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LONGTUDINAL AERODYNAMIC CHARACTERISTICS OF 45^{0} SWEPT WINGS AT MACH≈ 0

by

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16. Abstract

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LONGITUDINAL AERODYNAMIC CHARACTERISTICS OF 45° SWEPT WINGS AT MACH ≈ 0

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SUMMARY

A systematic experimental study has been undertaken to provide data concerning the effect of aft area on the 45° swept-wing longitudinal aerodynamic characteristics at low subsonic speeds. The study was conducted over an angle-of-attack range from approximately -2° to +28°. The data are presented without analysis.

INTRODUCTION

Moderately swept wings are often used for fixed-wing fighter aircraft, as shown in figure 1, due to the cruise requirement. However, these levels of sweep may reduce the high angle of attack maneuver capabilities of such a wing due to early breakdown of the organized leading-edge shed-vortex-flow system. A wind-tunnel investigation has been conducted to determine if this vortex flow could be stabilized by properly shaping the planform aft of the leading edge. Stabilizing this flow to higher angles of attack is important because of the extension in the associated high-lift characteristics. A wing with a 45° leading-edge sweep was chosen for study as being typical of this class of wings.

Presented in this paper are the static-longitudinal-aerodynamic characteristics of 14 cropped 45° wings at a Mach number less than 0.2. An analysis of the lift characteristics was made in reference 1 to assess the significance of planform shaping on the vortex flow aerodynamics of moderately swept wings; therefore, no analysis is included herein.

SYMBOLS

Values are given in both SI Units and U. S. Customary Units. The measurements and calculations were made in U. S. Customary Units.

A	aspect ratio
b	span, cm(in.)
C_D	drag coefficient, $\frac{\text{Drag}}{q_\infty S_{ref}}$
$C_{D,o}$	experimental value of drag coefficient at $C_L = 0$
C_L	lift coefficient, $\frac{\text{Lift}}{q_\infty S_{ref}}$
C_m	pitching-moment coefficient about the reference point, x_{ref} or at $c_{ref}/4$, $\frac{\text{Pitching moment}}{q_\infty S_{ref} c_{ref}}$
c	streamwise chord, cm(in.)
M	Mach number of free stream
q_∞	free-stream dynamic pressure, N/m^2 (lbf/ft^2)
S_{ref}	reference area, $m^2(ft^2)$
x_{ref}	reference point for pitch calculation, aft of apex, cm(in.)
α	angle of attack, degrees

Λ	leading-edge sweep angle, positive for sweepback, degrees
λ	taper ratio, c_t/c_r
Ω	trailing-edge sweep angle, positive for sweepback, degrees

Subscripts:

r	root
ref	reference
t	tip

MODEL AND TEST DESCRIPTION

Tables I and II present the geometrical and reference values for fifteen wind tunnel models, respectively. The reference values are the true planform areas and mean geometric chords. Most of the models were obtained from models I and X as is shown in figures 2 and 3. Model VIII is an $A=1$, $\Lambda=45^\circ$, $\lambda=1$ wing (figure 4) and model IX is model IV with its trailing edge beveled and used as the leading edge. (Model IX was tested to provide data for an investigation of augmented vortex lift associated with the side edge. The results are reported in reference 1.) All models were obtained from flat plates and the leading and side edges were beveled symmetrically.

The tests were conducted in the Langley 7 x 10 foot wind tunnel at Mach numbers less than 0.20 and at Reynolds numbers less than 3.74×10^6. The test set-up is shown in figure 4 with the active and dummy balance housings in place. No blockage or jet boundary corrections were necessary due to the slotted configuration of the test section. Chamber and two base pressures were measured and the axial forces corrected to these pressures being equal to free-stream static.

CONCLUSIONS

Longitudinal aerodynamic characteristics for fourteen 45° swept-wing models at low subsonic speeds have been presented. In addition, one of the models was tested trailing edge forward and these data are also reported. The angle-of-attack range utilized was from approximately -2° to +28°. The data are presented without analysis.

Reference

Lamar, John E.: Summary of Some Recent Studies of Subsonic Vortex Lift and Parmeters Affecting the Leading-Edge Vortex Stability. AIAA No. 76-414, presented at the AIAA Ninth Fluid and Plasma Dynamics Conference, San Diego, CA, July 14-16, 1976.

