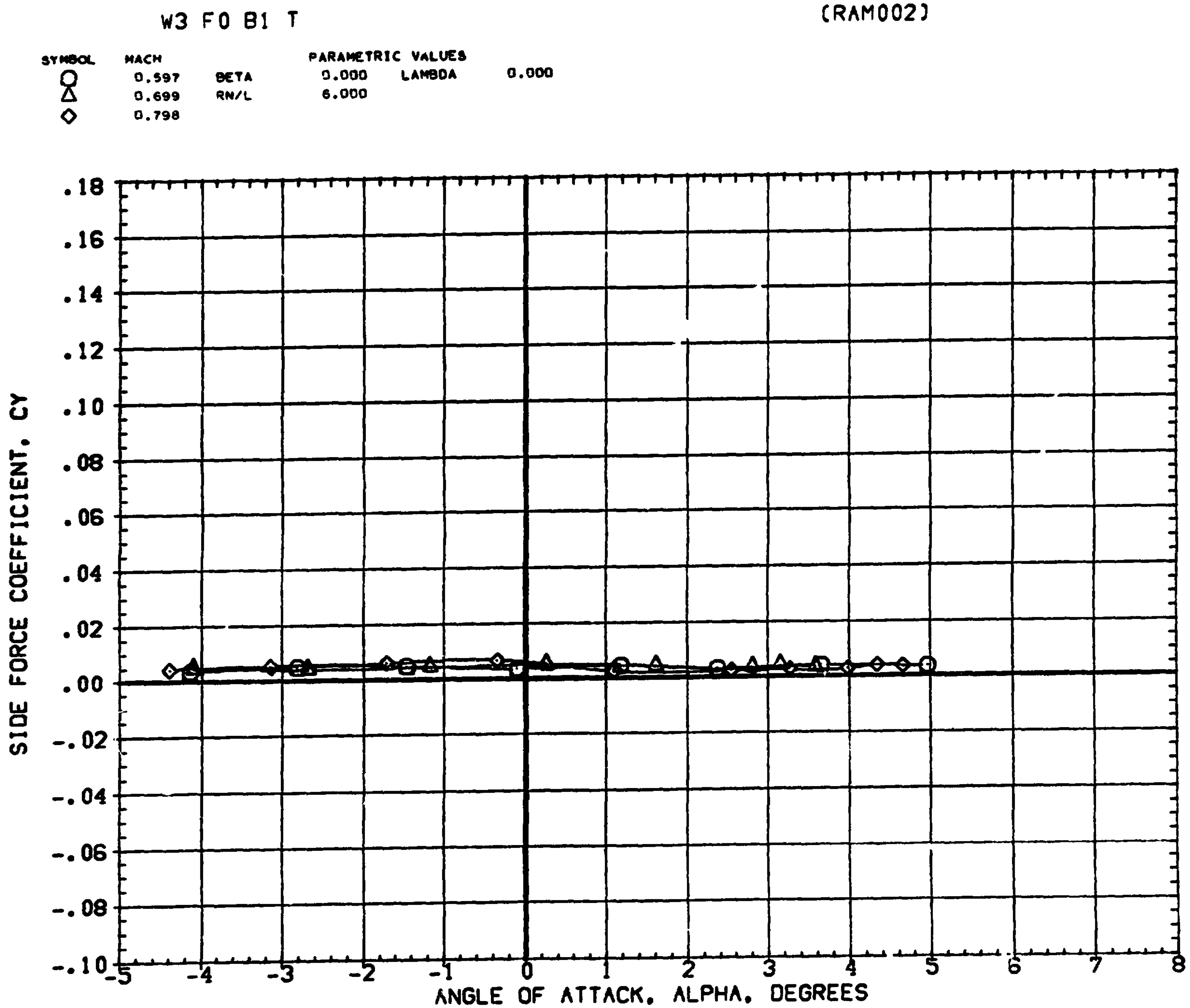


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

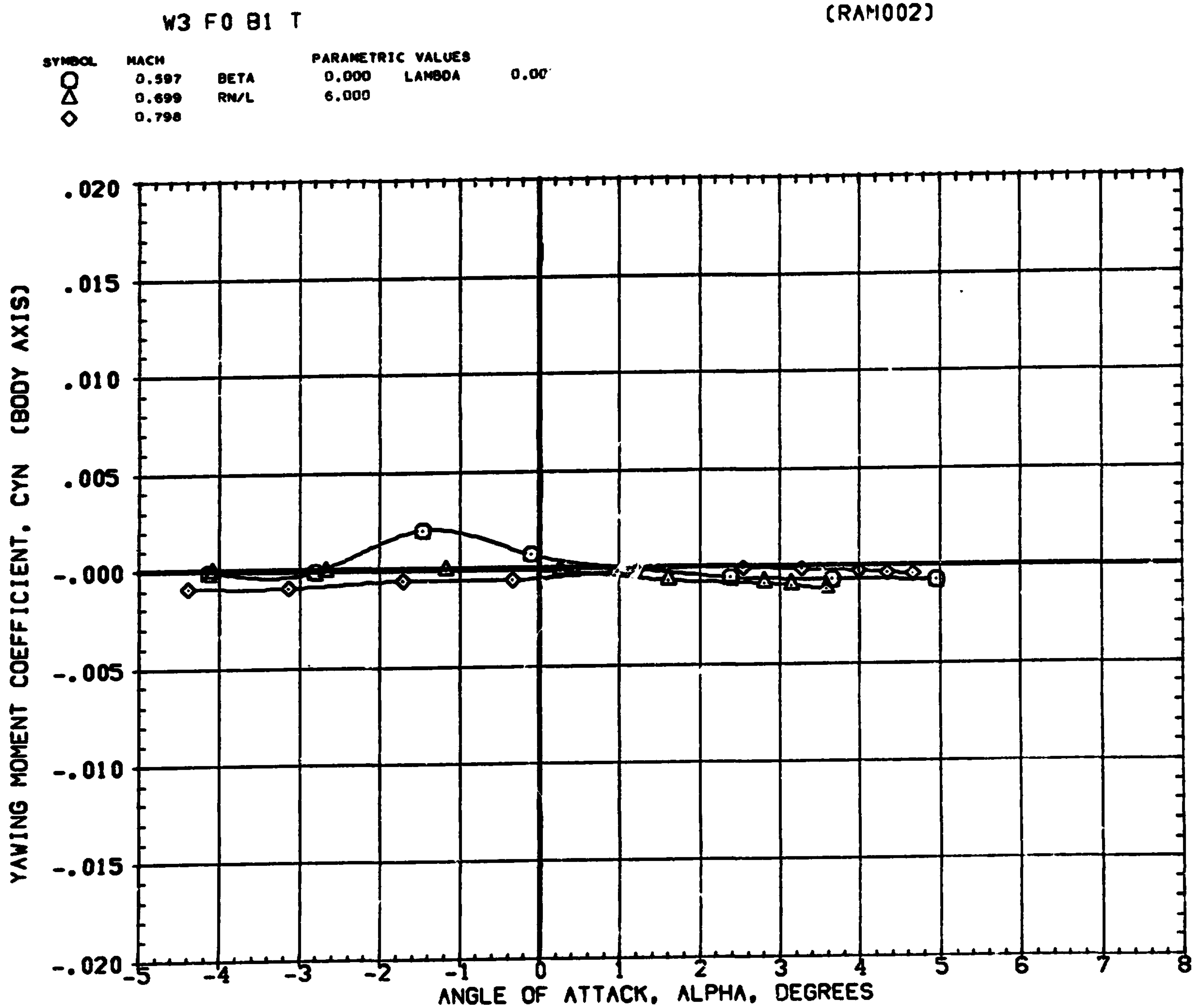


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

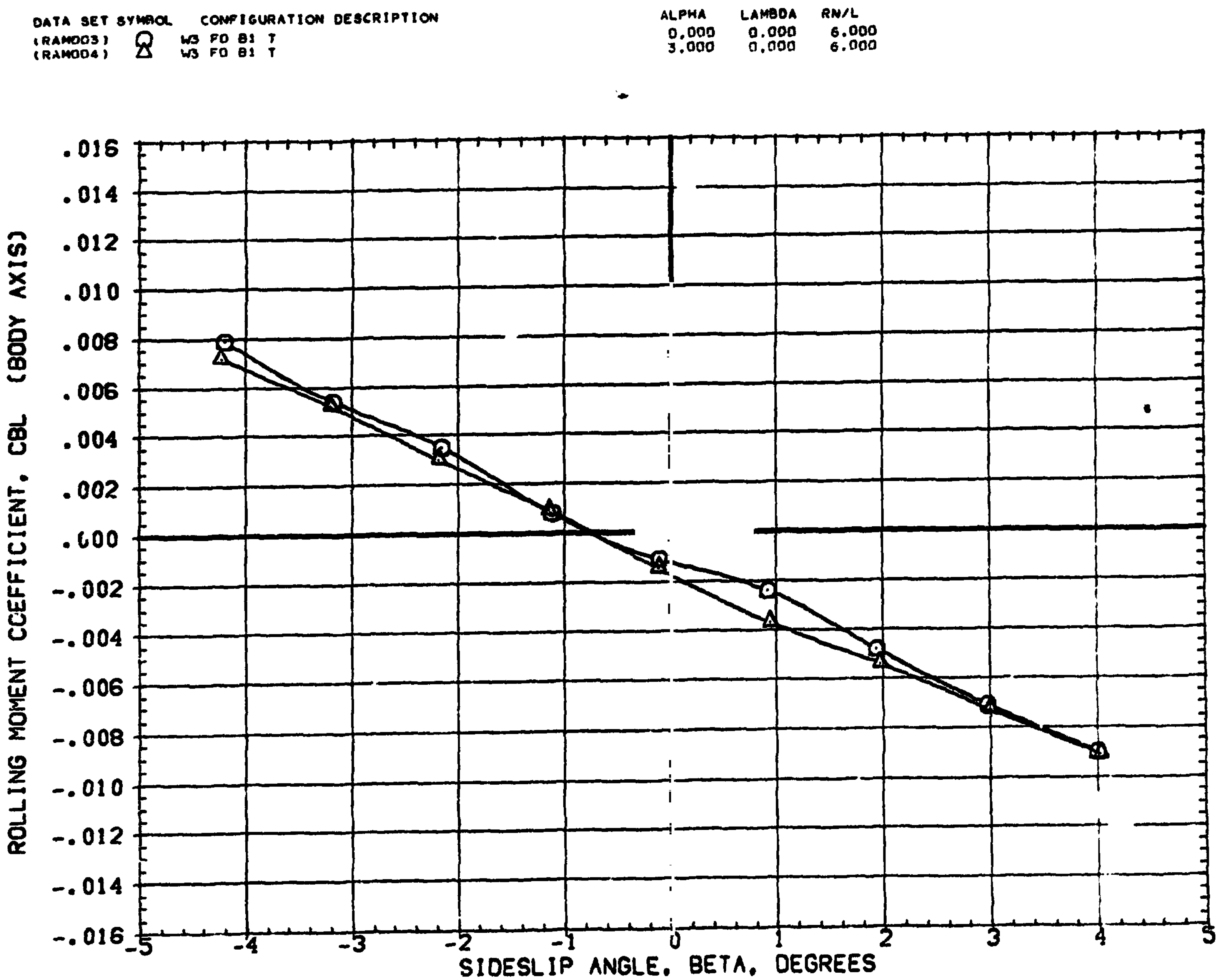


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

(A)MACH = 0.60

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAW003)	○	W3 FO B1 T	0.000	0.000	6.000
(RAW004)	△	W3 FO B1 T	3.000	0.000	6.000