TABLE I

MODEL GEOMETRIC CHARACTERISTICS

Model	A	Λ,deg	Ω,deg	λ	c_r cm	c_r in	c_t cm	c_t in	b cm	b in
I	1.000	45	-45	.333	76.20	(30.00)	25.40	(10.00)	50.80	(20.00)
II	1.118	↓	-30	.388	65.46	(25.77)	↓	↓	↓	↓
III	1.224	↓	-15	.441	57.61	(22.68)	↓	↓	↓	↓
IV	1.333	↓	0	.500	50.80	(20.00)	↓	↓	↓	↓
V	1.464	↓	15	.577	43.99	(17.32)	↓	↓	↓	↓
VI	1.651	↓	30	.703	36.14	(14.23)	↓	↓	↓	↓
VII	2.000	↓	45	1.000	25.40	(10.00)	↓	↓	↓	↓
VIII	1.000	↓	↓	↓	50.80	(20.00)	50.80	(20.00)		
IX	1.333	0	-45	.500			25.40	(10.00)		
X	1.333	45	0	↓	101.60	(40.00	50.80	(20.00)	101.60	(40.00)
XI	1.714	↓	↓	.400	84.66	(33.33)	33.86	(13.33)	↓	↓
XII	2.154	↓	↓	.300	72.57	(28.57)	21.77	(8.57)	↓	↓
XIII	2.667	↓	↓	.200	63.50	(25.00)	12.70	(5.00)	↓	↓
XIV	3.273	↓	↓	.100	56.44	(22.22)	5.64	(2.22)	↓	↓
XV	4.000	↓	↓	0	50.80	(20.00)	0	(0.00)	↓	↓

TABLE II

MODEL REFERENCE VALUES

Model	c_{ref}		x_{ref}		S_{ref}	
	cm	in	cm	in	m^2	ft^2
I	55.04	(21.67)	24.33	(9.58)	.258	(2.78)
II	48.39	(19.05)	22.94	(9.03)	.230	(2.48)
III	43.59	(17.16)	21.95	(8.64)	.211	(2.27)
IV	39.52	(15.56)	21.16	(8.33)	.193	(2.08)
V	35.53	(13.99)	20.45	(8.05)	.177	(1.90)
VI	31.09	(12.24)	19.74	(7.77)	.156	(1.68)
VII	25.40	(10.00)	19.05	(7.50)	.129	(1.39)
VIII	50.80	(20.00)	25.40	(10.00)	.258	(2.78)
IX	39.52	(15.56)	9.88	(3.89)	.193	(2.08)
X	79.02	(31.11)	42.34	(16.67)	.774	(8.33)
XI	62.89	(24.76)	37.49	(14.76)	.602	(6.48)
XII	51.74	(20.37)	33.78	(13.30)	.479	(5.16)
XIII	43.74	(17.22)	30.68	(12.08)	.387	(4.17)
XIV	37.97	(14.95)	27.97	(11.01)	.316	(3.40)
XV	33.86	(13.33)	25.40	(10.00)	.258	(2.78)

TABLE III

TABULATED WIND TUNNEL DATA

MODEL 11

ALPHA DEG.	MACH NO.	CL	CD	CM
-1.55	.1850	-.0467	.0141	-.0002
-1.02	.1845	-.0316	.0136	-.0001
.04	.1851	-.0001	.0132	.0008
1.09	.1850	.0291	.0137	.0014
2.17	.1851	.0655	.0151	.0020
3.28	.1855	.1031	.0177	.0025
4.37	.1850	.1430	.0218	.0028
5.51	.1850	.1892	.0285	.0027
6.68	.1849	.2385	.0377	.0020
7.84	.1848	.2929	.0497	.0008
9.05	.1851	.3505	.0645	-.0008
10.21	.1852	.4013	.0803	-.0024
11.46	.1850	.4634	.1012	-.0047
13.90	.1848	.5809	.1496	-.0114
16.42	.1853	.6995	.2106	-.0202
18.81	.1854	.8097	.2788	-.0313
21.10	.1844	.9099	.3533	-.0446
23.46	.1851	1.0096	.4396	-.0615
25.04	.1847	1.0631	.4978	-.0737

MODEL II

ALPHA DEG.	MACH NO.	CL	CD	CM
-1.55	.1850	-.0467	.0141	-.0002
-1.02	.1845	-.0316	.0136	-.0001
.04	.1851	-.0001	.0132	.0008
1.09	.1850	.0291	.0137	.0014
2.17	.1851	.0655	.0151	.0020
3.28	.1855	.1031	.0177	.0025
4.37	.1850	.1430	.0218	.0028
5.51	.1850	.1892	.0285	.0027
6.68	.1849	.2385	.0377	.0020
7.84	.1848	.2929	.0497	.0008
9.05	.1851	.3505	.0645	-.0008
10.21	.1852	.4013	.0803	-.0024
11.46	.1850	.4634	.1012	-.0047
13.90	.1848	.5809	.1496	-.0114
16.42	.1853	.6995	.2106	-.0202
18.81	.1854	.8097	.2788	-.0313
21.10	.1844	.9099	.3533	-.0446
23.46	.1851	1.0096	.4396	-.0615
25.04	.1847	1.0631	.4978	-.0737

MODEL III

ALPHA DEG.	MACH NO.	CL	CD	CM
-1.62	.1848	-.0568	.0158	.0021
-1.03	.1850	-.0364	.0151	.0021
.04	.1852	-.0025	.0147	.0027
1.10	.1852	.0309	.0152	.0032
2.17	.1854	.0671	.0164	.0034
3.28	.1852	.1080	.0191	.0035
4.37	.1852	.1482	.0233	.0036
5.52	.1852	.1984	.0303	.0031
6.67	.1850	.2538	.0405	.0019
7.84	.1847	.3103	.0531	.0003
9.01	.1852	.3641	.0675	-.0017
10.17	.1845	.4198	.0843	-.0038
11.43	.1856	.4830	.1058	-.0067
13.86	.1853	.6041	.1558	-.0141
16.34	.1849	.7242	.2175	-.0243
18.67	.1850	.8335	.2857	-.0365
21.00	.1853	.9336	.3618	-.0520
23.28	.1856	1.0226	.4434	-.0703
24.82	.1847	1.0768	.5015	-.0845

MODEL IV

ALPHA DEG.	MACH NO.	CL	CD	CM
-1.48	.1849	-.0489	.0174	.0006
-1.03	.1852	-.0346	.0170	.0007
.05	.1855	.0037	.0165	.0015
1.09	.1855	.0369	.0169	.0021
2.16	.1852	.0750	.0182	.0023
3.26	.1853	.1165	.0204	.0025
4.36	.1850	.1593	.0245	.0029
5.49	.1856	.2091	.0314	.0026
6.65	.1852	.2654	.0418	.0014
7.81	.1852	.3221	.0550	.0000
8.97	.1851	.3786	.0698	-.0018
10.15	.1853	.4382	.0877	-.0040
11.35	.1852	.4966	.1082	-.0067
13.79	.1854	.6176	.1584	-.0144
16.21	.1849	.7375	.2194	-.0248
18.52	.1850	.8393	.2843	-.0368
20.83	.1850	.9412	.3610	-.0544
23.05	.1854	1.0266	.4397	-.0752
24.38	.1849	1.0669	.4870	-.0887

MODEL V

ALPHA DEG.	MACH NO.	CL	CD	CM
-1.53	.1852	-.0543	.0194	.0007
-1.04	.1851	-.0354	.0191	.0007
.04	.1854	.0028	.0184	.0012
1.09	.1857	.0408	.0188	.0016
2.16	.1855	.0809	.0198	.0012
3.26	.1855	.1258	.0222	.0013
4.35	.1854	.1720	.0265	.0011
5.47	.1852	.2236	.0337	.0004
6.63	.1852	.2833	.0447	-.0013
7.78	.1851	.3420	.0580	-.0037
8.96	.1856	.4065	.0743	-.0062
10.11	.1852	.4662	.0925	-.0093
11.34	.1854	.5299	.1144	-.0126
13.73	.1858	.6528	.1657	-.0210
16.16	.1852	.7719	.2278	-.0318
18.44	.1853	.8766	.2943	-.0448
20.68	.1851	.9691	.3679	-.0622
22.88	.1851	1.0436	.4437	-.0839
24.46	.1852	1.0781	.4962	-.1020