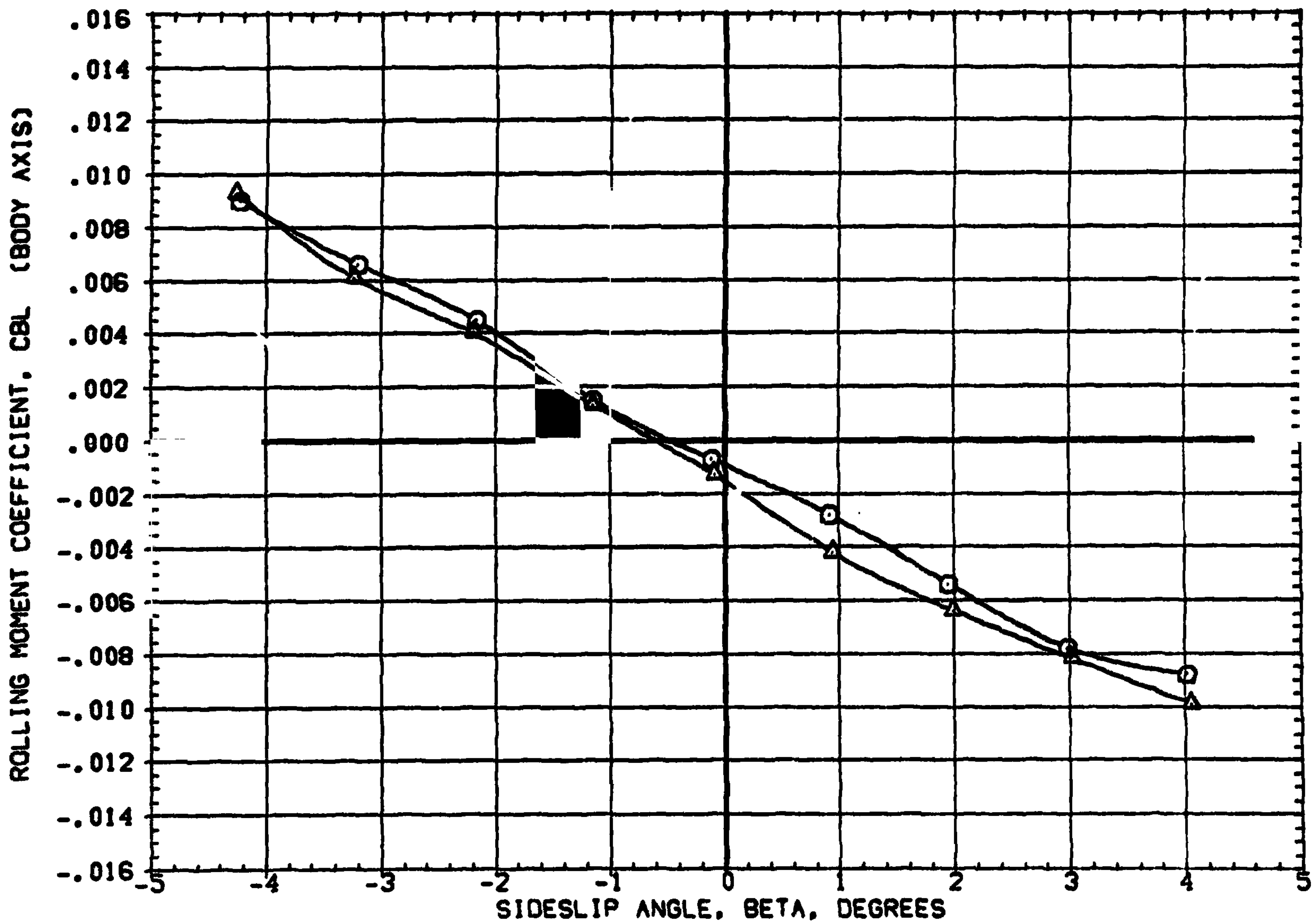


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.
(B)MACH = 0.70

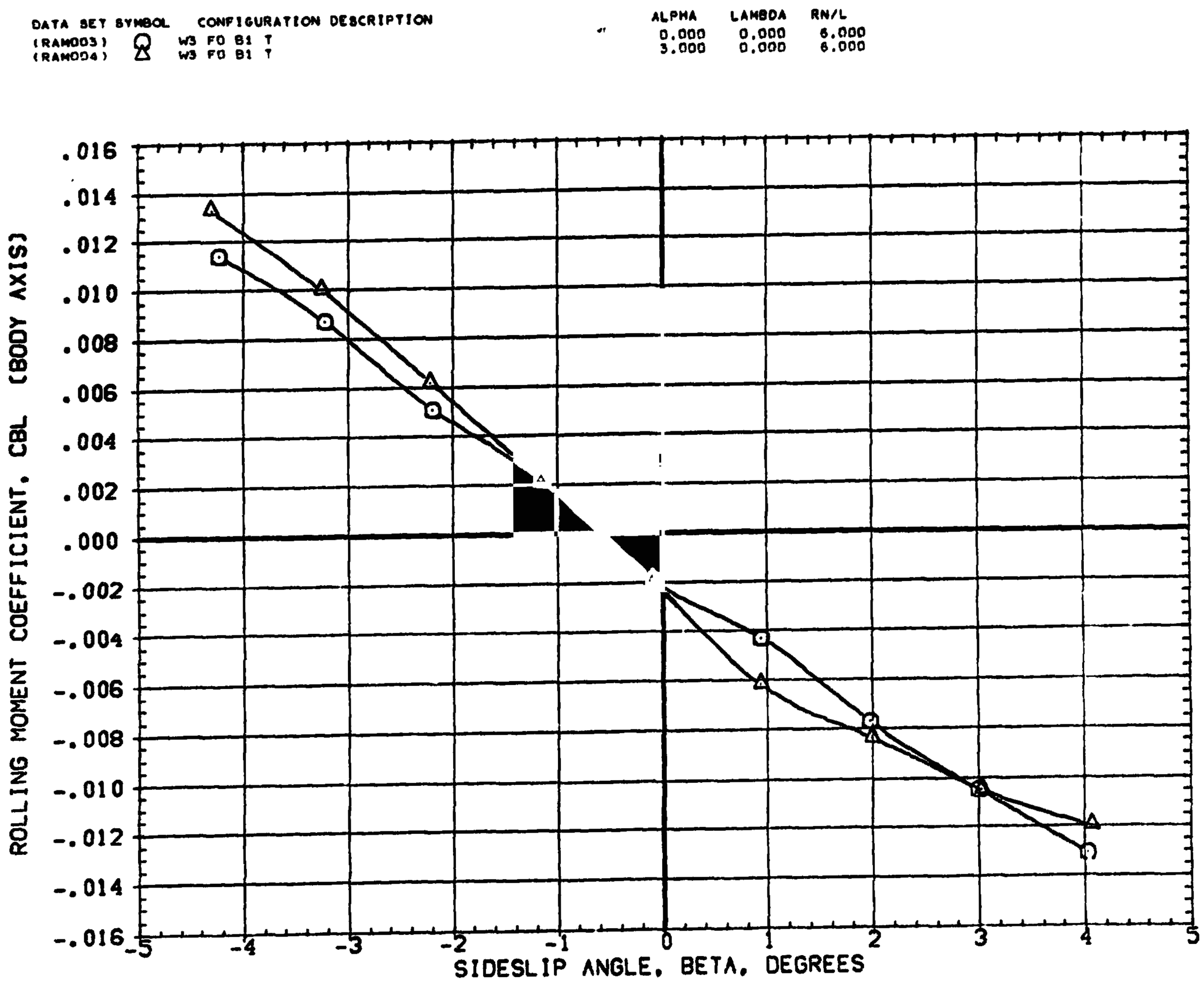


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

(C)MACH = 0.80

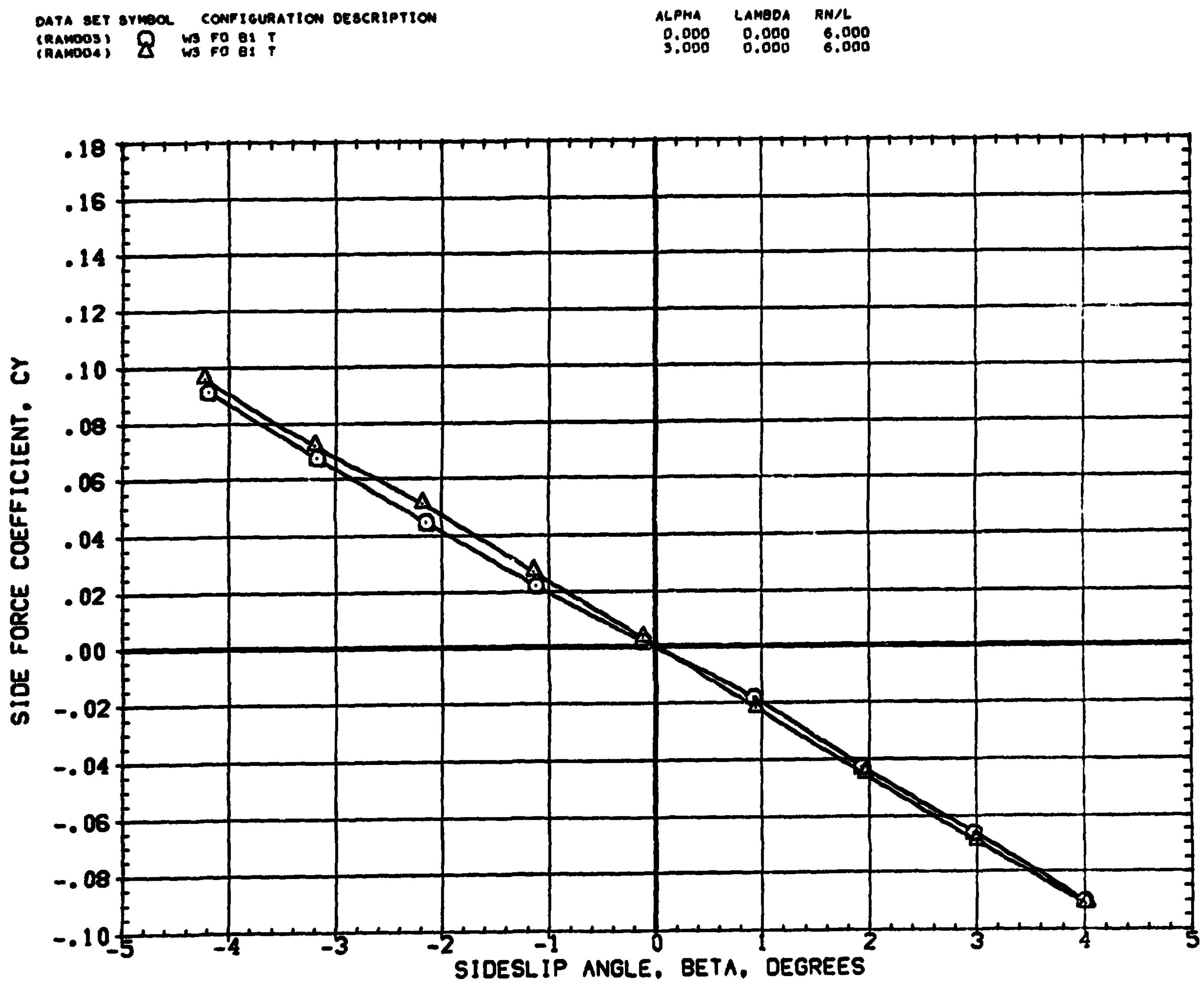


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

(A)MACH = 0.60

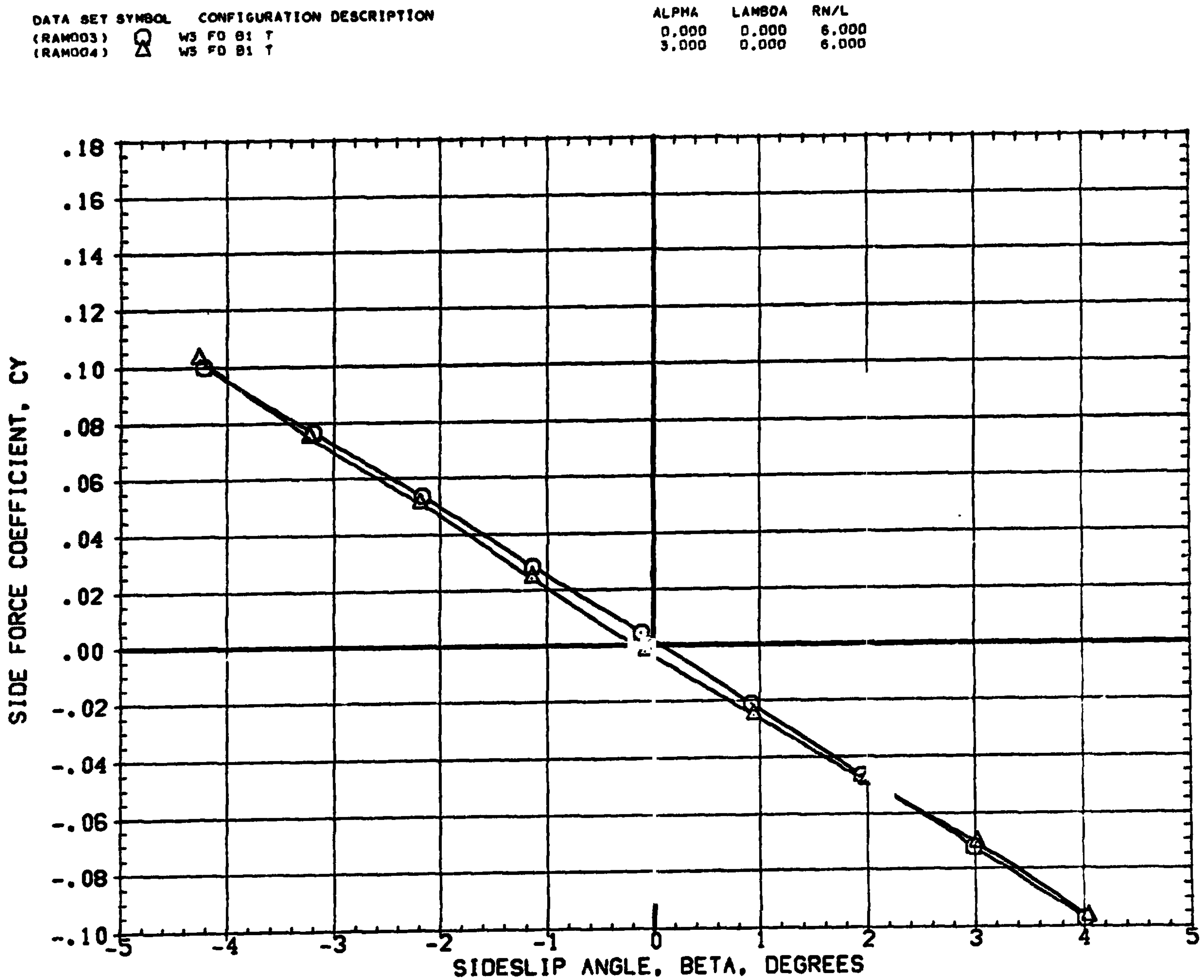


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.
(B)MACH = 0.70

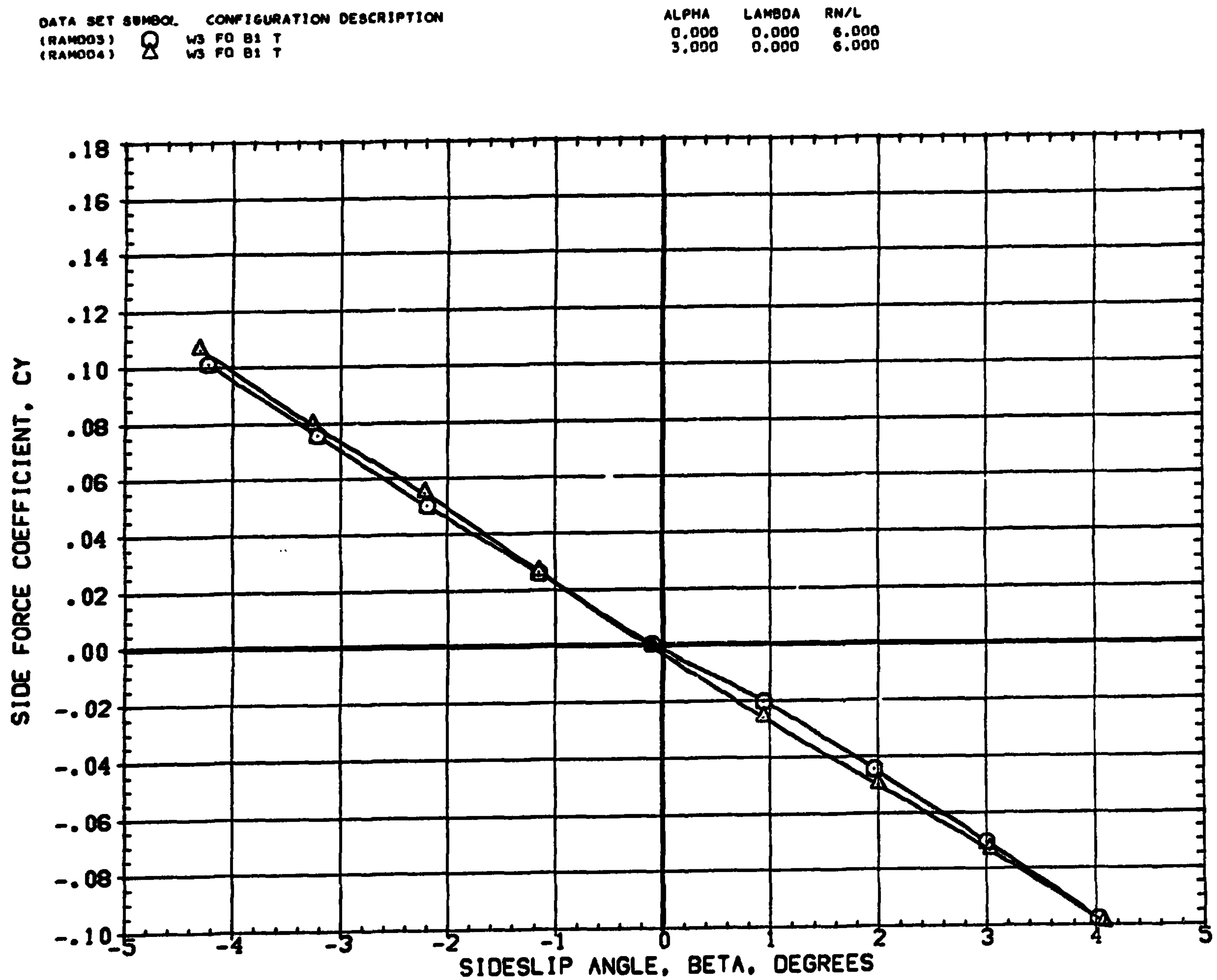


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.
(C)MACH = 0.80

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAM003)	○	W3 F0 B1 T	0.000	0.000	6.000
(RAM004)	△	W3 F0 B1 T	3.000	0.000	6.000

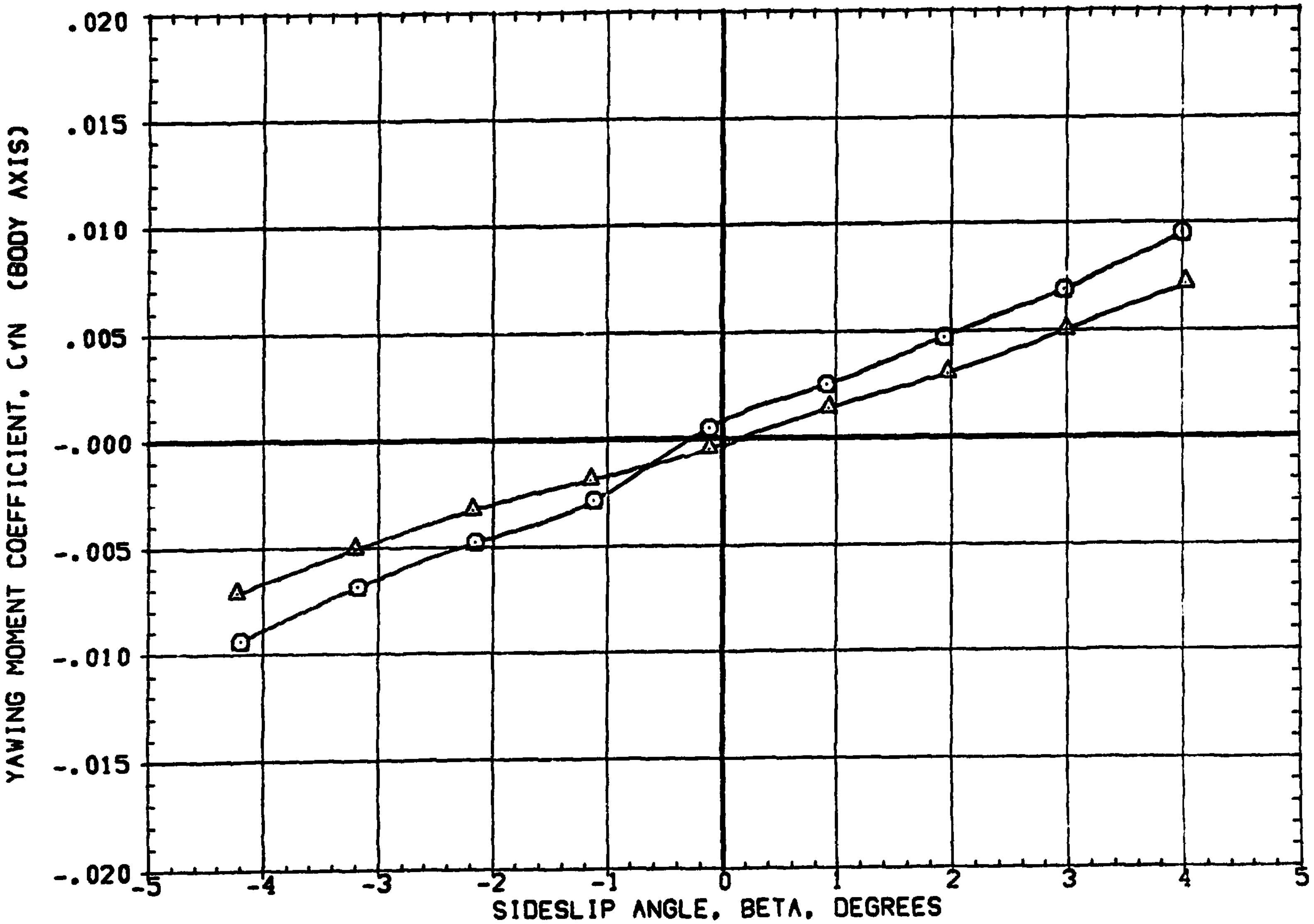


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

(A)MACH = 0.60

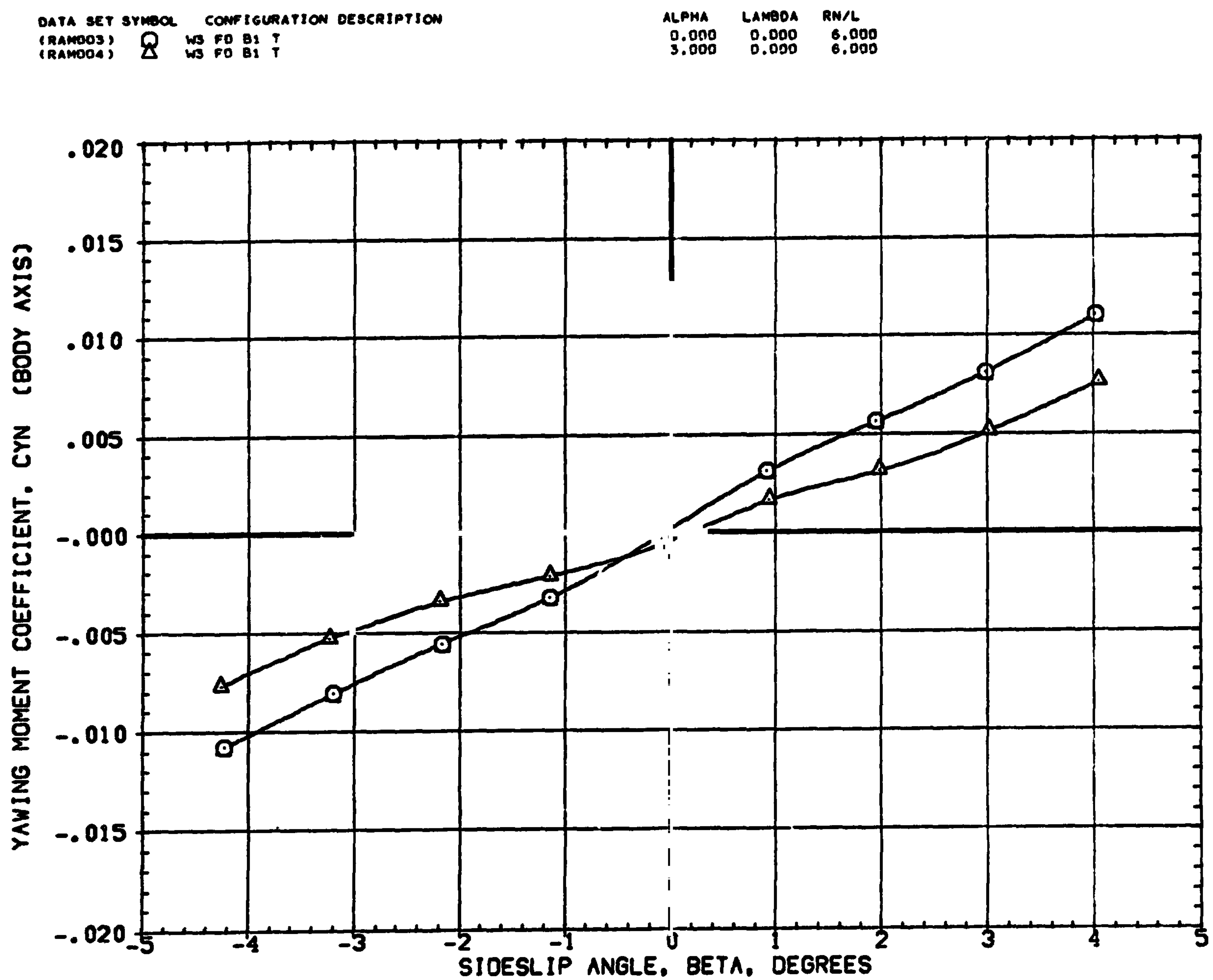


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

(B)MACH = 0.70

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAM003)	○	W3 F0 B1 T	0.000	0.000	6.000
(RAM004)	△	W3 F0 B1 T	3.000	0.000	6.000

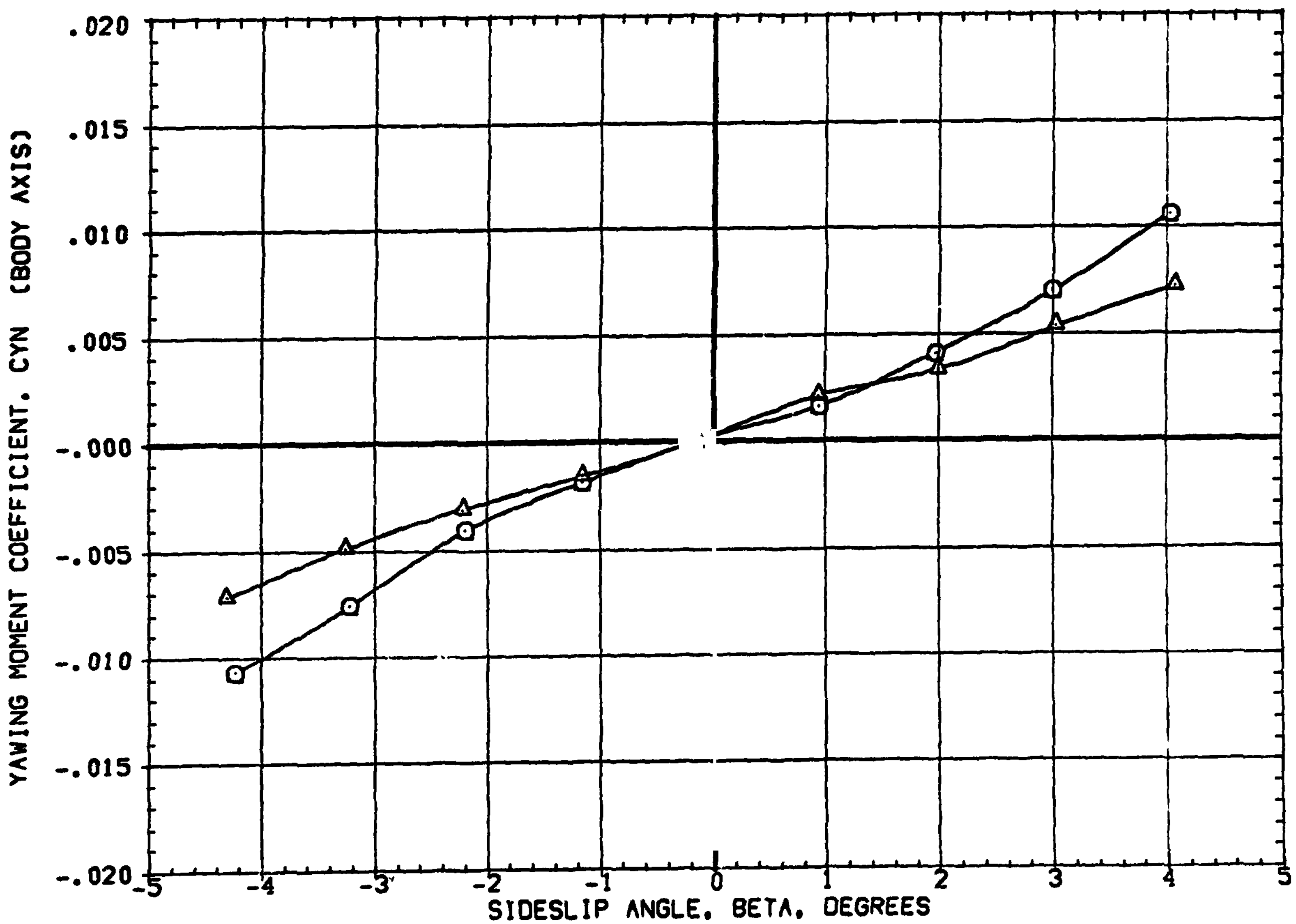


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 0 DEGREES.

(C)MACH = 0.80

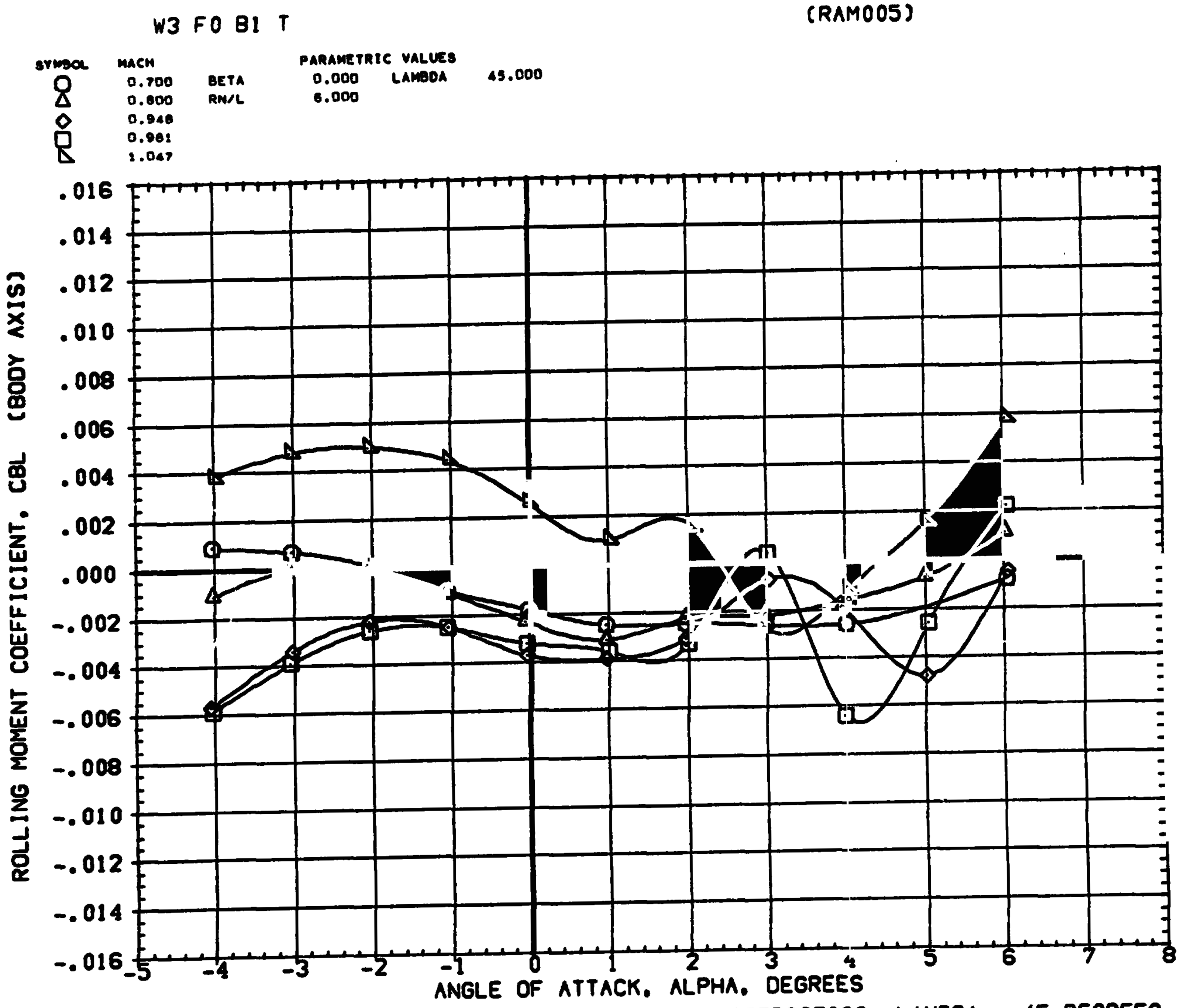


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

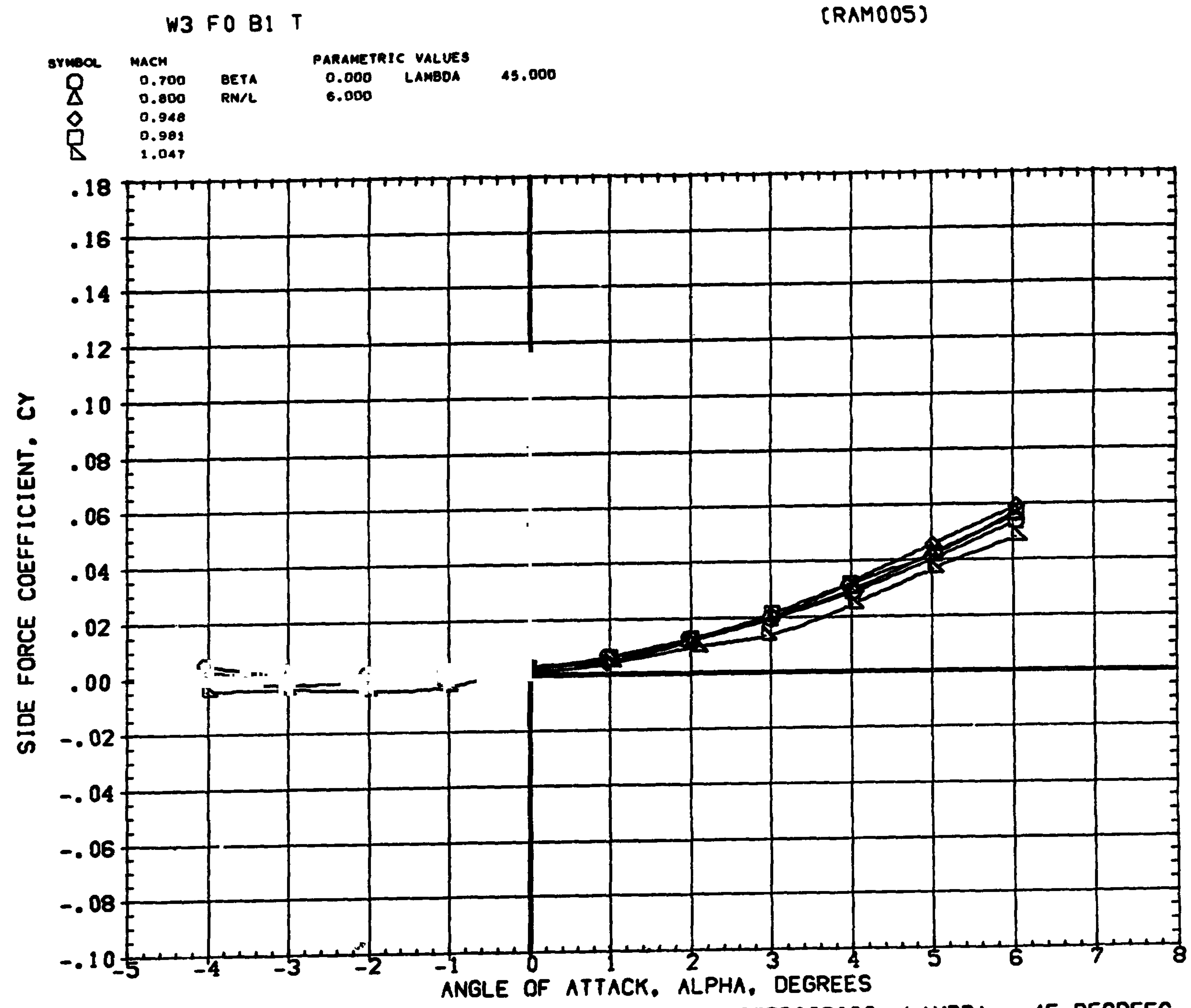


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

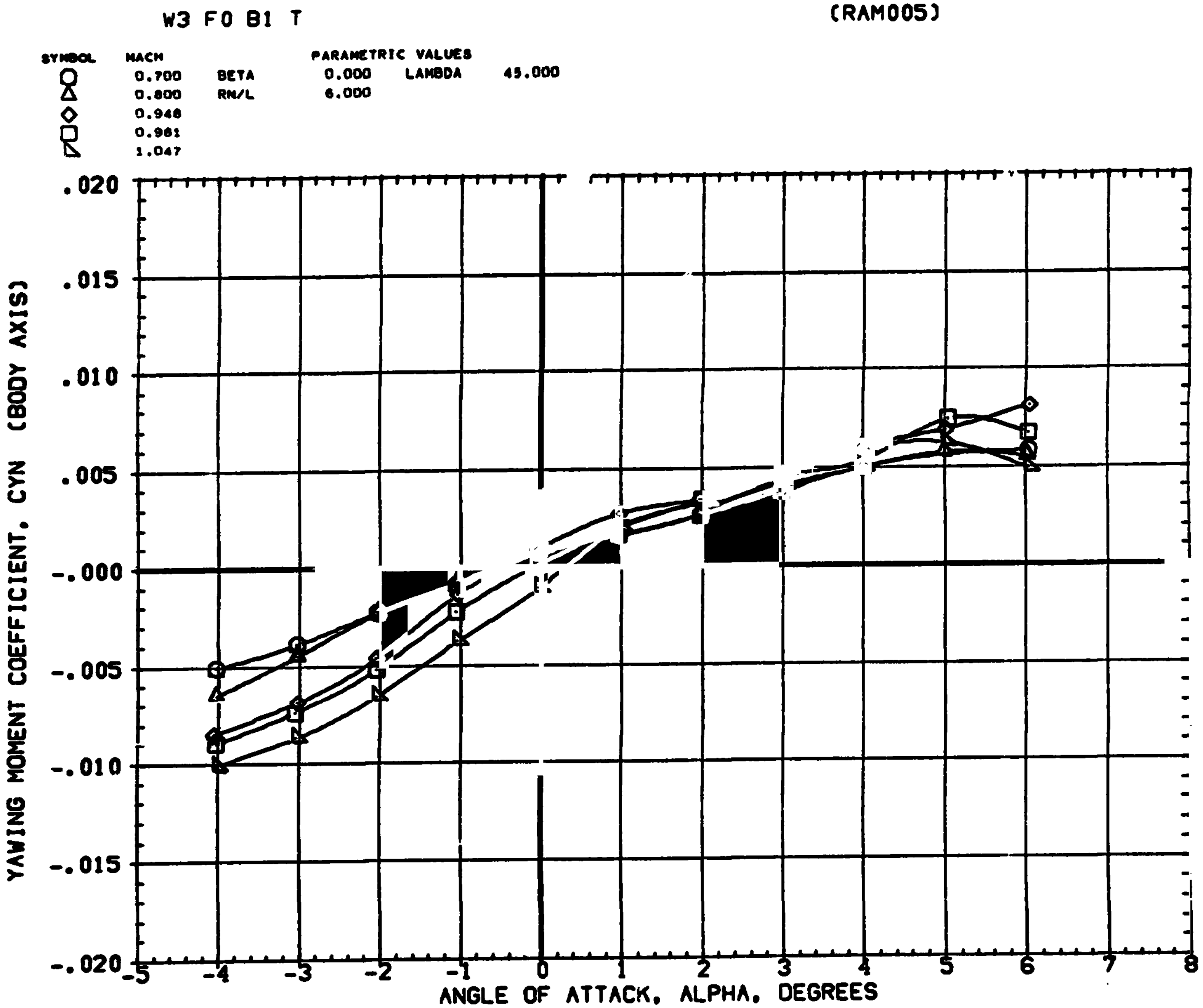


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

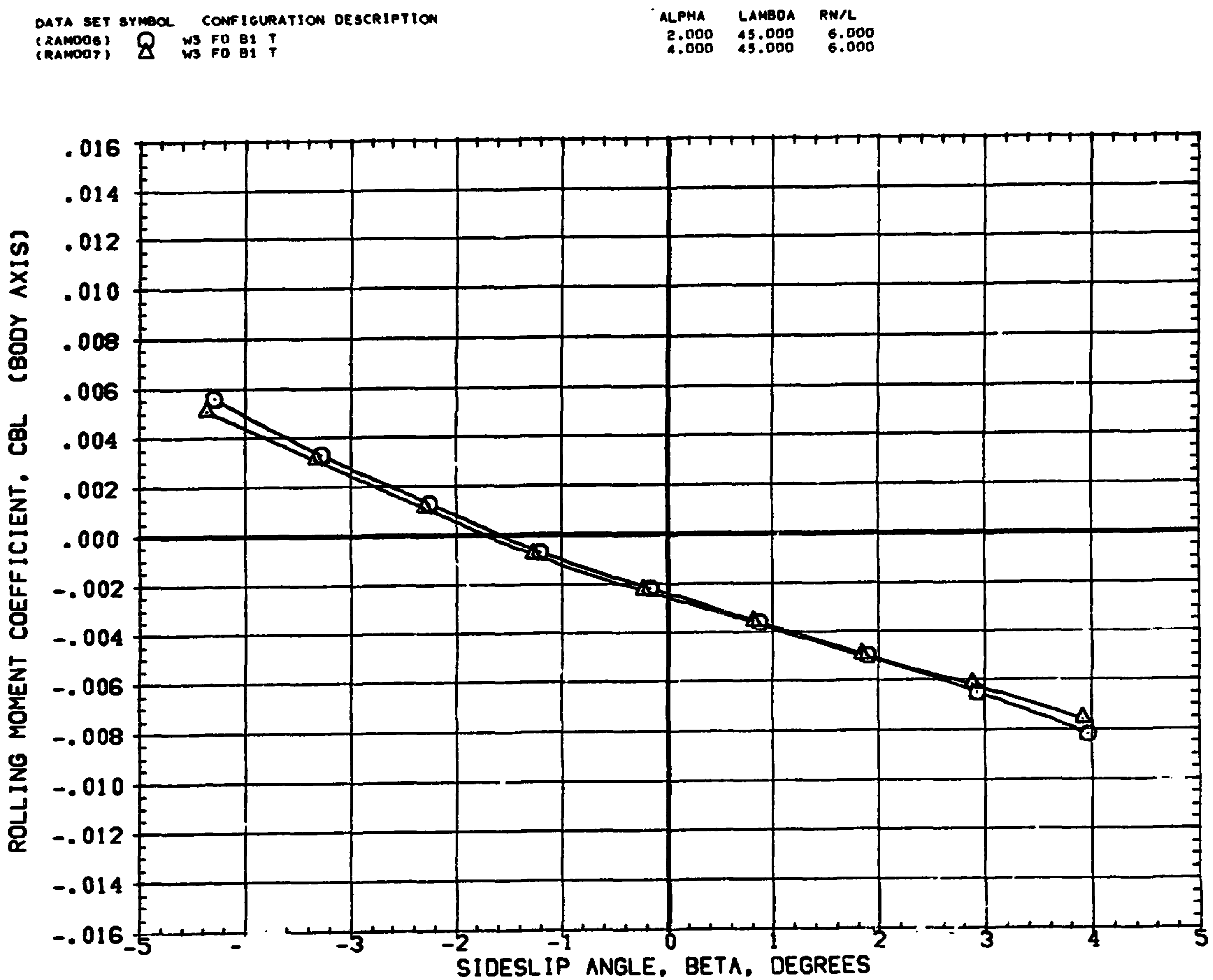


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

(A)MACH = 0.70

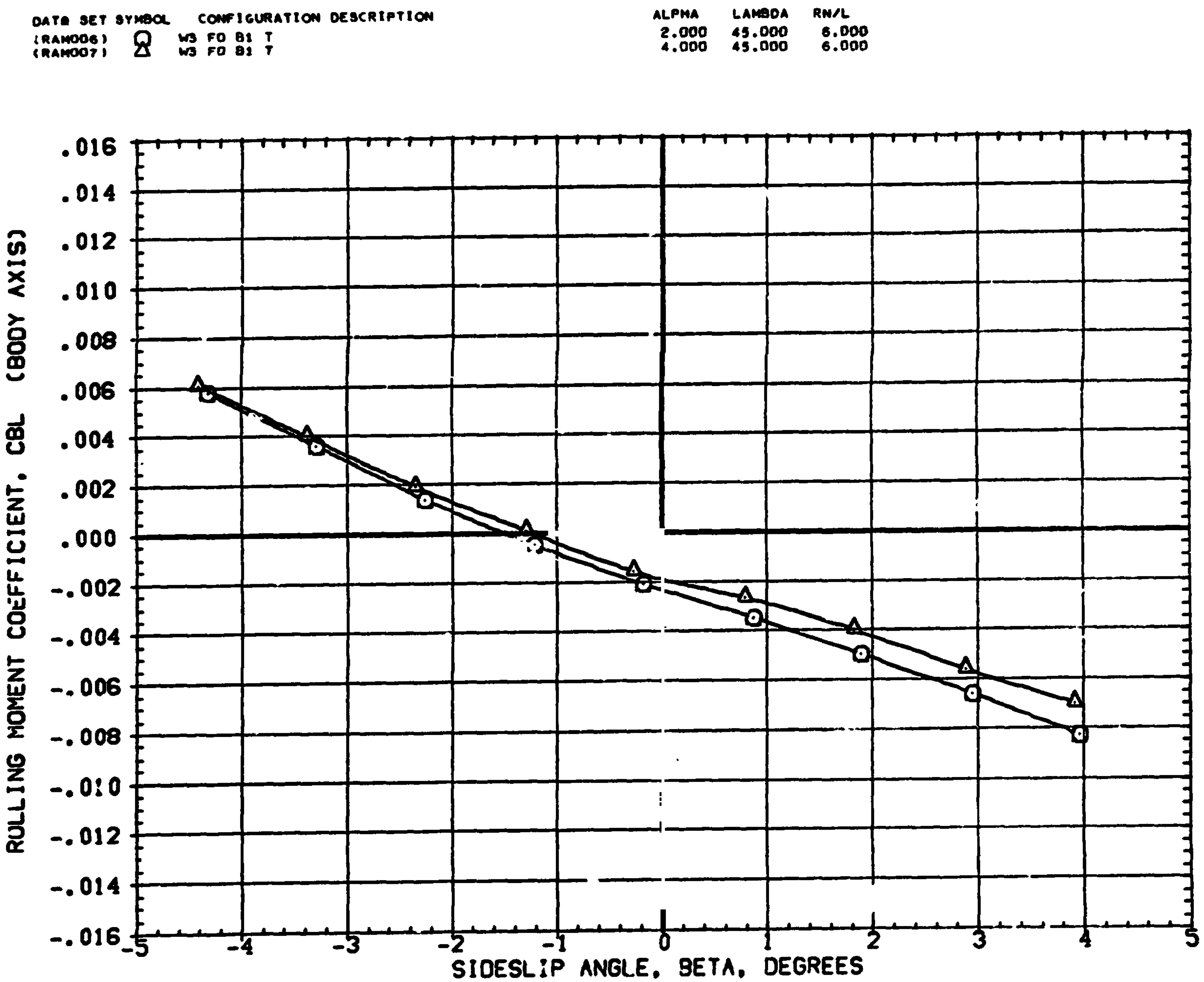


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

(B)MACH = 0.60

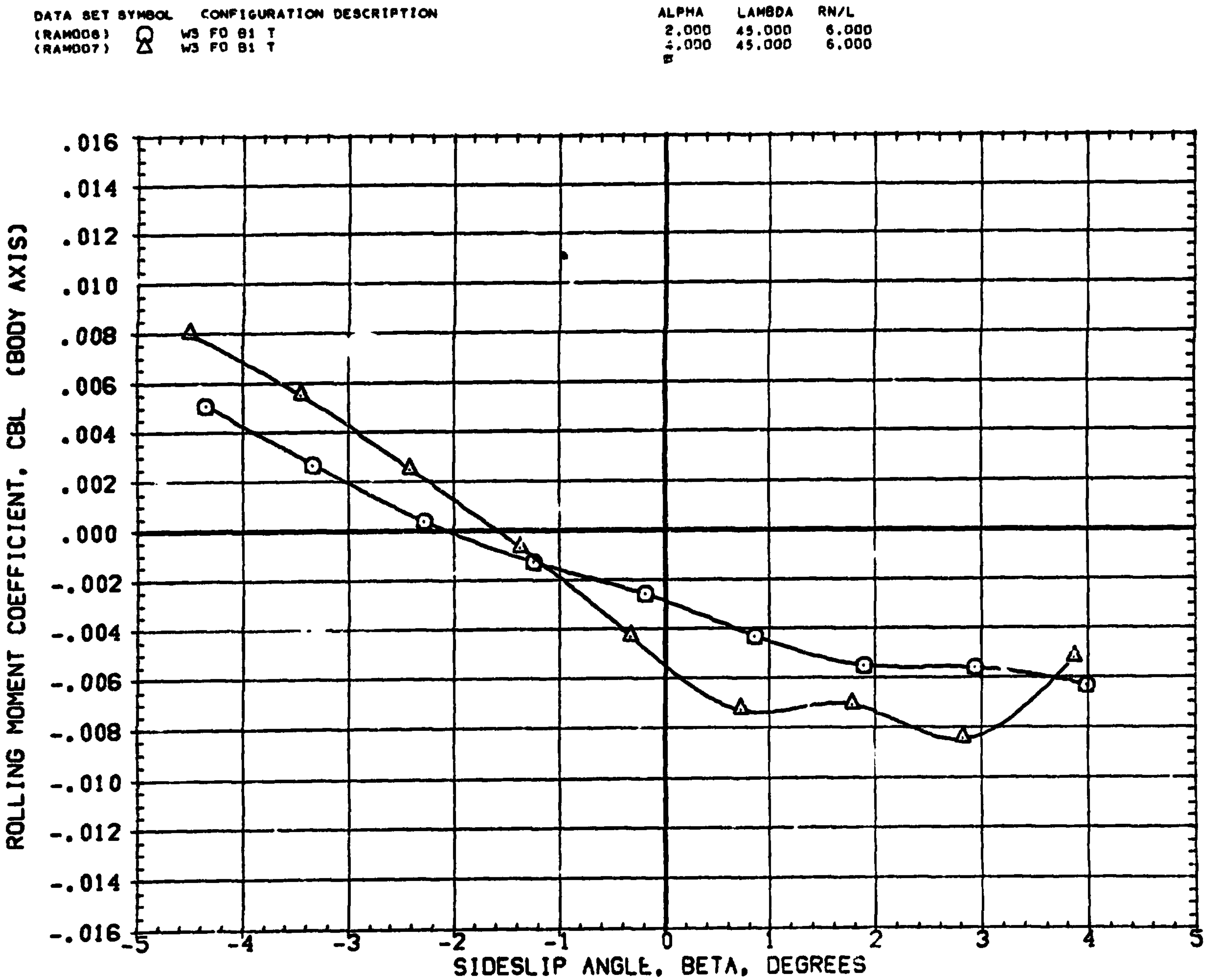


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.
(C)MACH = 0.95

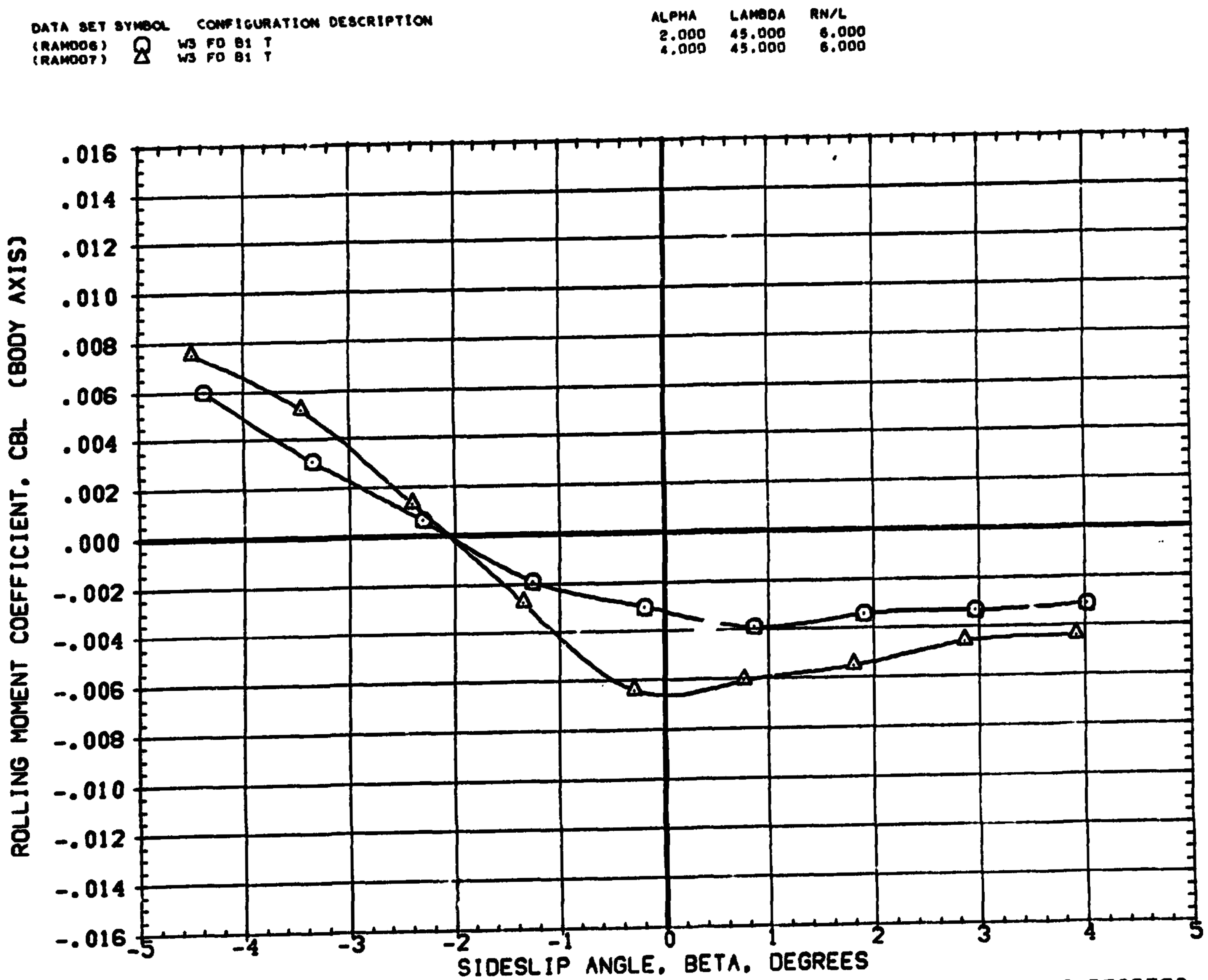


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

(D)MACH = 0.98

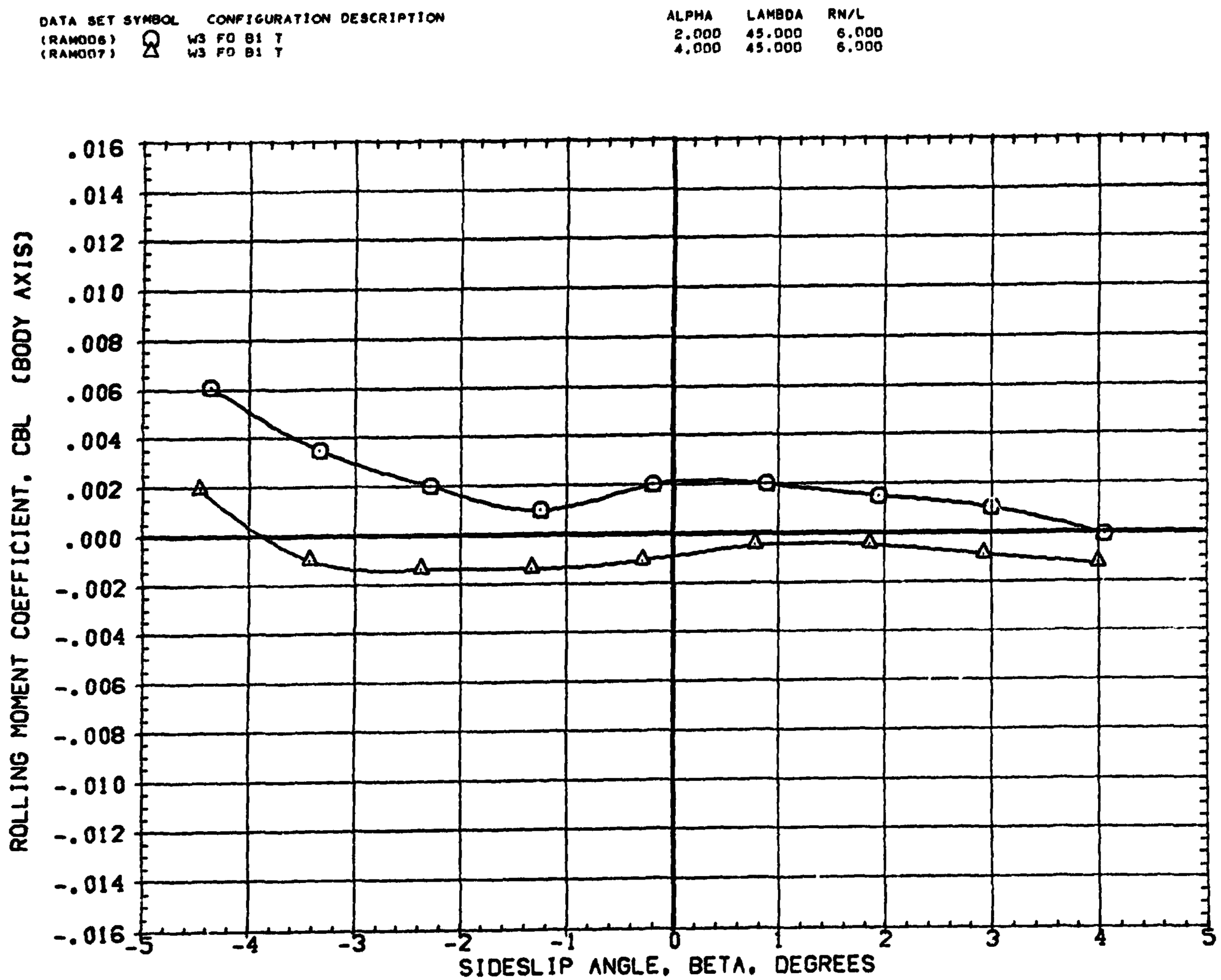