MODEL VI

ALPHA DEG.	MACH NO.	CL	CD	CM
-1.48	.1854	-.0564	.0201	.0001
-1.03	.1854	-.0415	.0196	.0000
.04	.1856	.0041	.0192	.0004
1.07	.1856	.0420	.0197	.0005
2.13	.1860	.0865	.0210	.0002
3.20	.1855	.1321	.0234	-.0001
4.27	.1859	.1803	.0277	-.0005
5.38	.1856	.2367	.0350	-.0013
6.51	.1854	.2976	.0459	-.0037
7.63	.1856	.3640	.0601	-.0067
8.75	.1857	.4239	.0761	-.0100
9.91	.1863	.4906	.0955	-.0138
11.08	.1854	.5566	.1175	-.0189
13.40	.1856	.6794	.1678	-.0275
15.77	.1853	.8037	.2304	-.0393
17.97	.1857	.8962	.2925	-.0518
20.13	.1856	.9752	.3595	-.0677
22.17	.1857	1.0123	.4171	-.0867

MODEL VII

ALPHA DEG.	MACH NO.	CL	CD	CM
-1.24	.1859	-.0477	.0208	-.0007
-.99	.1857	-.0345	.0205	-.0005
.06	.1864	.0110	.0202	.0004
1.09	.1865	.0552	.0208	.0009
2.14	.1861	.1028	.0223	.0008
3.20	.1864	.1519	.0251	.0010
4.28	.1862	.2074	.0298	.0014
5.36	.1856	.2682	.0374	.0004
6.48	.1857	.3347	.0490	-.0021
7.59	.1856	.4088	.0646	-.0065
8.74	.1857	.4804	.0830	-.0112
9.85	.1857	.5489	.1030	-.0155
11.03	.1858	.6227	.1273	-.0213
13.31	.1860	.7518	.1806	-.0295
15.62	.1858	.8662	.2433	-.0378
17.74	.1857	.9391	.3018	-.0436
19.87	.1857	.9871	.3605	-.0540

MODEL VIII

ALPHA DEG.	MACH NO.	CL	CD	CM
-2.11	.1854	-.0648	.0127	-.0009
-1.03	.1355	-.0342	.0114	-.0000
.02	.1855	-.0041	.0106	.0014
1.07	.1852	.0231	.0110	.0029
2.14	.1853	.0546	.0119	.0037
3.26	.1851	.0904	.0140	.0042
4.36	.1853	.1296	.0174	.0046
5.49	.1855	.1692	.0223	.0046
6.65	.1852	.2173	.0300	.0044
7.83	.1853	.2702	.0413	.0039
9.03	.1855	.3250	.0551	.0021
10.23	.1853	.3813	.0711	.0004
11.47	.1853	.4417	.0906	-.0019
13.98	.1857	.5668	.1393	-.0079
16.55	.1852	.7053	.2049	-.0161
19.01	.1855	.8261	.2772	-.0245
21.42	.1852	.9400	.3588	-.0342
23.82	.1856	1.0500	.4516	-.0461
26.15	.1857	1.1455	.5484	-.0622
27.00	.1859	1.1749	.5845	-.0688

MODEL IX

ALPHA DEG.	MACH NO.	CL	CD	CM
-2.92	.1163	-.0914	.0162	-.0097
-.93	.1168	-.0259	.0142	-.0036
.03	.1167	.0040	.0139	-.0003
1.02	.1164	.0329	.0142	.0027
2.01	.1165	.0649	.0152	.0058
3.04	.1167	.0980	.0168	.0083
4.08	.1165	.1349	.0195	.0116
5.11	.1168	.1727	.0230	.0140
6.18	.1168	.2148	.0282	.0167
7.25	.1168	.2575	.0358	.0191
8.27	.1166	.3020	.0475	.0219
9.33	.1167	.3471	.0605	.0234
10.45	.1165	.3936	.0744	.0230
12.63	.1165	.4939	.1104	.0144
14.84	.1167	.5974	.1567	-.0032
16.94	.1163	.7053	.2121	-.0271
19.05	.1162	.7808	.2657	-.0444
21.07	.1163	.8491	.3224	-.0589
22.24	.1163	.8807	.3565	-.0731