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.
(E)MACH = 1.05

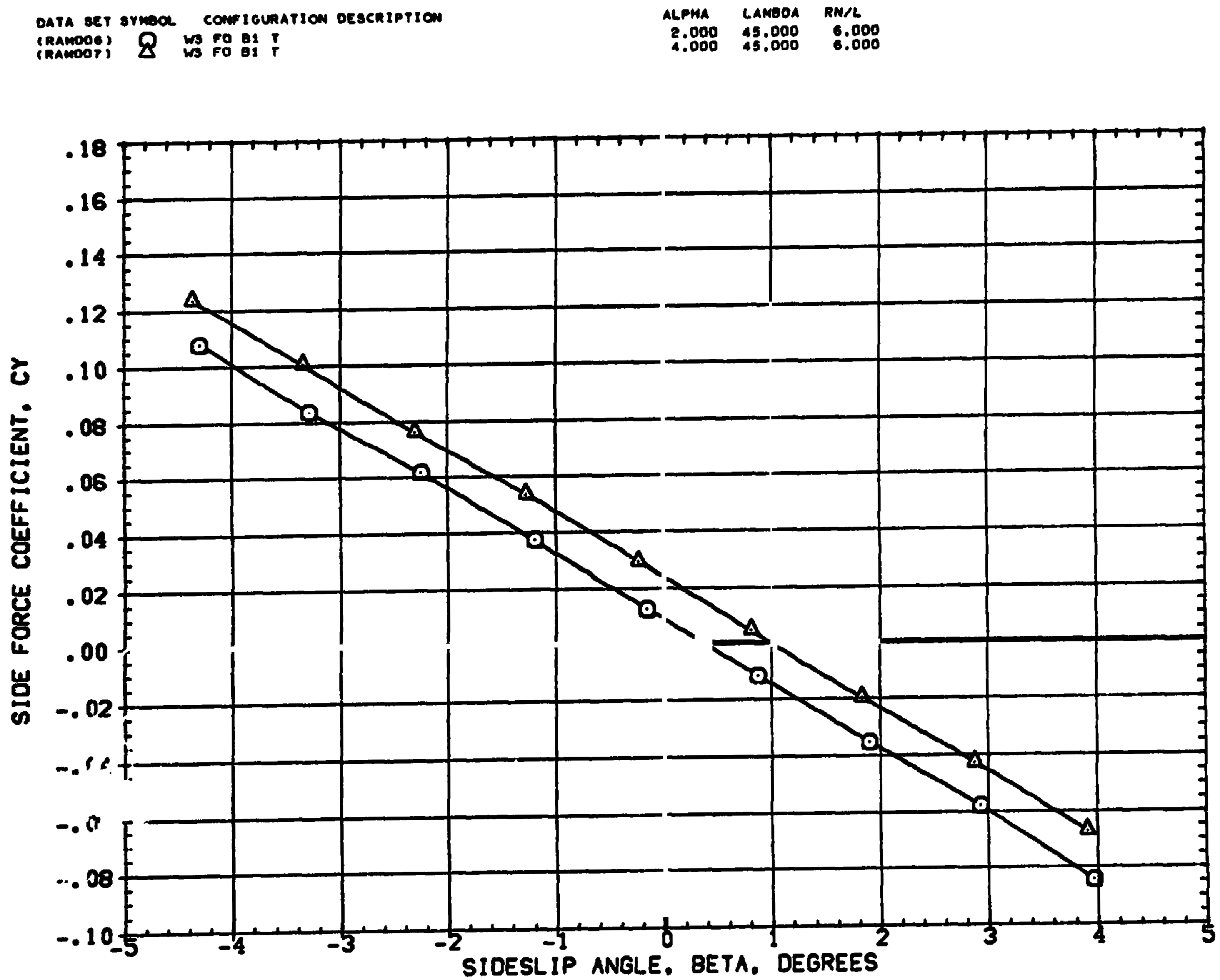


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.
(A)MACH = 0.70

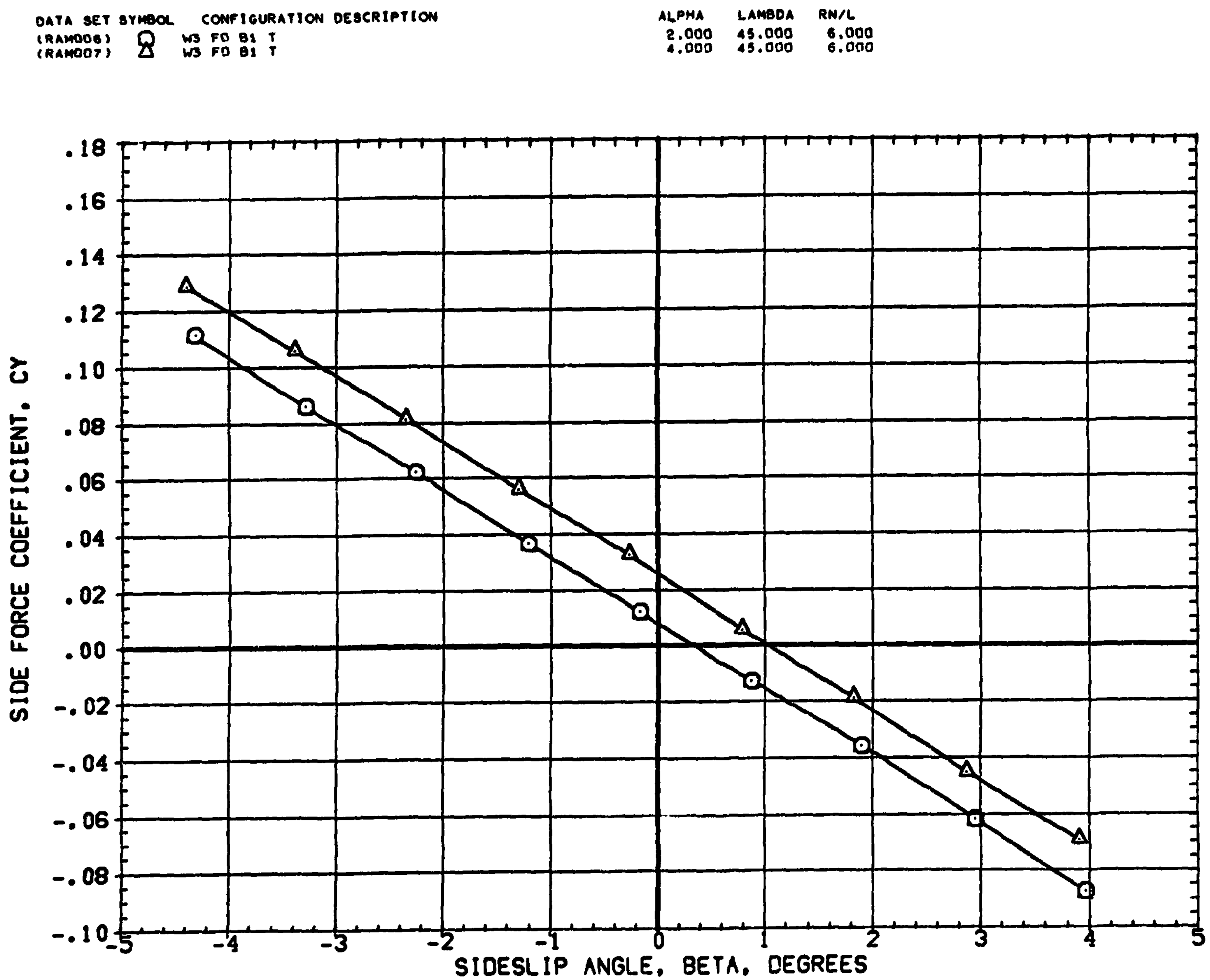


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

(B)MACH = 0.80

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAMD06)	○	W3 F0 B1 T	2.000	45.000	6.000
(RAMD07)	△	W3 F0 B1 T	4.000	45.000	6.000

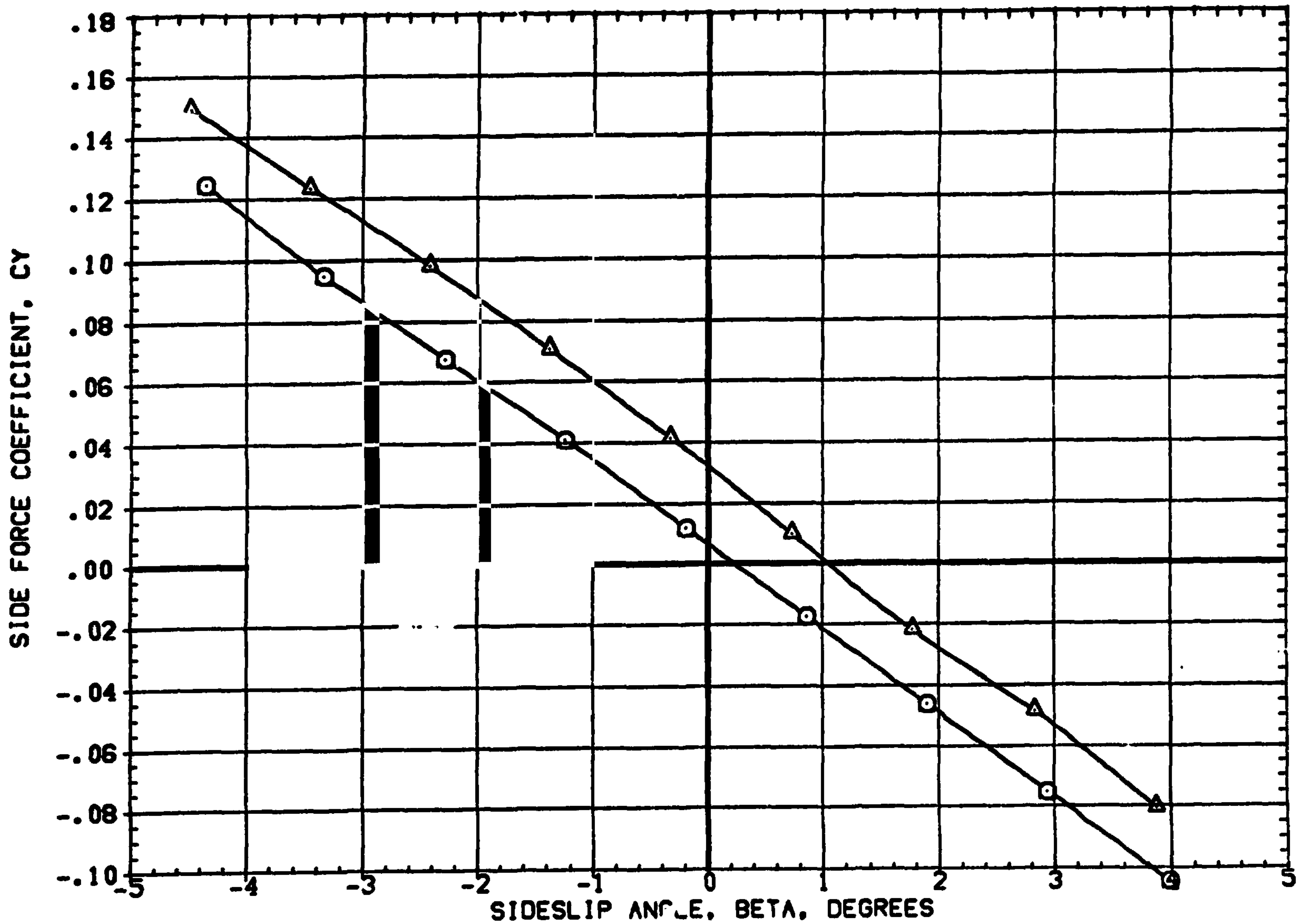


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

(C)MACH = 0.95

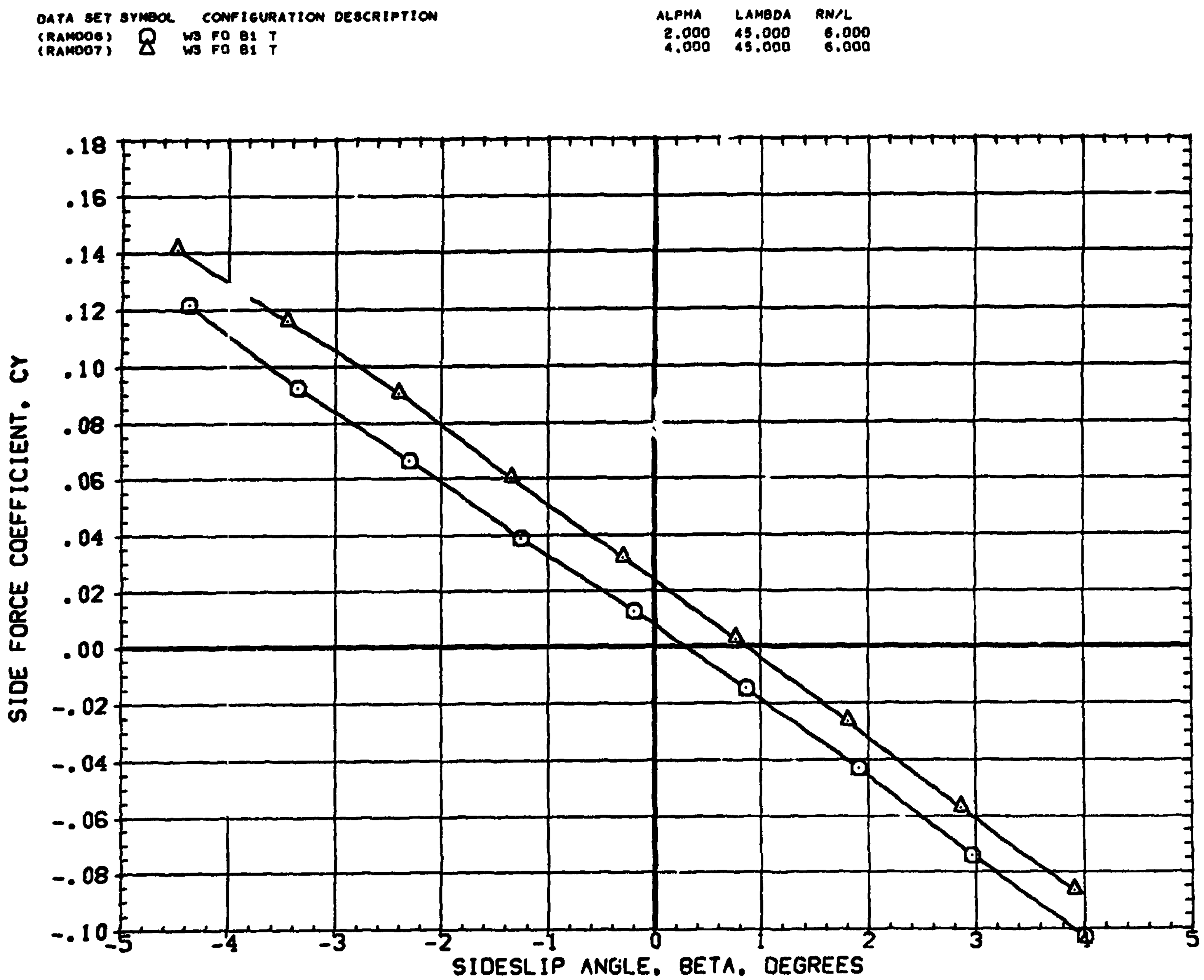


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

(D)MACH = 0.98

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAM006)	○	W3 F0 B1 T	2.000	45.000	6.000
(RAM007)	△	W3 F0 B1 T	4.000	45.000	6.000

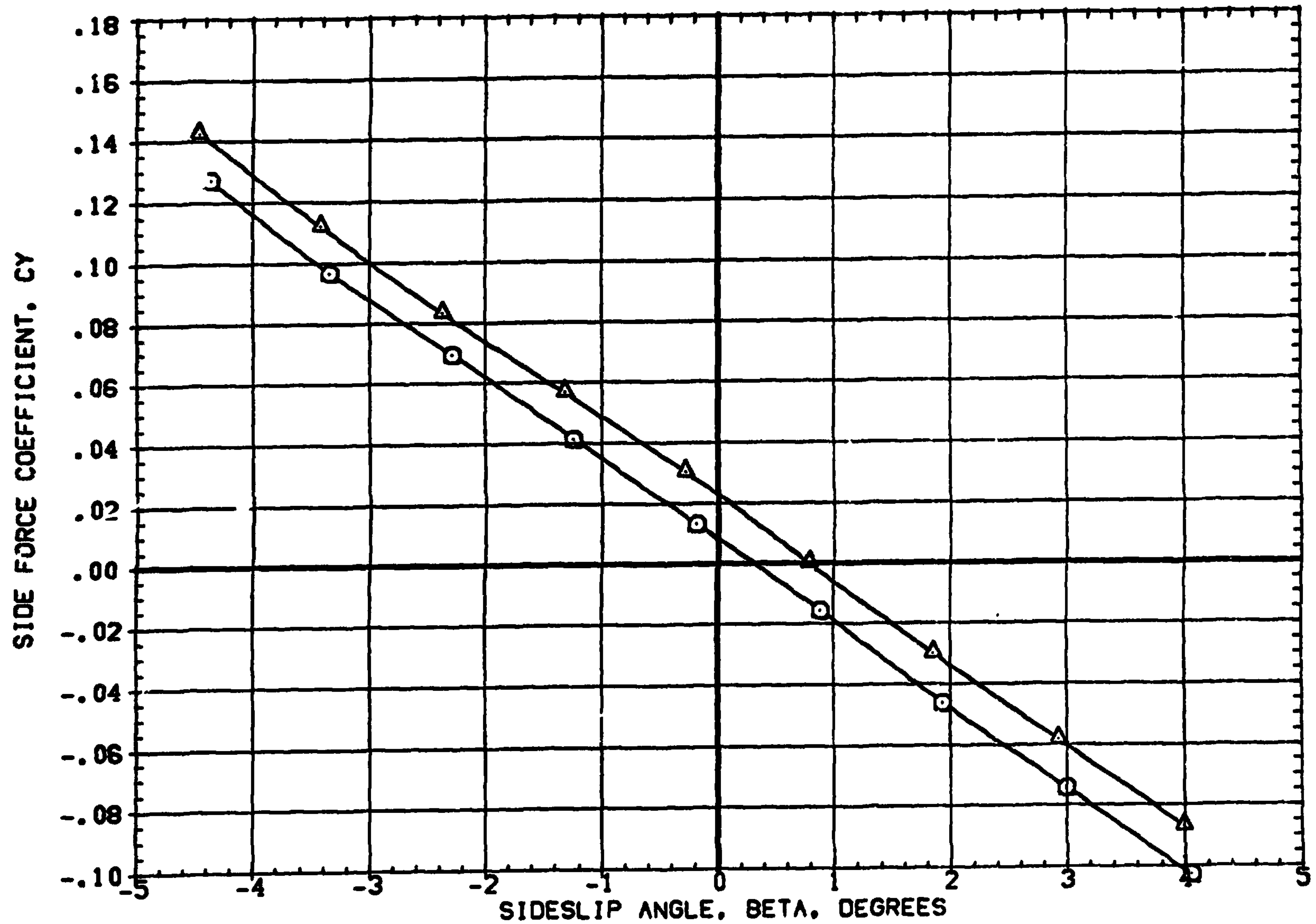


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

(E)MACH = 1.05

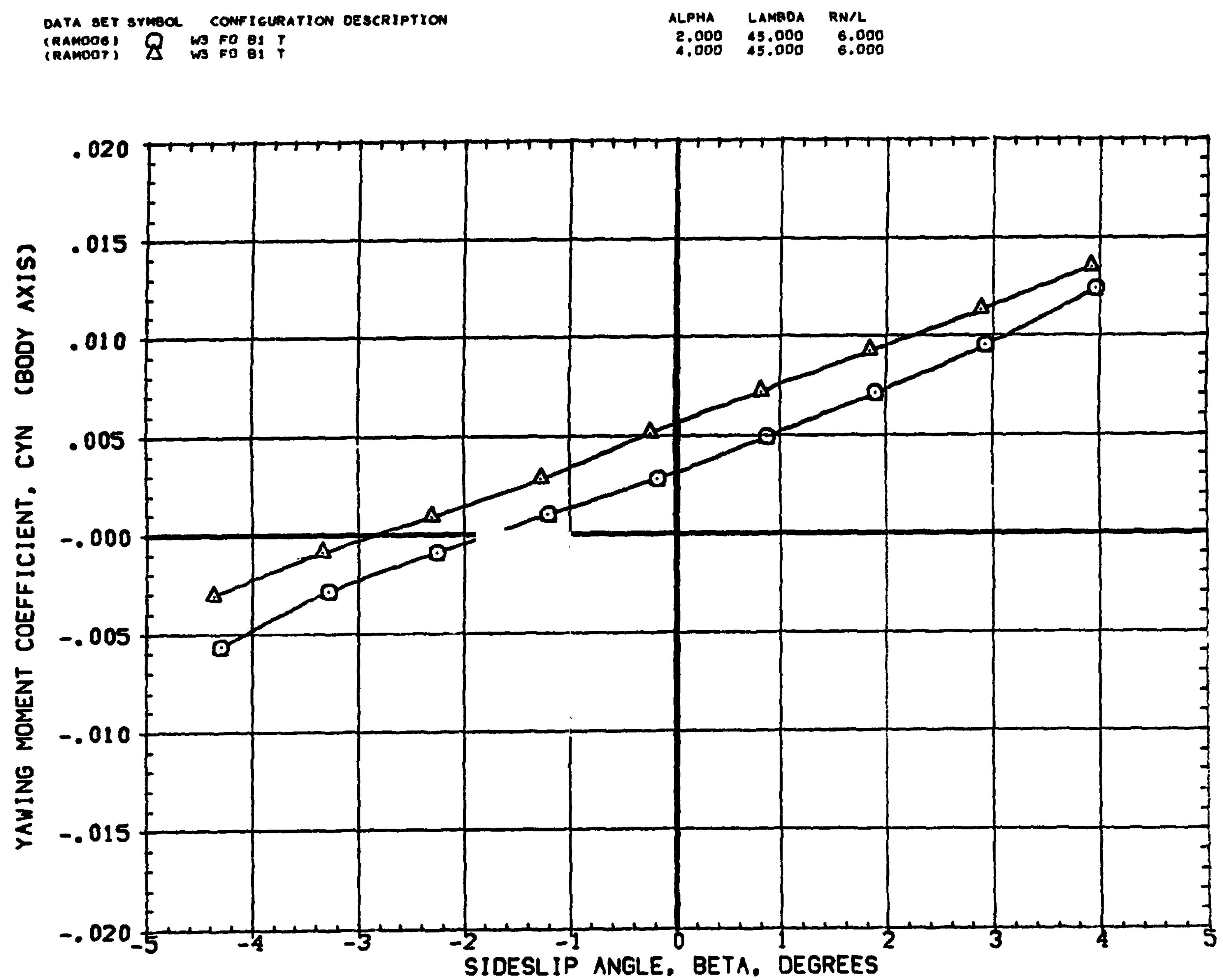


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

(A)MACH = 0.70

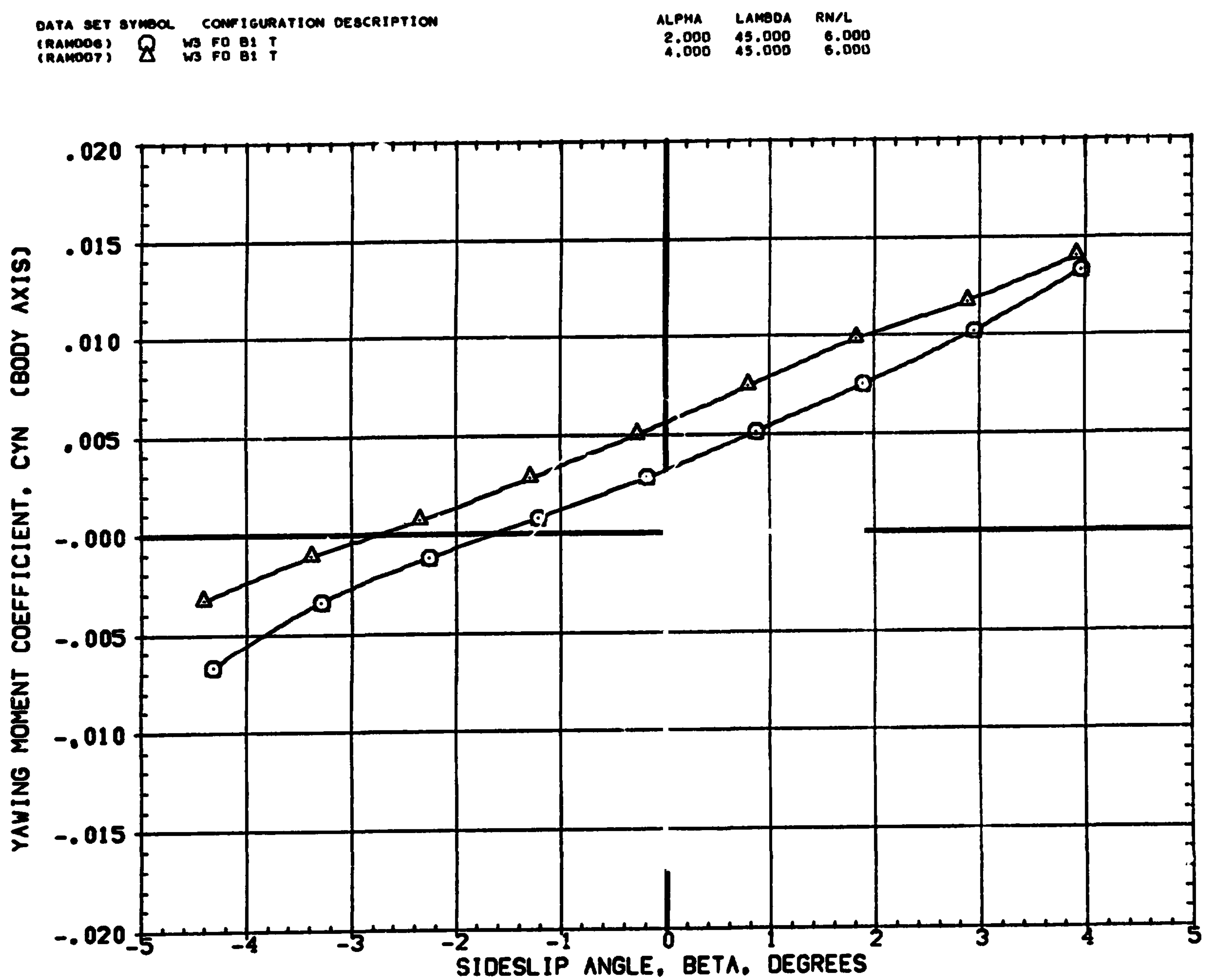


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.
(B)MACH = 0.80

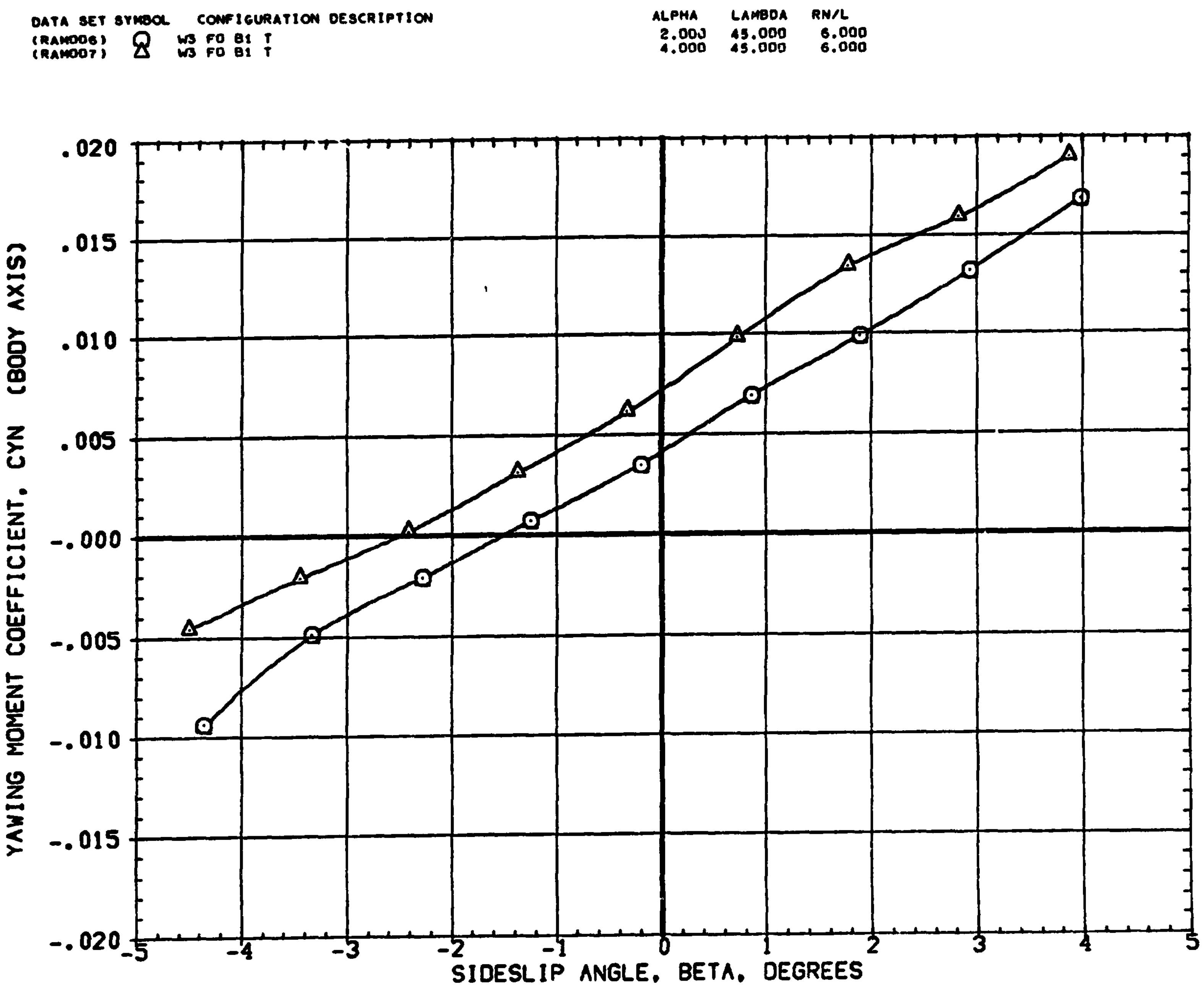


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.
(C)MACH = 0.95

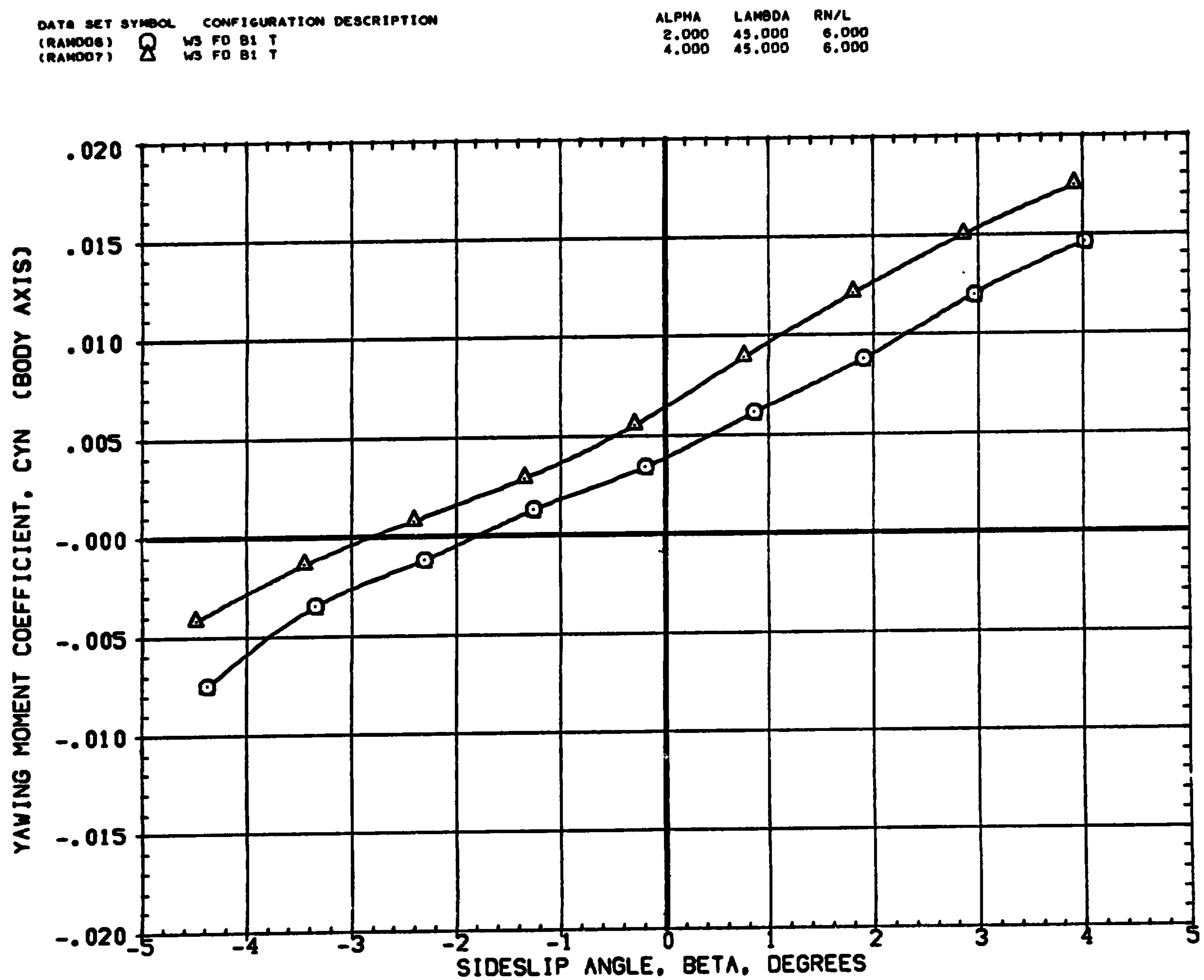


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.
(D)MACH = 0.98

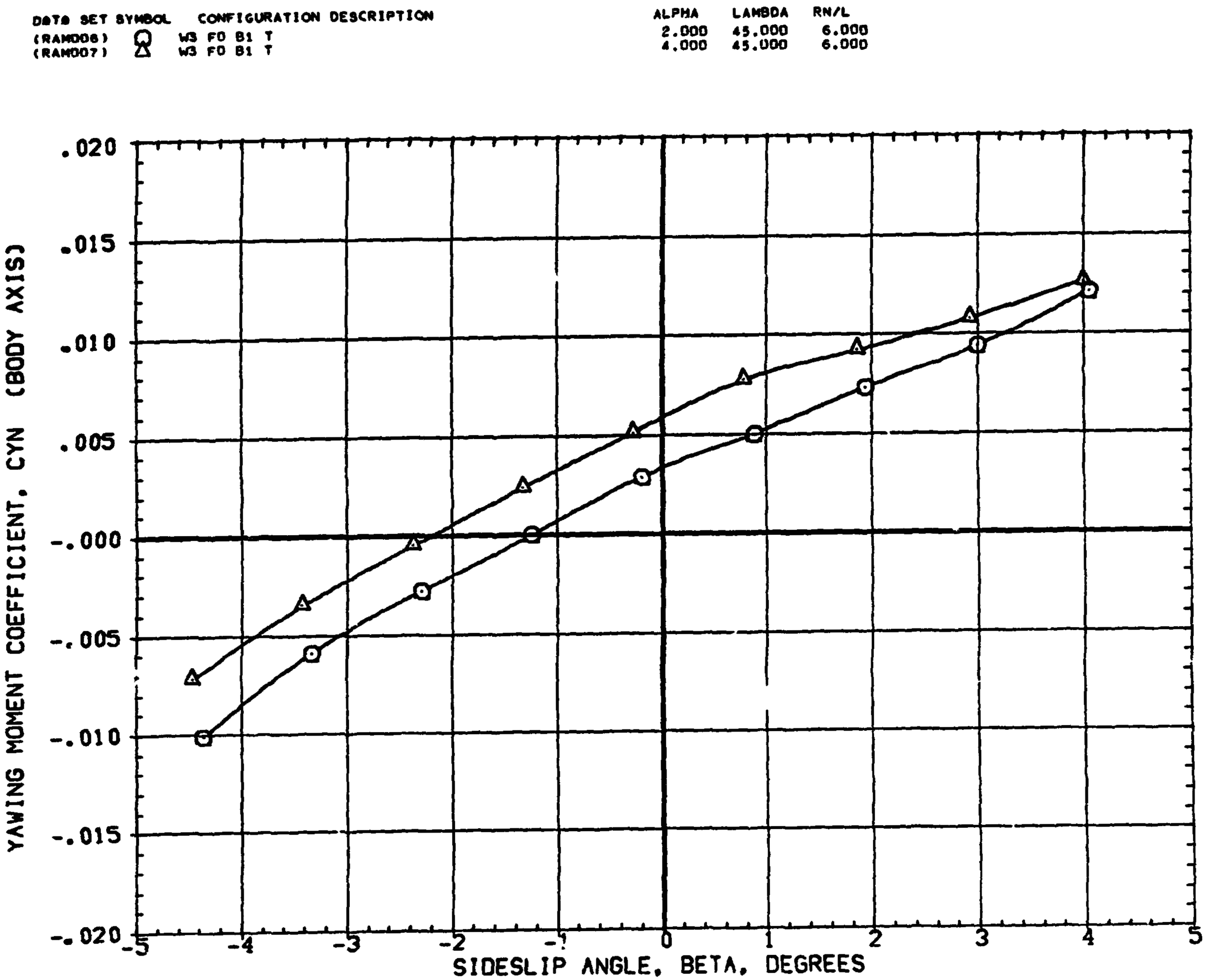


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 45 DEGREES.

(E)MACH = 1.05

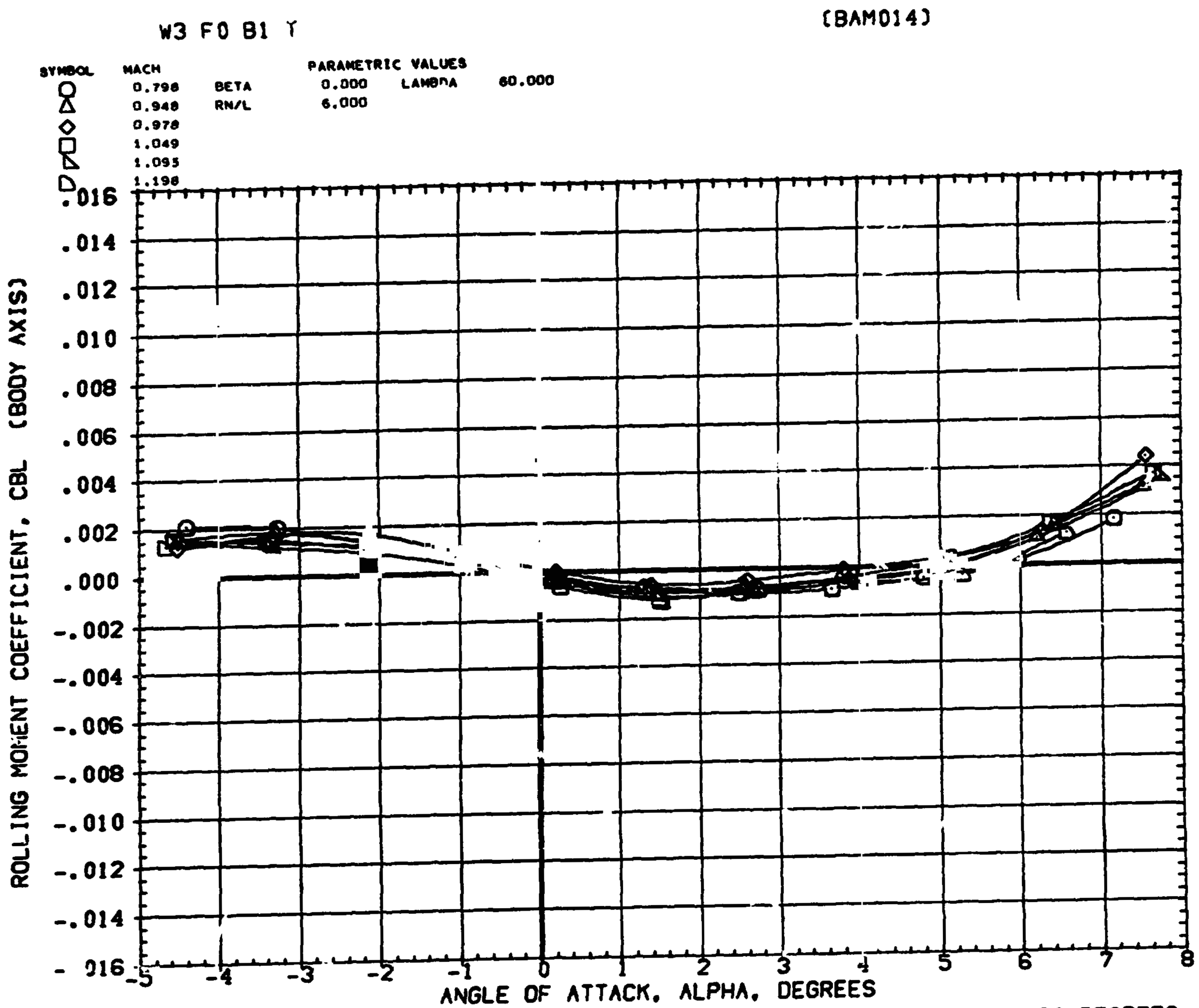


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

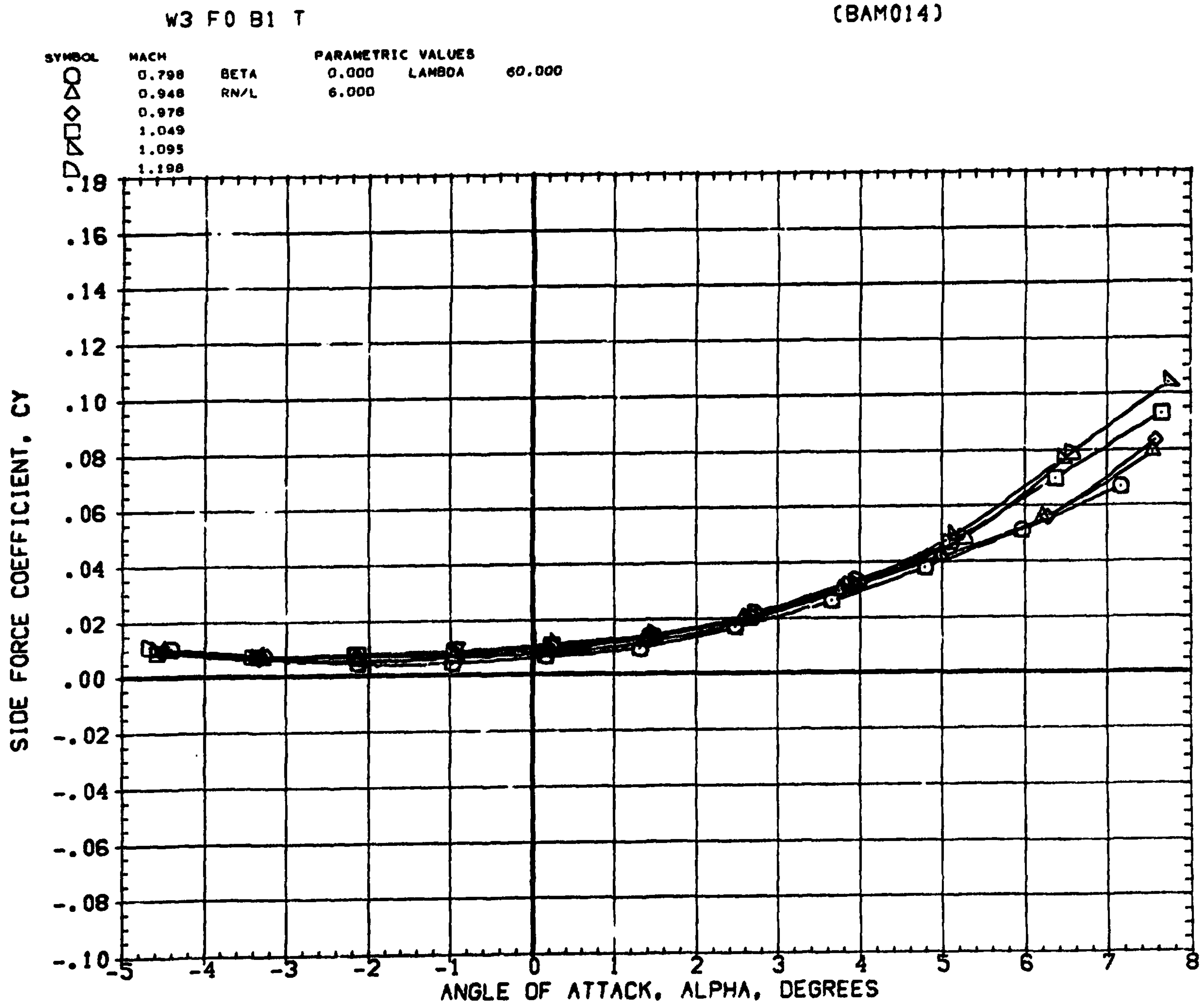


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

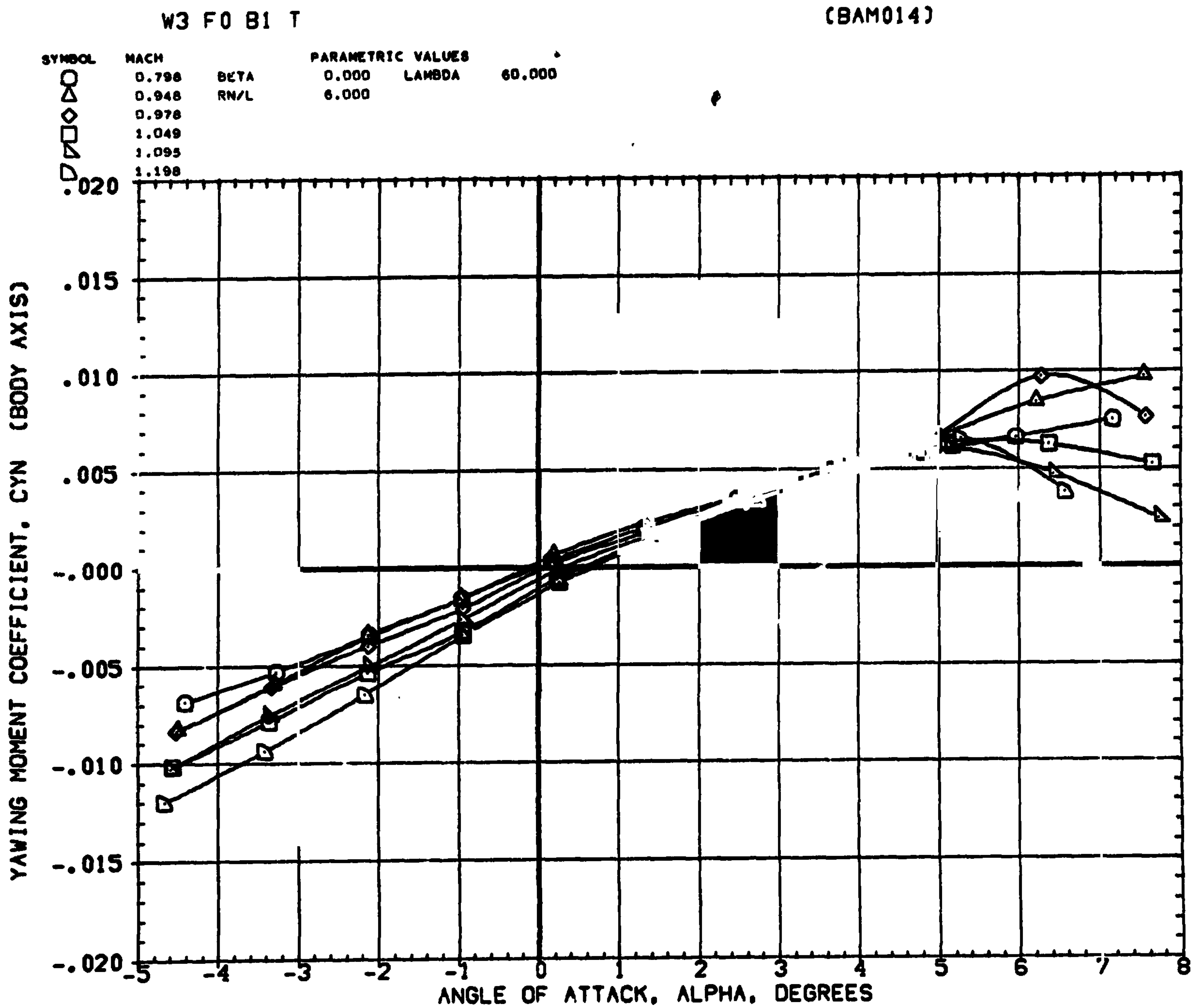


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

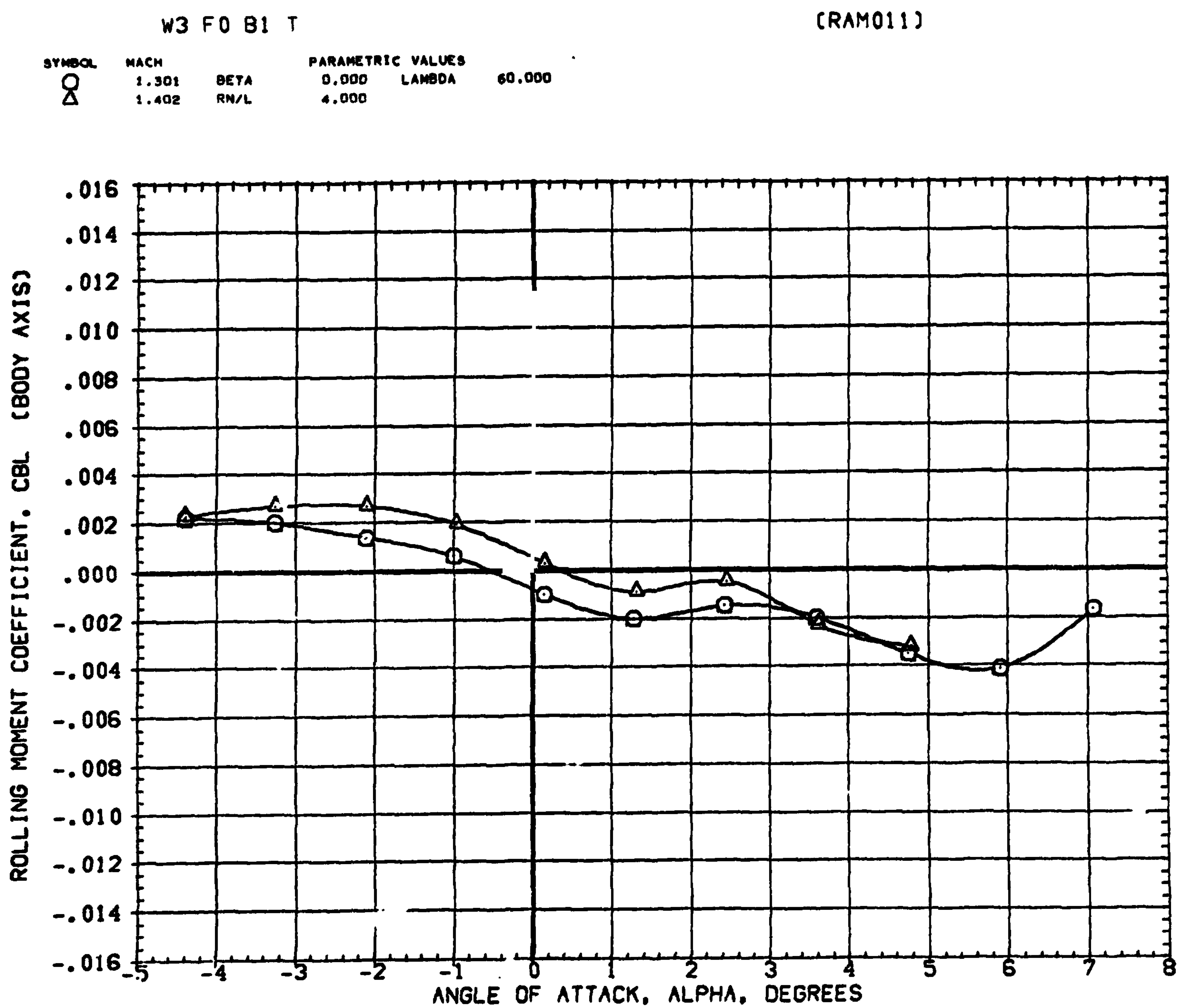


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

W3 F0 B1 T (RAM011)

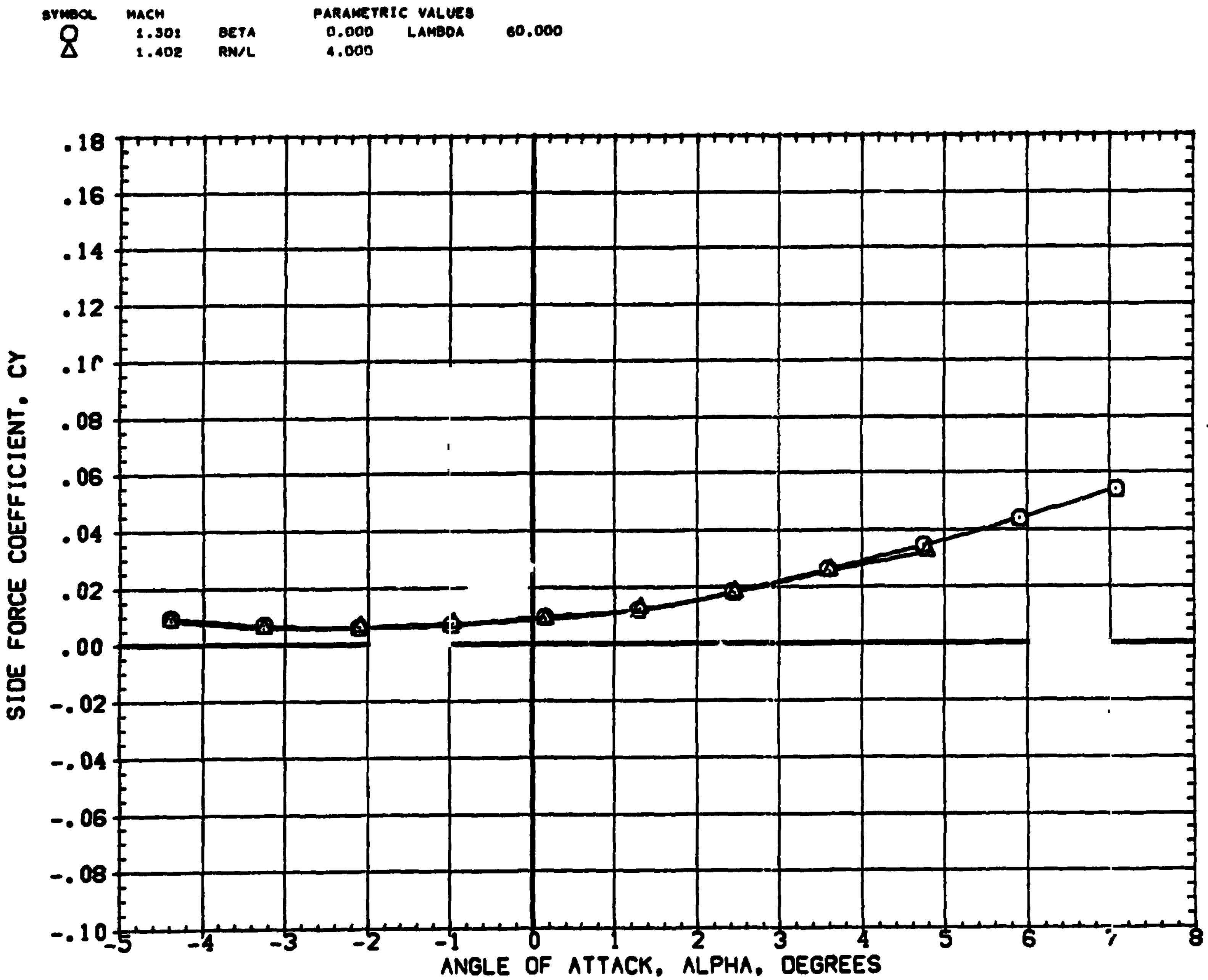


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

W3 F0 B1 T (RAM011)

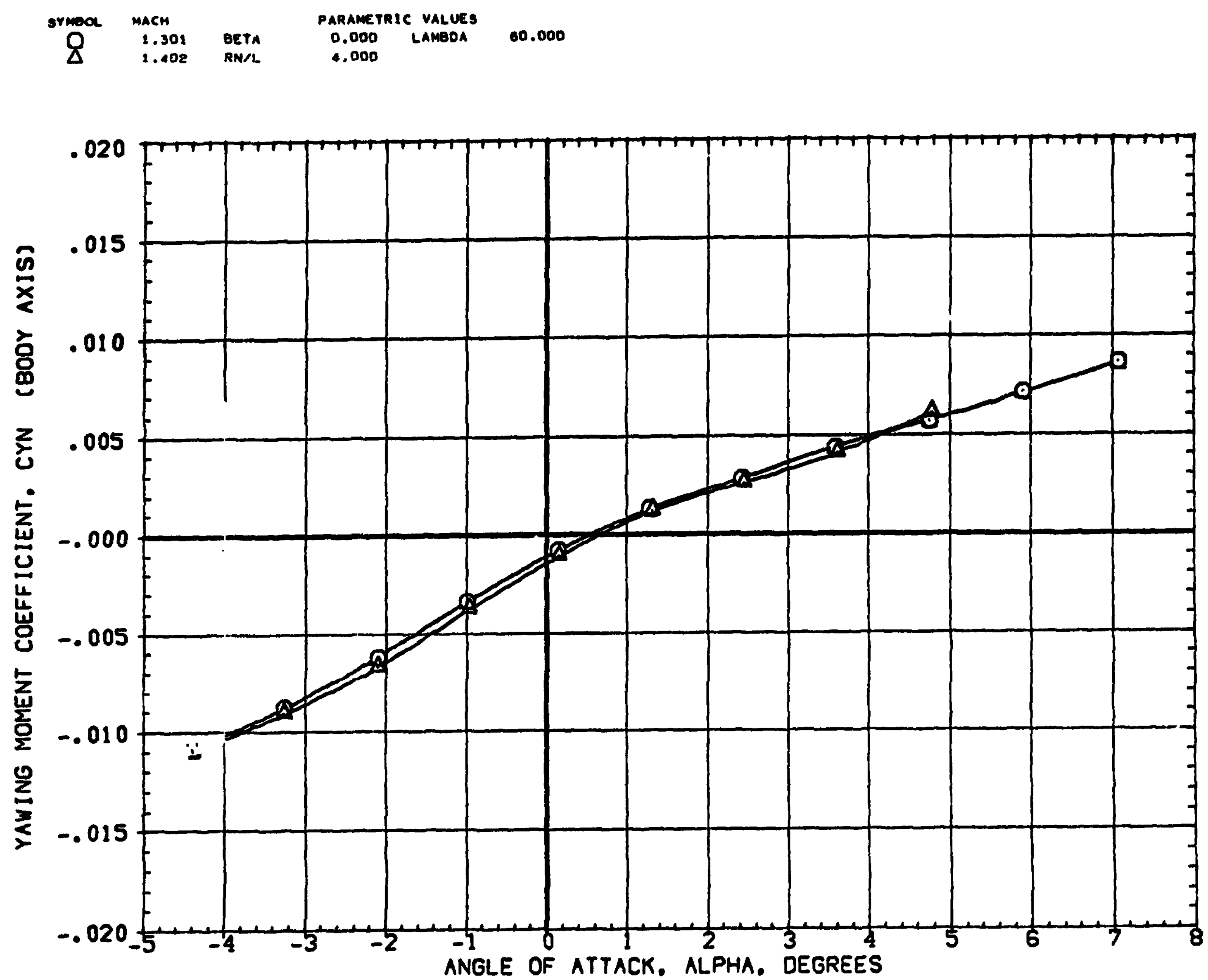


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

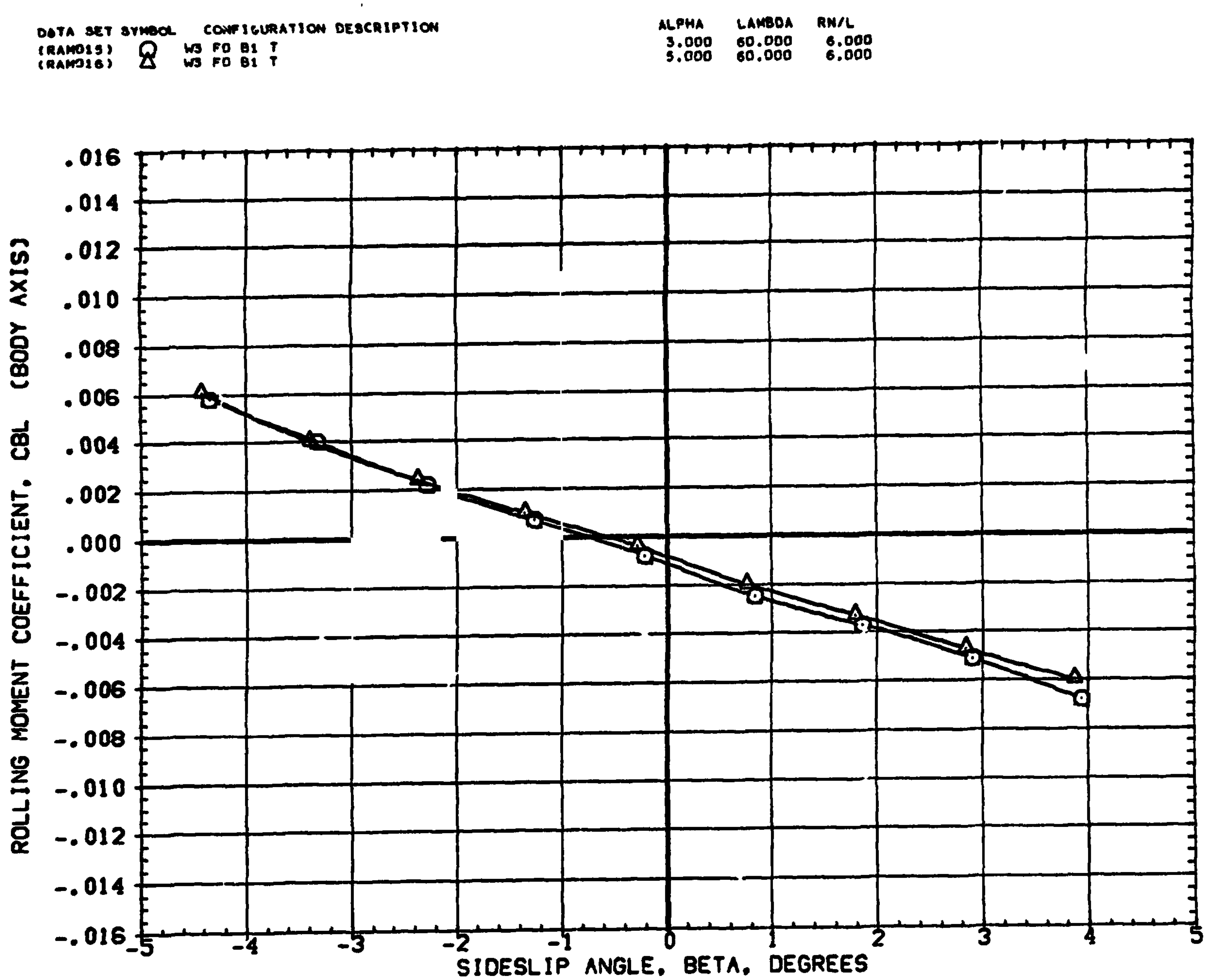


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(A)MACH = 0.80

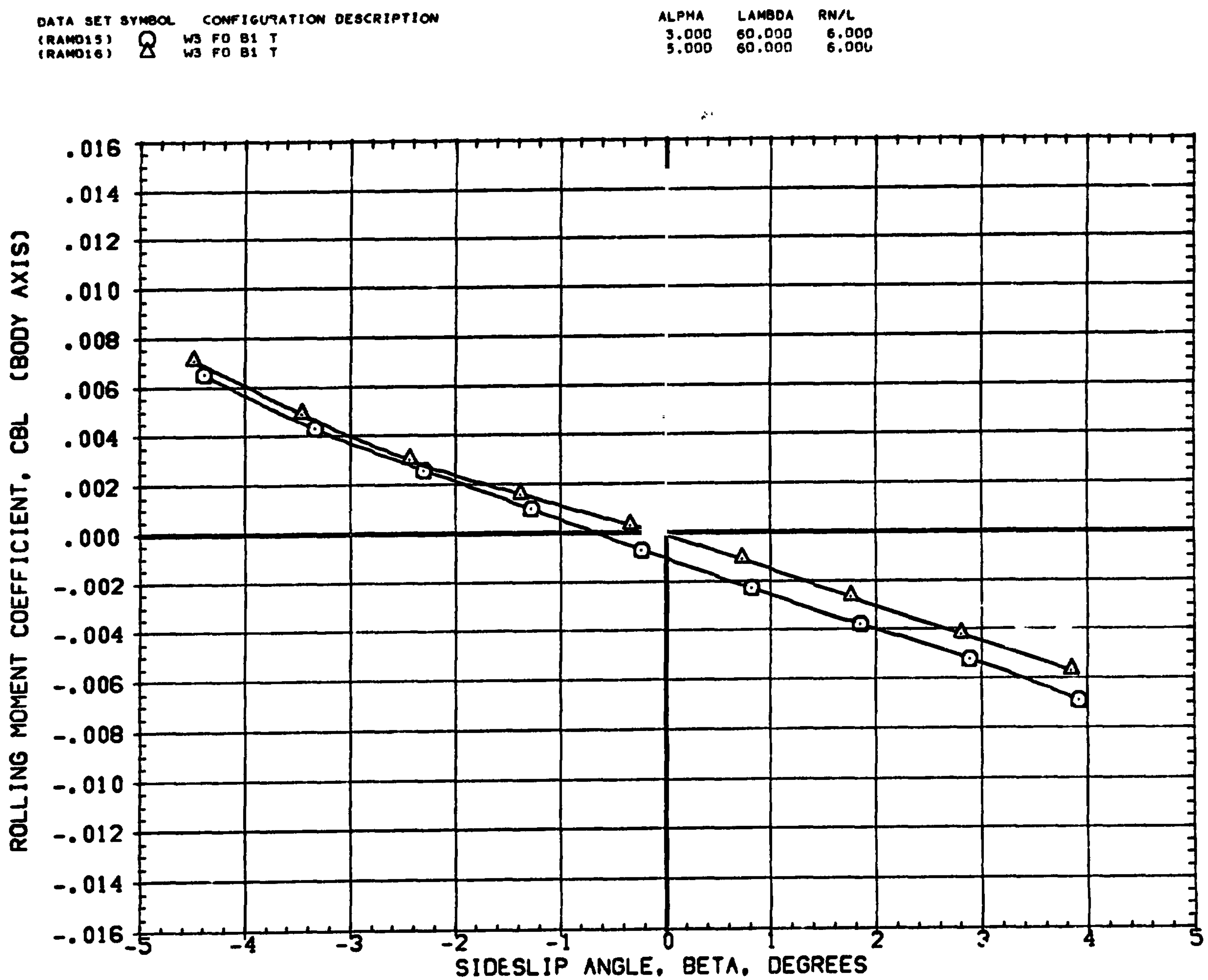


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(B)MACH = 0.95

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAND15)	○	W3 F0 B1 T	3.000	60.000	6.000
(RAND16)	△	W3 F0 B1 T	5.000	60.000	6.000

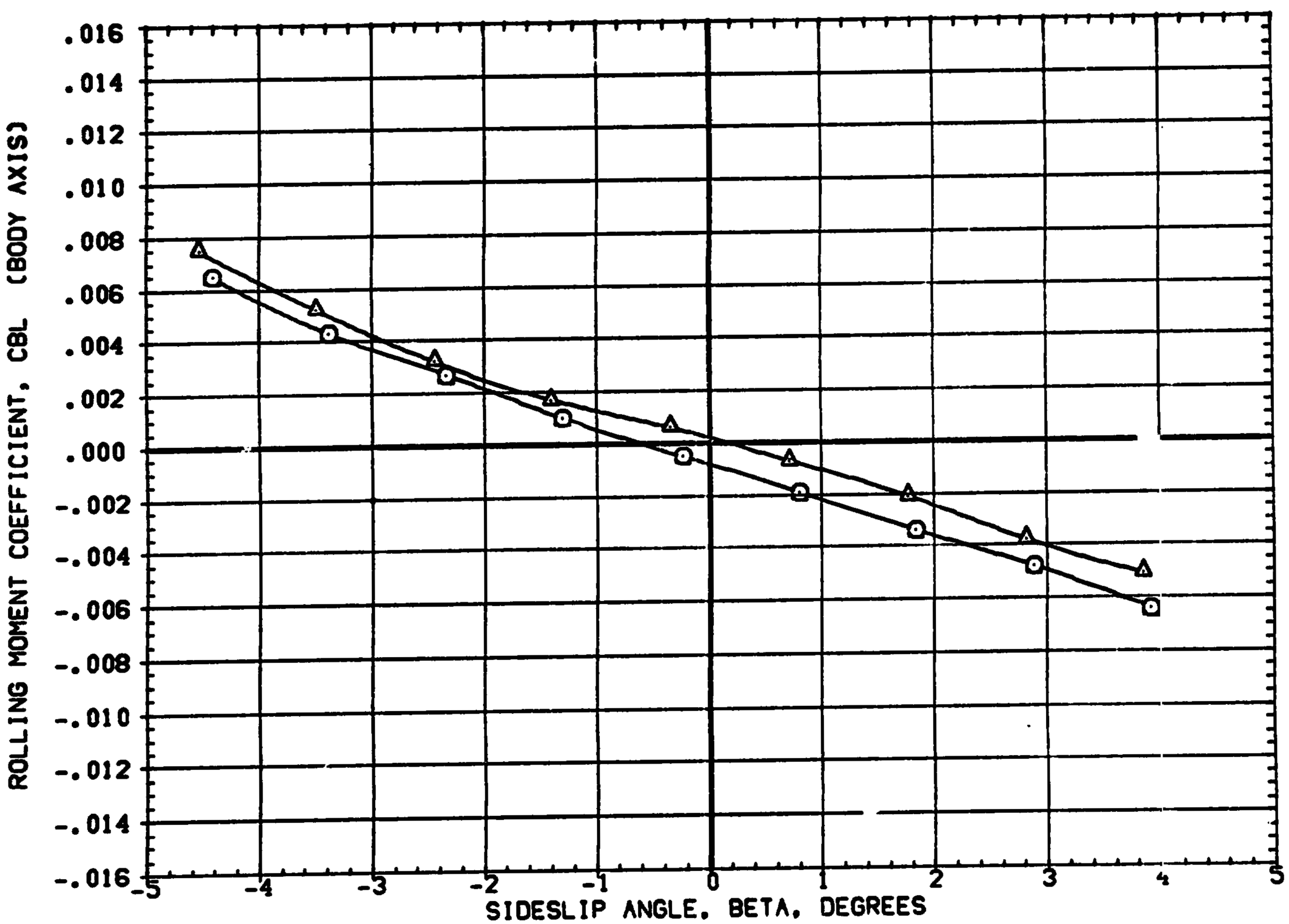


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(C)MACH = 0.98

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAM015)	○	W3 F0 B1 T	3.000	60.000	6.000
(RAM016)	△	W3 F0 B1 T	5.000	60.000	6.000

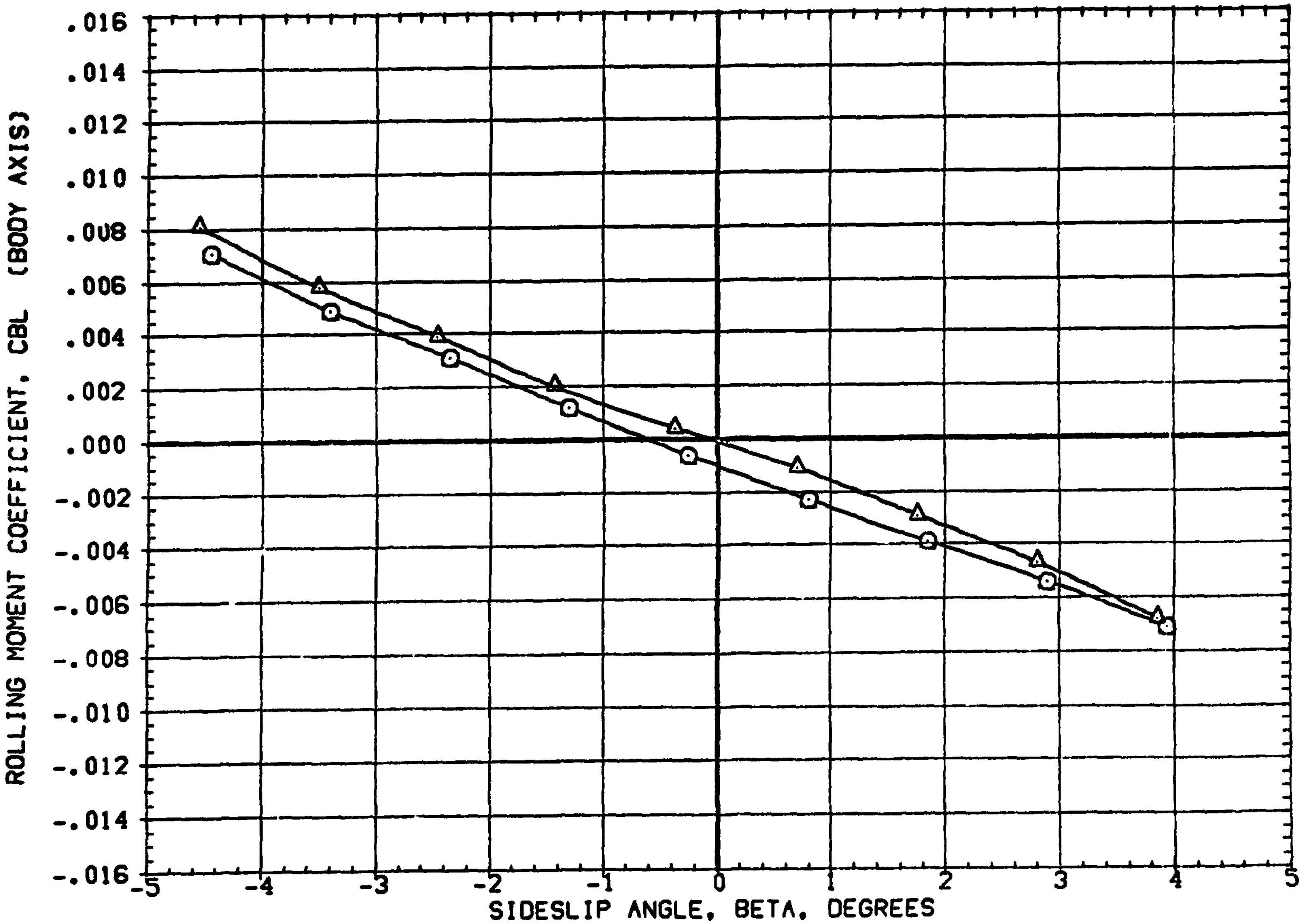


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(D)MACH = 1.05

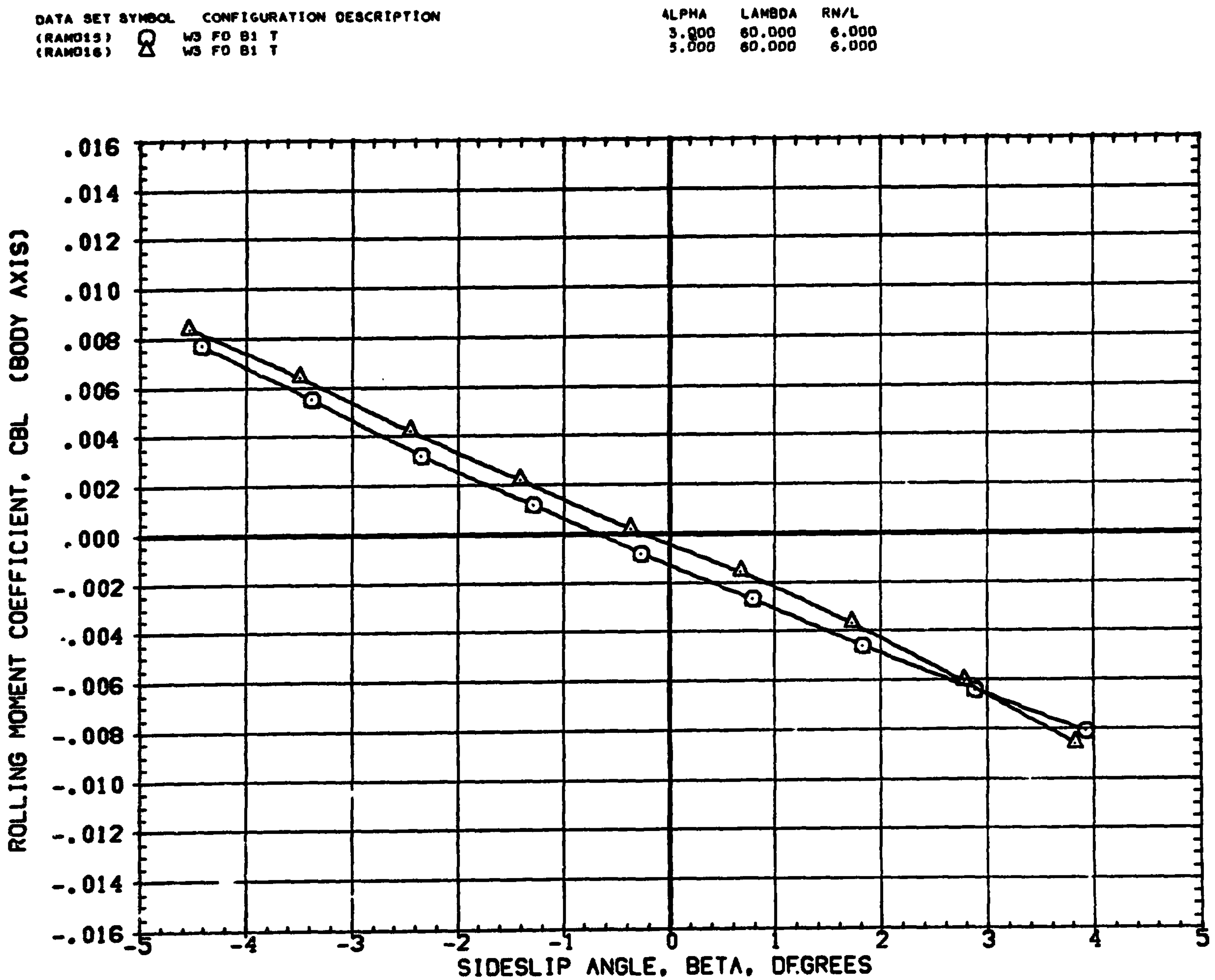


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(E)MACH = 1.10

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAM015)	○	W3 F0 B1 T	3.000	60.000	6.000
(RAM016)	△	W3 F0 B1 T	5.000	60.000	6.000

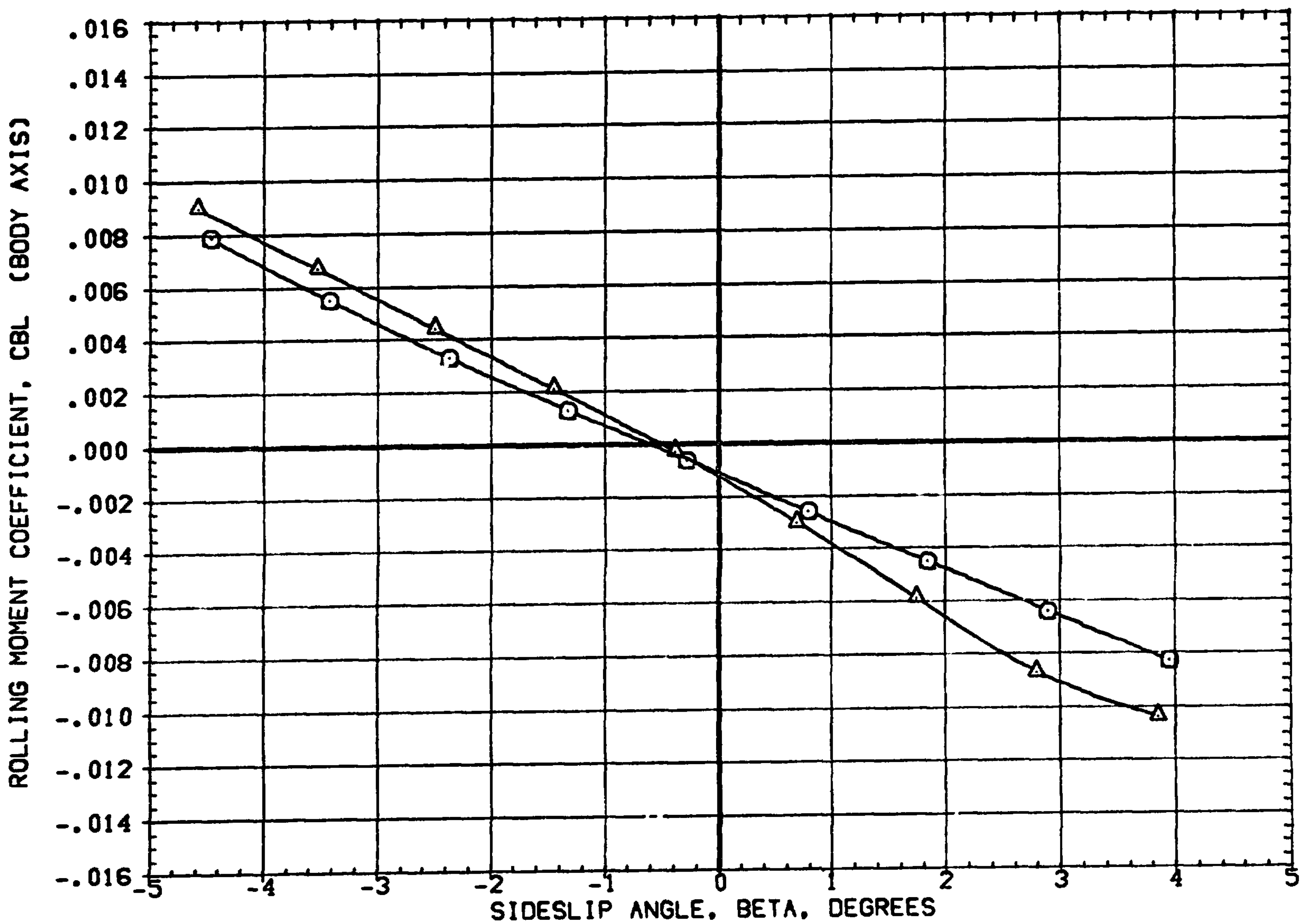


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(F)MACH = 1.20

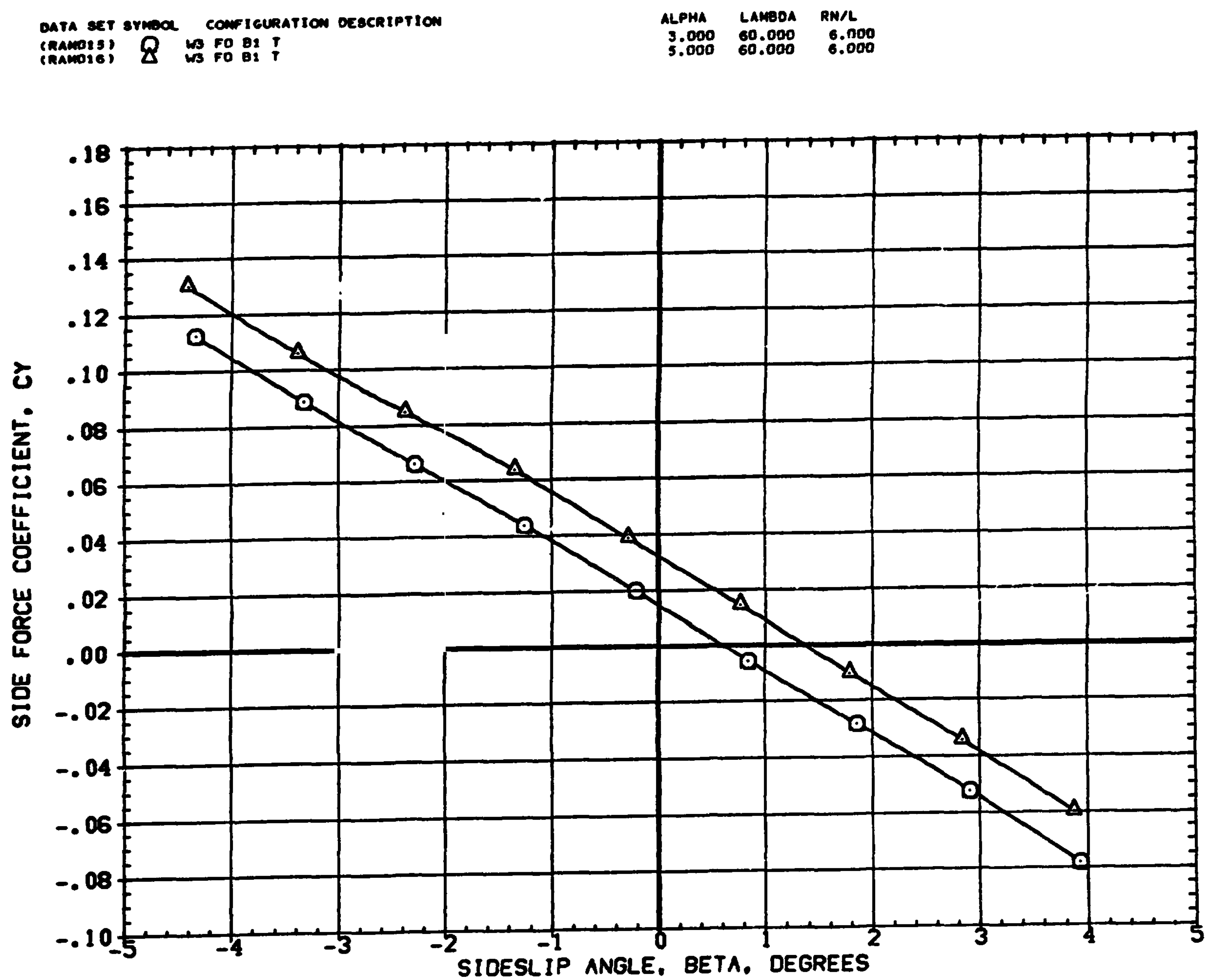


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(A)MACH = 0.80

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAM015)	○	W3 F0 B1 T	3.000	60.000	6.000
(RAM016)	△	W3 F0 B1 T	5.000	60.000	6.000

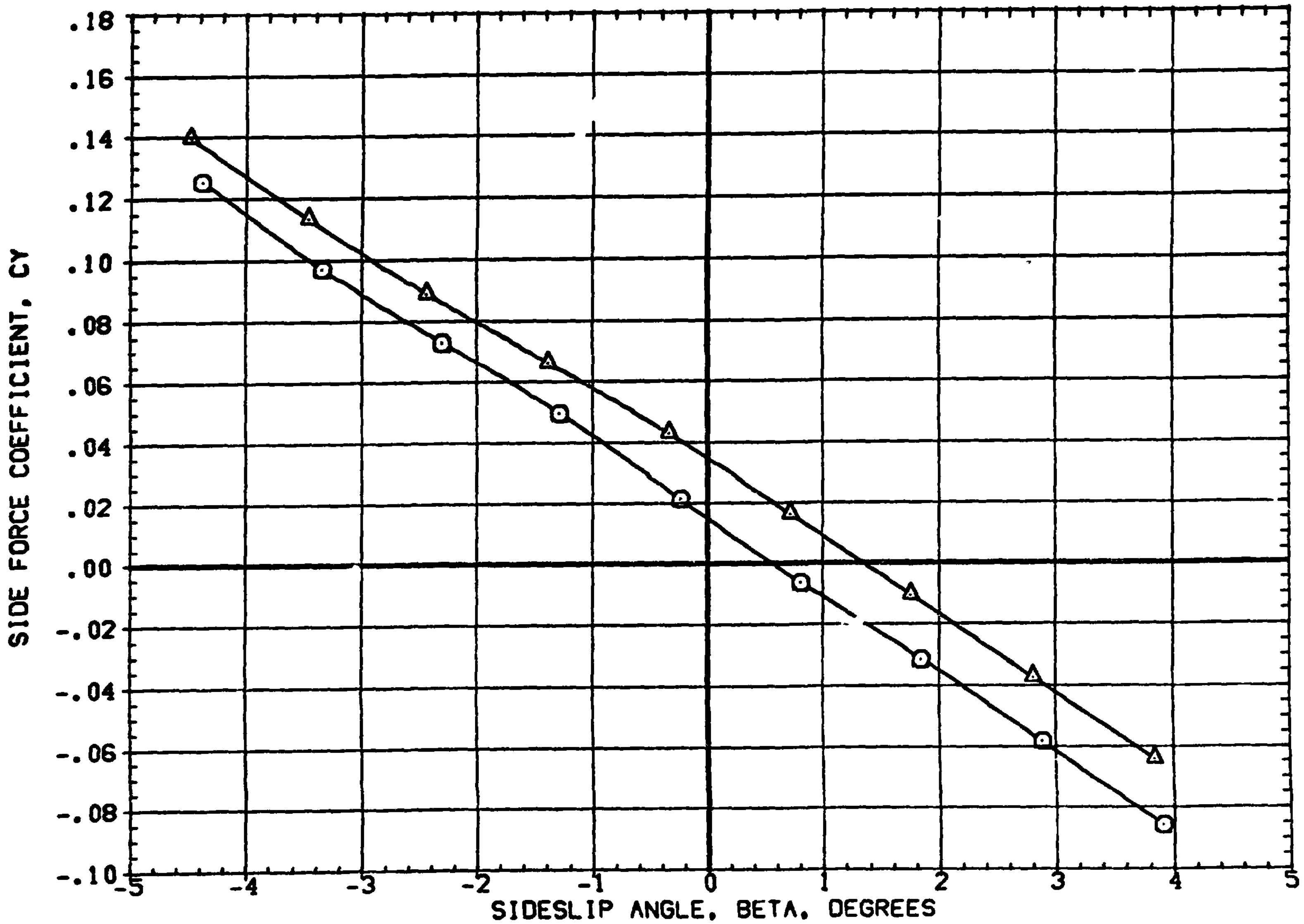


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(B)MACH = 0.95

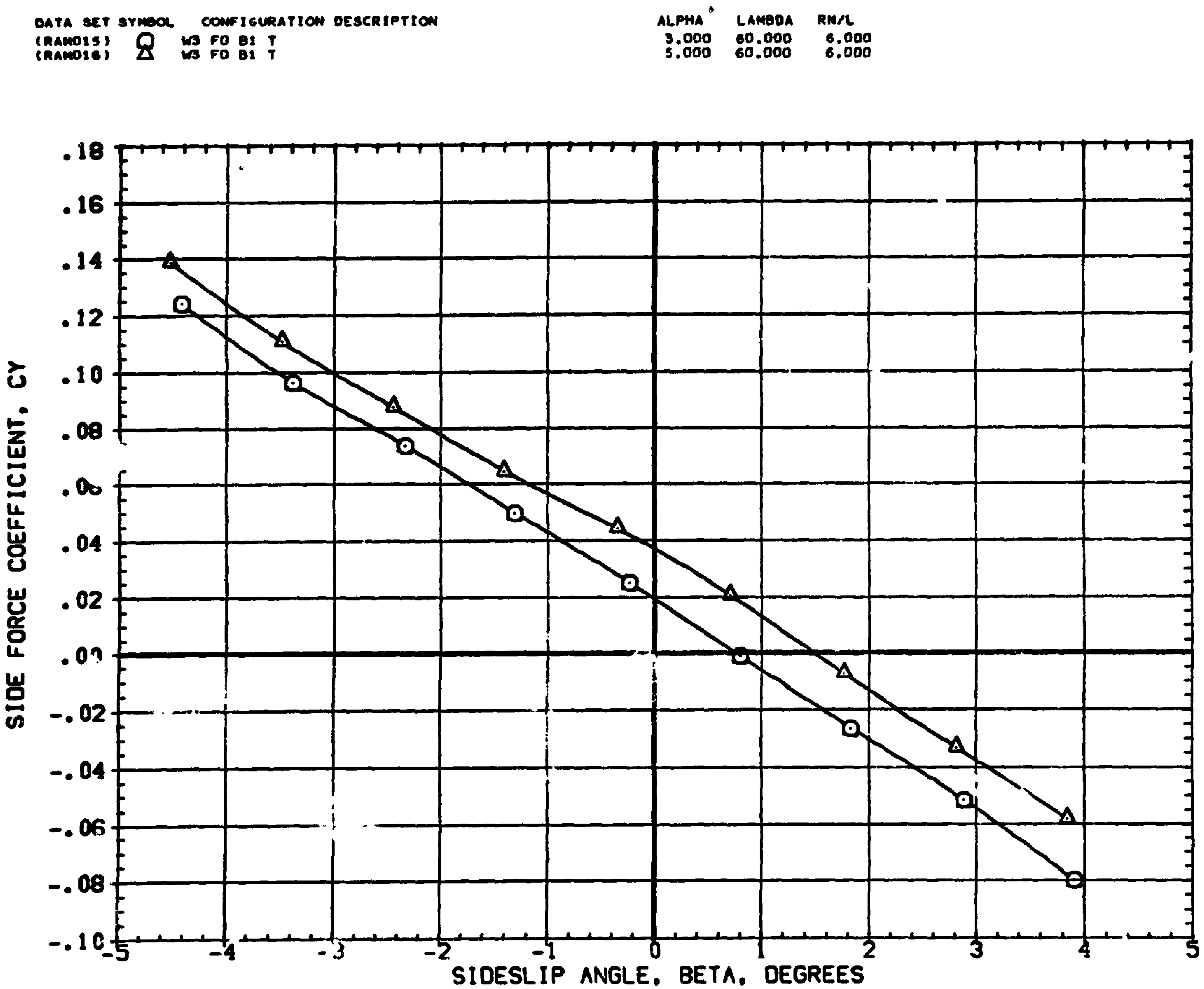


FIGURE 5. LATERAL-DIRECTIONAL AERODYN.MIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(C)MACH = 0.98

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAH015)	⊙	W3 F0 B1 T	3.000	60.000	6.000
(RAH016)	△	W3 F0 B1 T	5.000	60.000	6.000

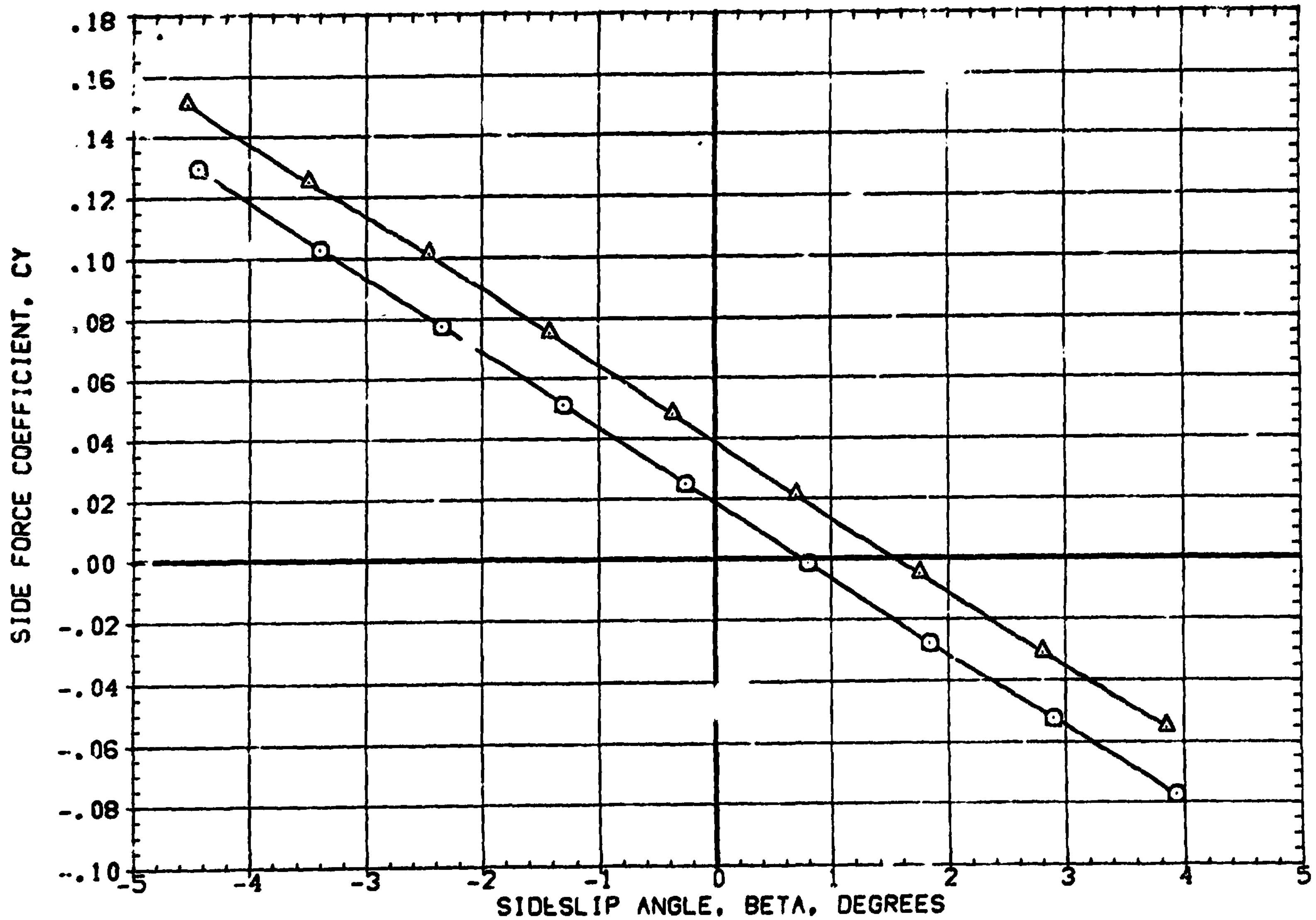


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(D)MACH = 1.05

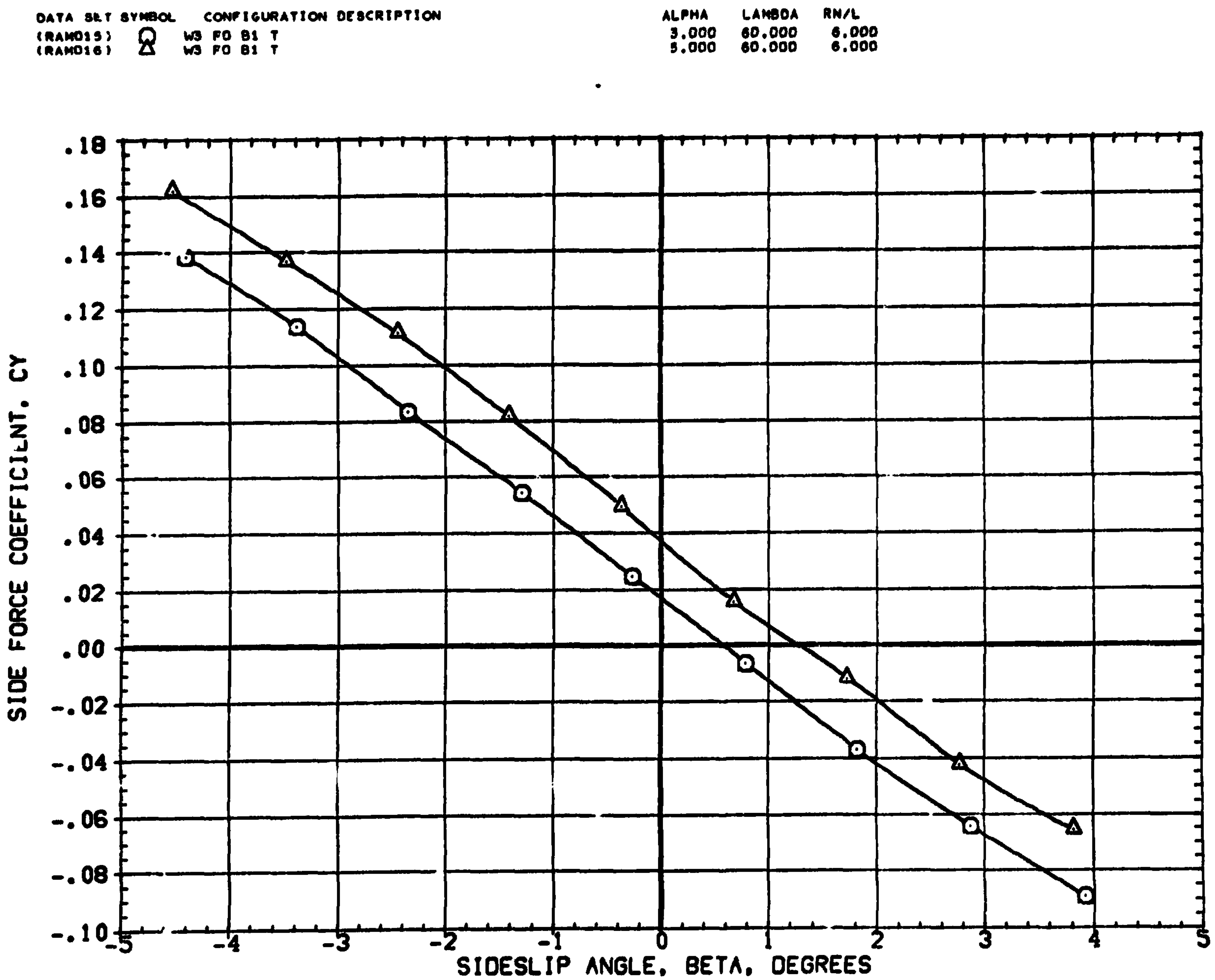


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(E)MACH = 1.10

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAM015)	○	W3 FD B1 T	3.000	60.000	6.000
(RAM016)	△	W3 FD B1 T	5.000	60.000	6.000

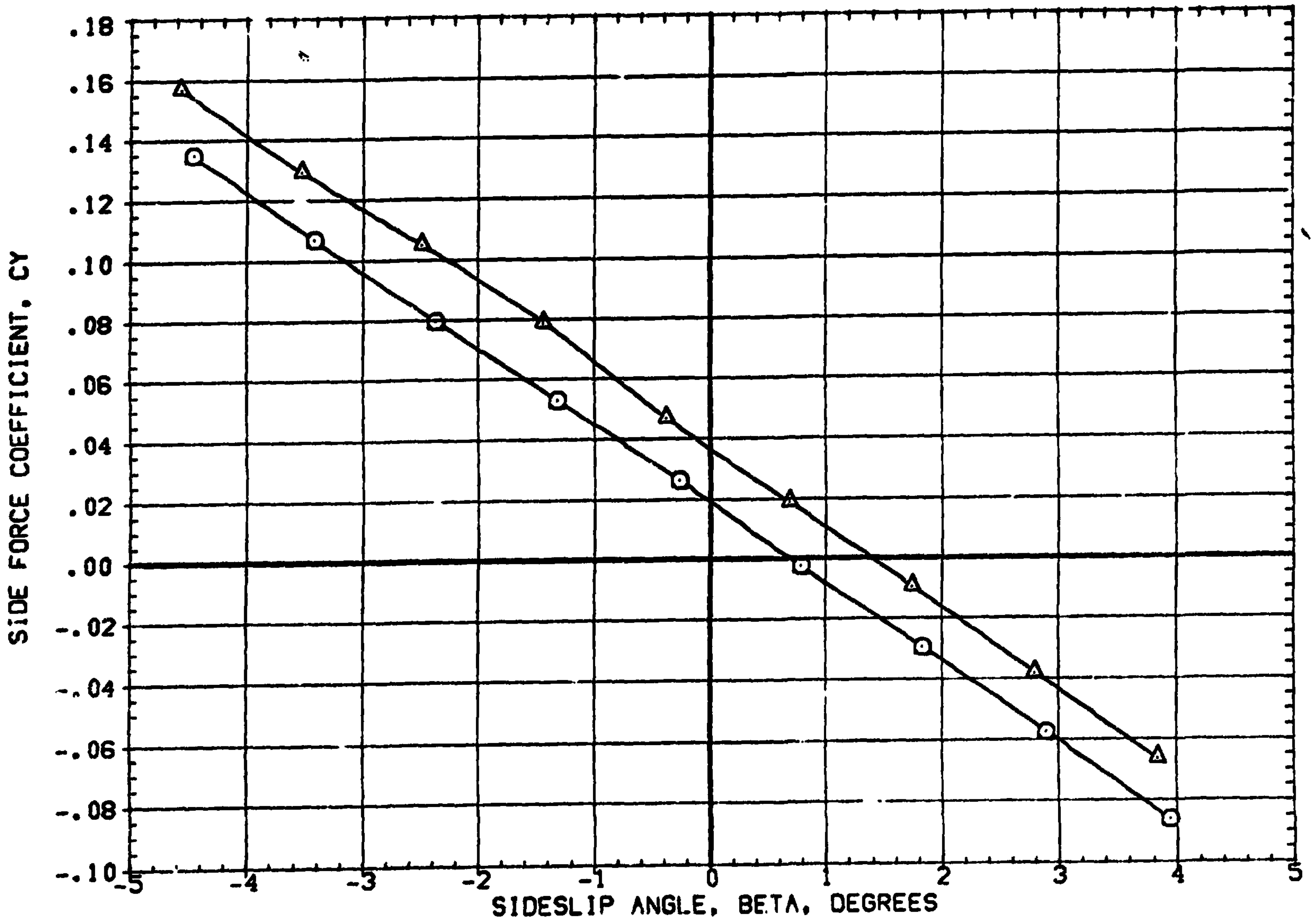


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(F)MACH = 1.20

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAM015)	○	W3 F0 B1 T	3.000	60.000	6.000
(RAM016)	△	W3 F0 B1 T	5.000	60.000	6.000

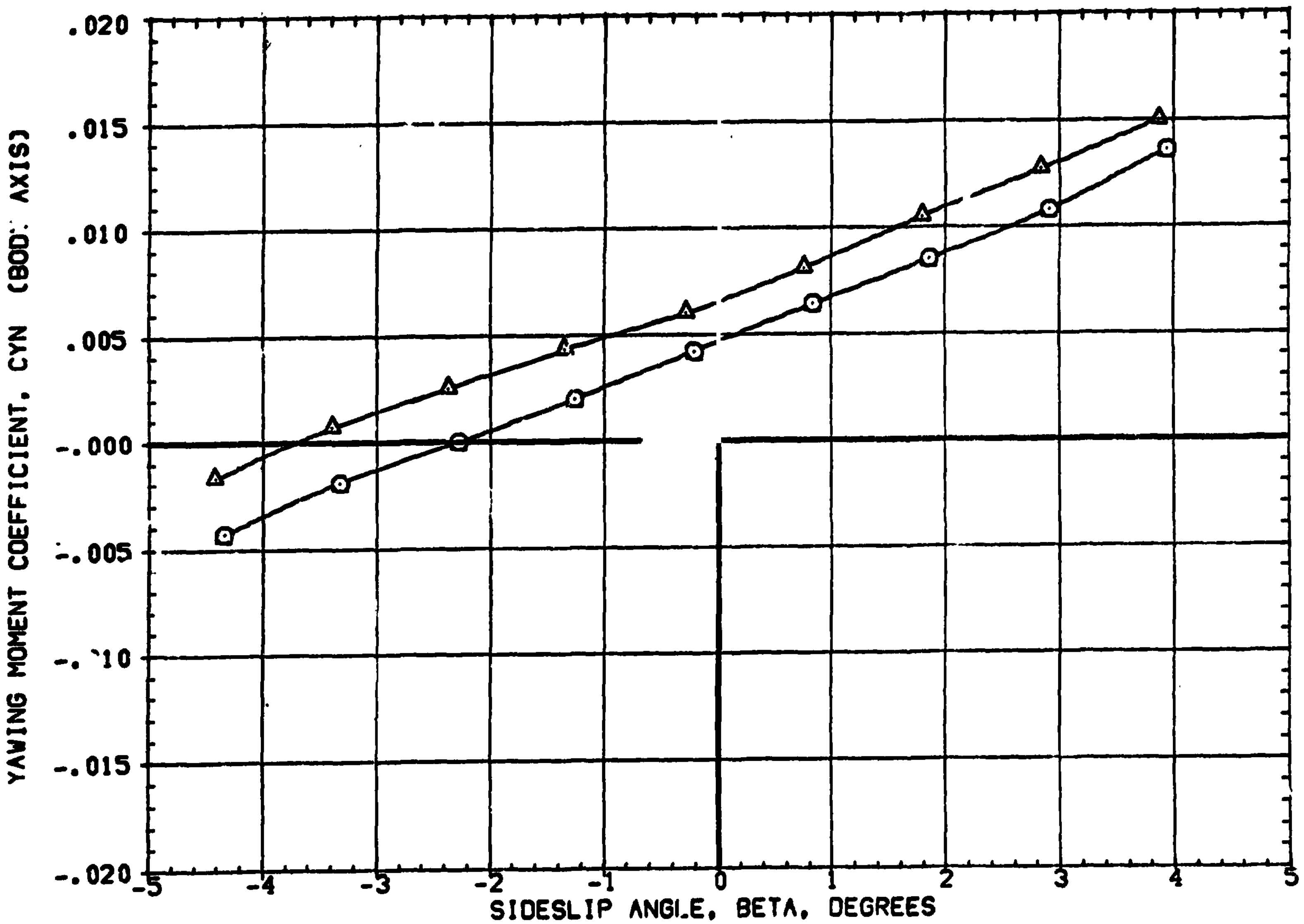


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(A)MACH = 0.80

DATA SET	SYMBOL	CONFIGURATION DESCRIPTION	ALPHA	LAMBDA	RN/L
(RAM015)	○	W3 FO B1 T	3.000	60.000	6.000
(RAM016)	△	W3 FO B1 T	5.000	60.000	6.000

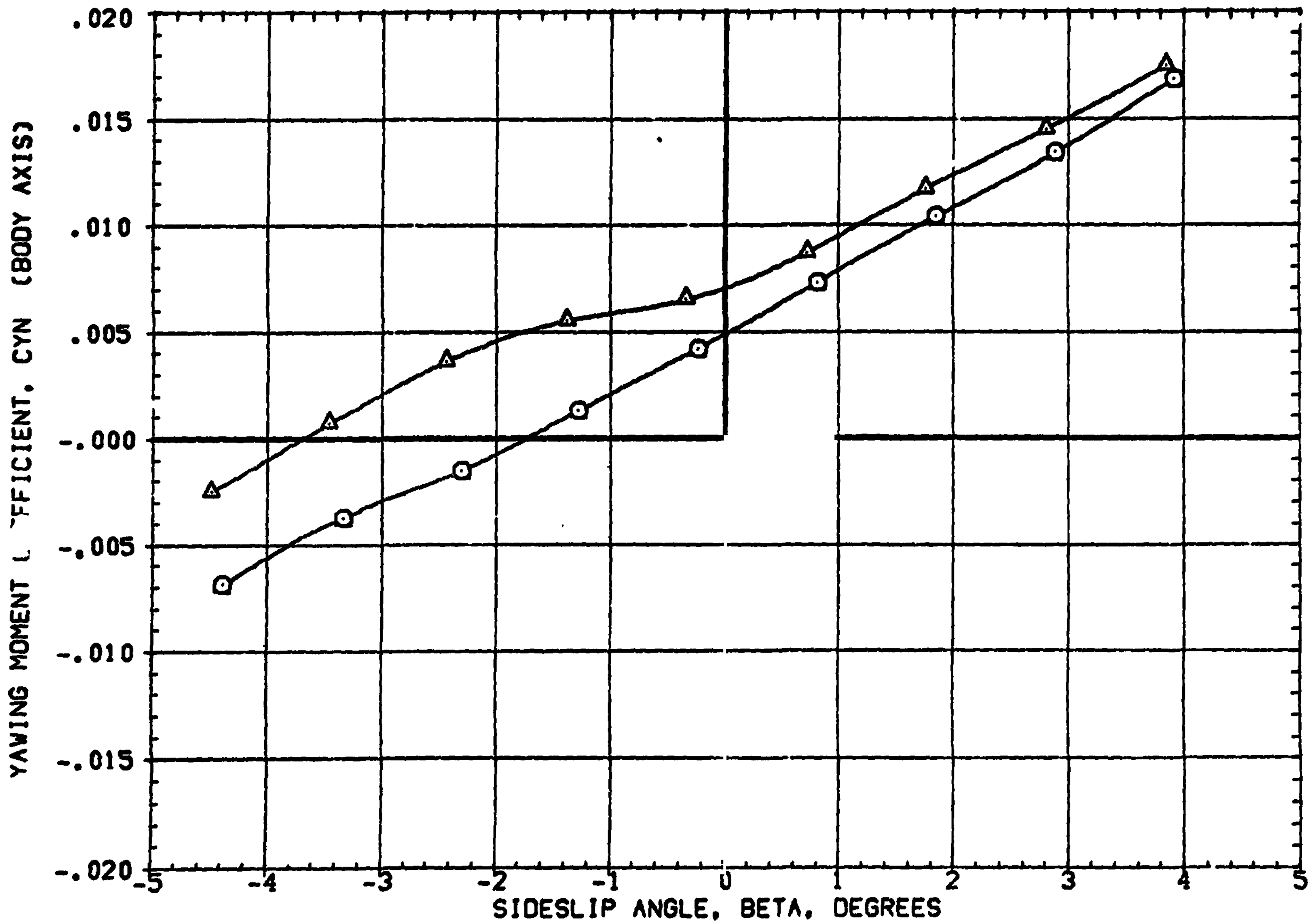


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(B)MACH = 0.95

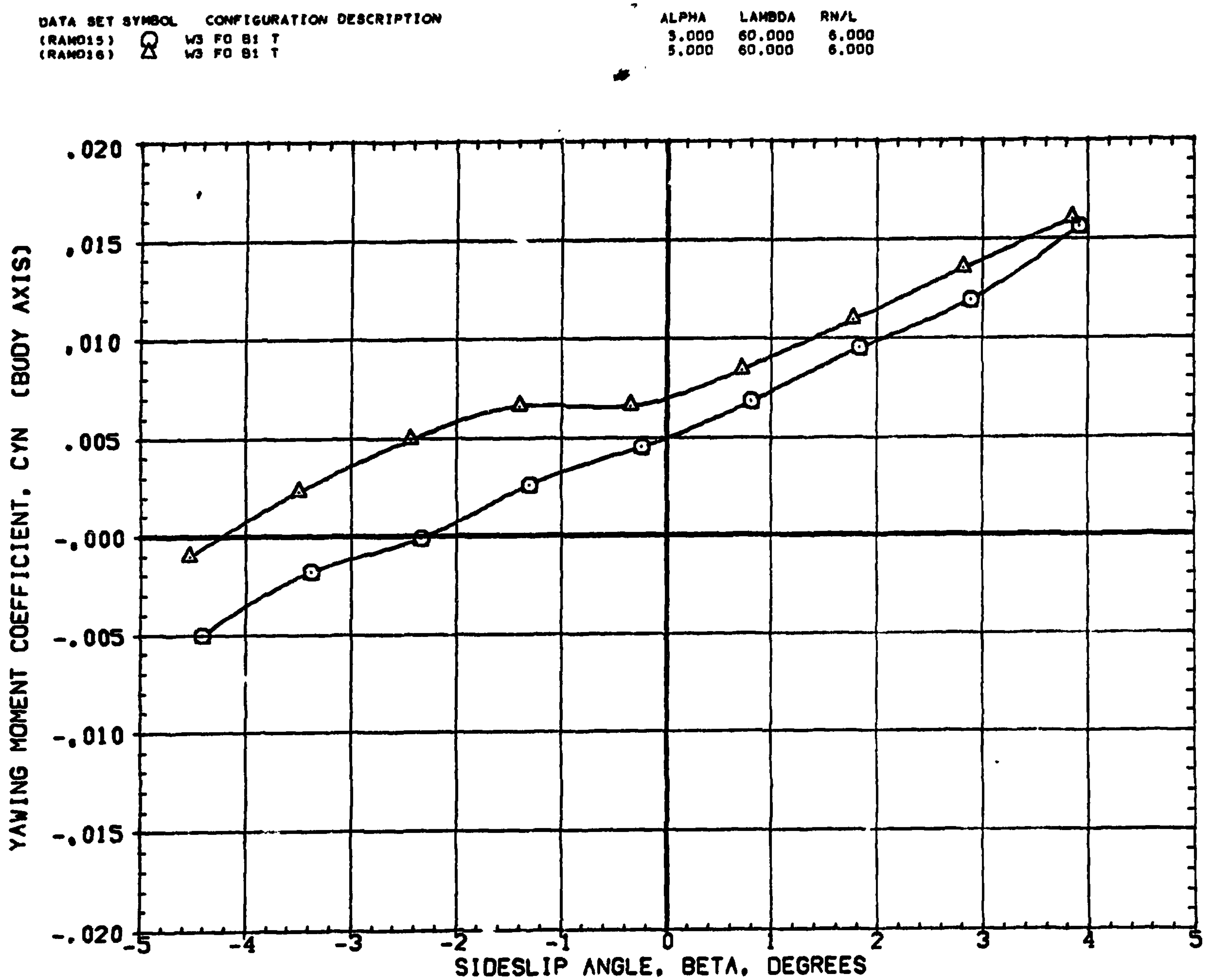


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

MACH = 0.98

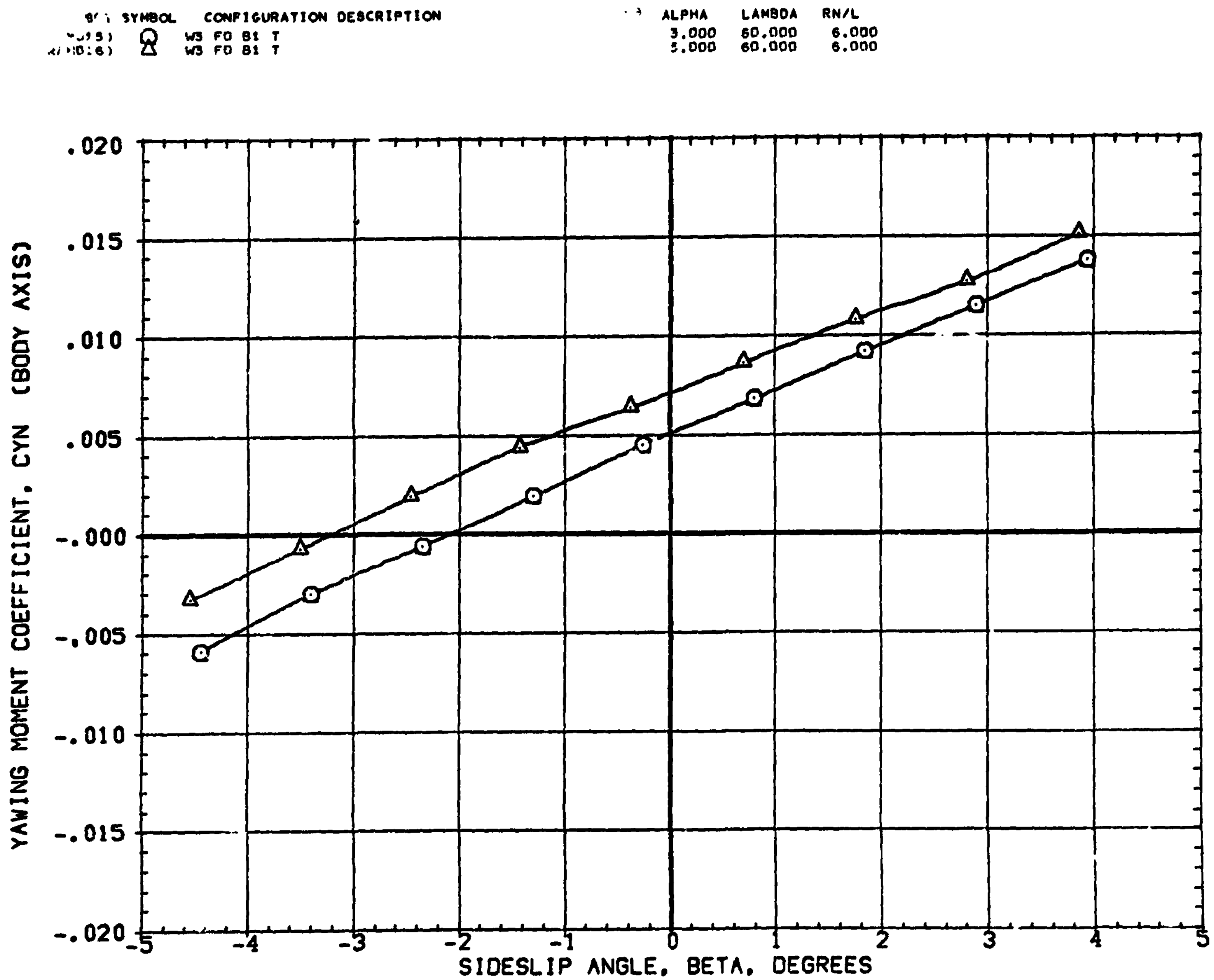


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(D)MACH = 1.05

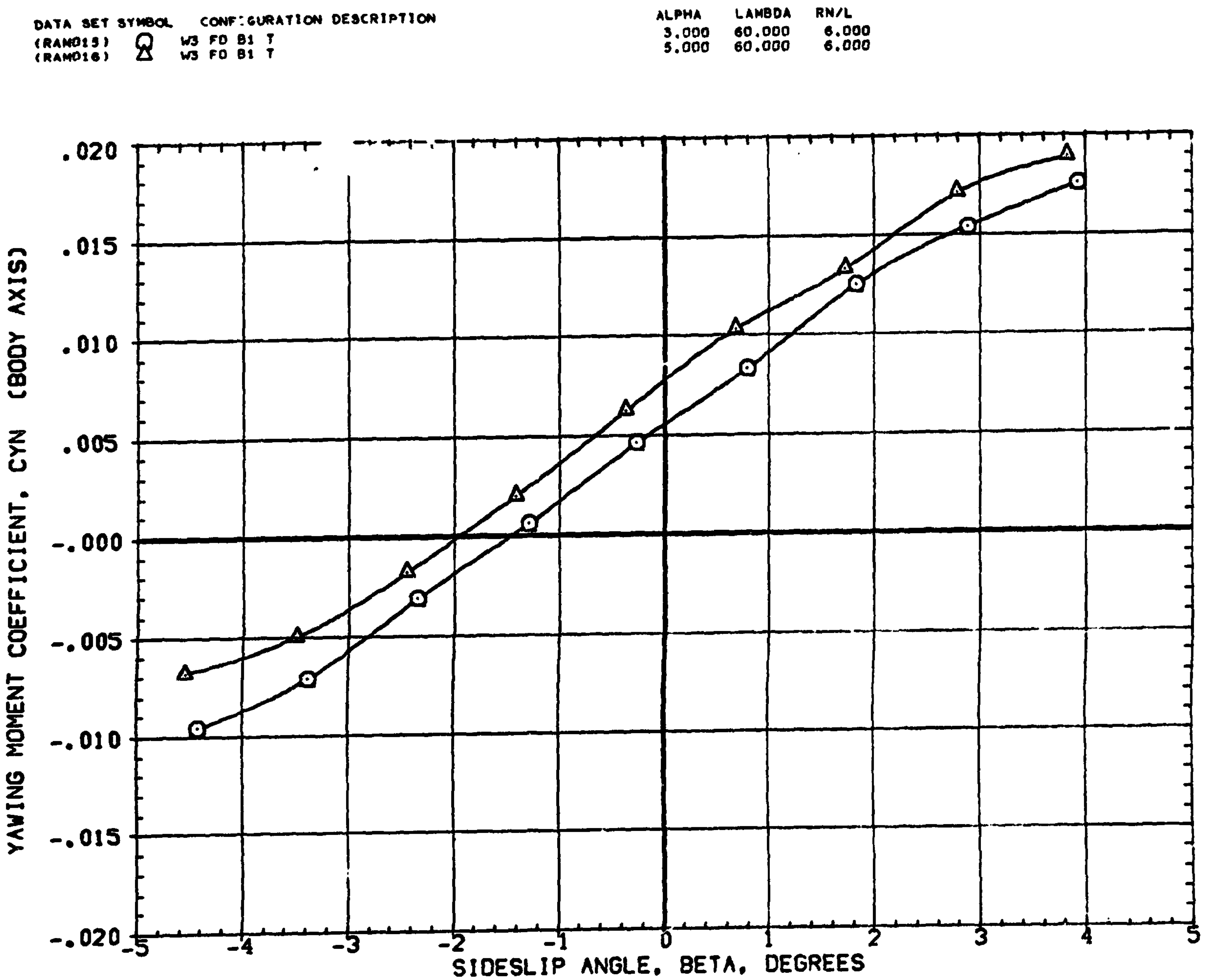


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(E)MACH = 1.10

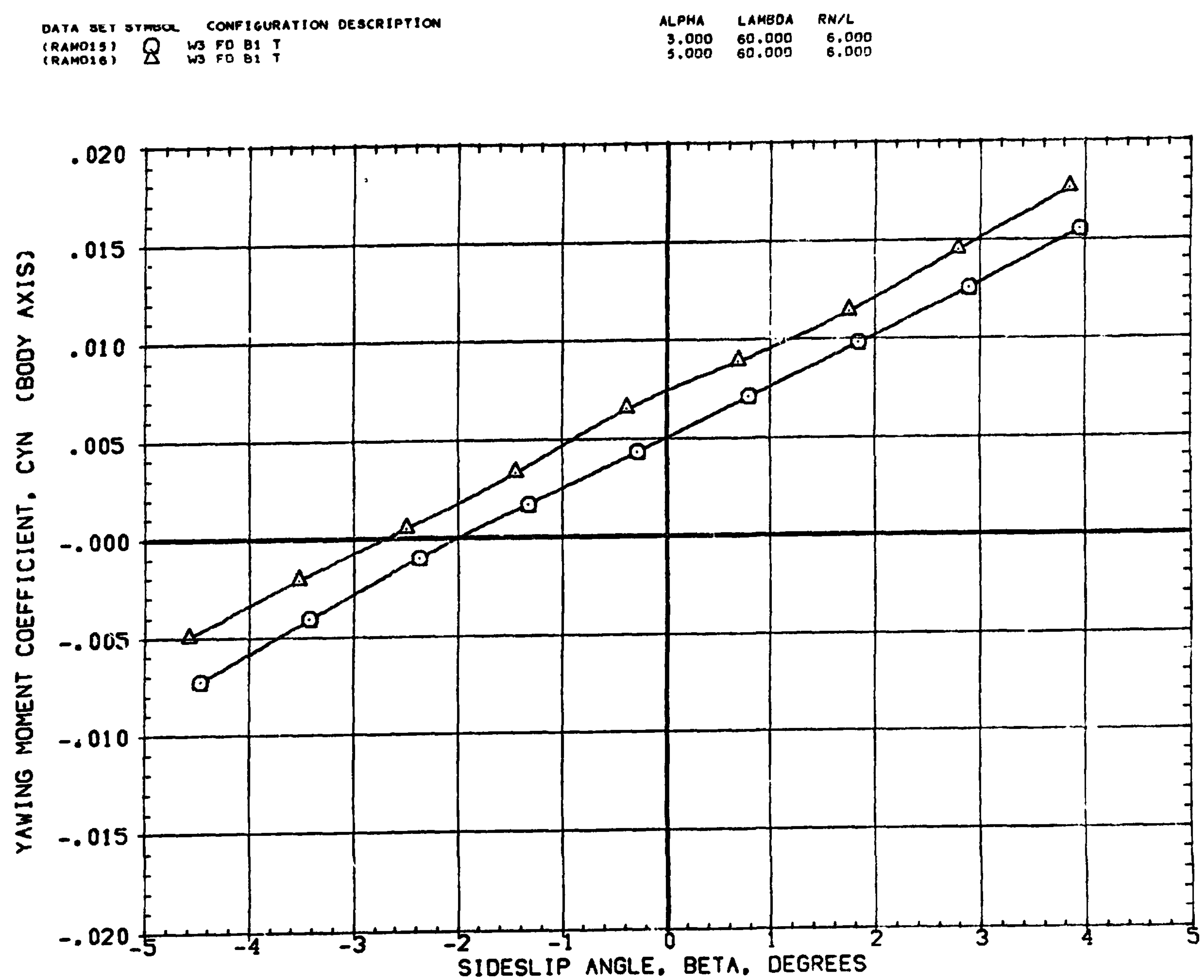


FIGURE 5. LATERAL-DIRECTIONAL AERODYNAMIC CHARACTERISTICS, LAMBDA = 60 DEGREES.

(F)MACH = 1.20