MODEL XI

ALPHA DEG.	MACH NO.	CL	CD	CM
-.04	.0805	.0043	.0142	-.0029
-1.04	.0811	-.0355	.0143	-.0024
-2.07	.0817	-.0819	.0162	-.0017
-2.78	.0805	-.1138	.0173	-.0039
-.01	.0811	.0074	.0141	-.0027
.98	.0802	.0484	.0152	-.0031
2.03	.0820	.0929	.0166	-.0037
3.09	.0802	.1411	.0198	-.0037
4.20	.0820	.1914	.0239	-.0051
5.21	.0802	.2508	.0330	-.0063
6.41	.0814	.3121	.0437	-.0094
7.50	.0805	.3669	.0569	-.0105
8.60	.0791	.4243	.0726	-.0123
9.70	.0805	.4859	.0915	-.0146
10.81	.0788	.5446	.1121	-.0175
11.91	.0782	.6019	.1341	-.0211
13.03	.0788	.6590	.1599	-.0251
15.36	.0770	.7693	.2164	-.0350
17.58	.0761	.8676	.2788	-.0474
19.91	.0794	.9477	.3466	-.0648
21.97	.0785	1.0135	.4141	-.0884
23.15	.0800	1.0350	.4491	-.1303

MODEL XII

ALPHA DEG.	MACH NO.	CL	CD	CM
-.04	.0804	-.0031	.0136	-.0003
-1.04	.0830	-.0474	.0141	.0005
-2.09	.0858	-.1007	.0158	.0026
-2.57	.0847	-.1242	.0163	.0037
-.01	.0841	-.0042	.0144	.0008
1.01	.0830	.0465	.0145	-.0017
2.05	.0850	.0970	.0155	-.0037
3.14	.0833	.1479	.0179	-.0057
4.21	.0850	.2061	.0236	-.0072
5.26	.0833	.2705	.0329	-.0102
6.42	.0844	.3376	.0446	-.0125
7.47	.0836	.3938	.0575	-.0128
8.58	.0822	.4592	.0747	-.0159
9.66	.0827	.5147	.0929	-.0170
10.86	.0827	.5718	.1137	-.0190
11.99	.0824	.6277	.1361	-.0216
13.14	.0816	.6912	.1607	-.0247
15.39	.0819	.7820	.2165	-.0332
17.57	.0810	.8627	.2736	-.0455
19.66	.0798	.9258	.3322	-.0604
21.71	.0831	.9273	.3754	-.0981
22.84	.0795	.9068	.3888	-.1187

MODEL XIII

ALPHA DEG.	MACH NO.	CL	CD	CM
-.20	.0805	.0099	.0180	-.0051
-1.24	.0805	-.0370	.0196	-.0046
-2.24	.0811	-.1008	.0222	.0037
-2.85	.0797	-.1348	.0247	.0046
-.20	.0799	.0081	.0181	-.0046
.82	.0814	.0615	.0188	-.0063
1.84	.0808	.1154	.0195	-.0098
2.90	.0814	.1728	.0218	-.0133
3.95	.0805	.2319	.0262	-.0159
5.05	.0817	.3029	.0356	-.0199
6.13	.0802	.3709	.0477	-.0227
7.20	.0808	.4334	.0626	-.0250
8.32	.0811	.4865	.0788	-.0243
9.39	.0805	.5386	.0960	-.0240
10.52	.0797	.6005	.1174	-.0269
11.54	.0798	.6462	.1376	-.0250
12.76	.0797	.6975	.1629	-.0271
14.97	.0779	.7931	.2155	-.0328
17.11	.0776	.8620	.2682	-.0414
19.23	.0773	.9076	.3200	-.0521
21.22	.0773	.9198	.3663	-.0860
22.58	.0776	.9053	.3872	-.1142

MODEL XIV

ALPHA DEG.	MACH NO.	CL	CD	CM
-.61	.1149	.0026	.0199	-.0012
-1.86	.1147	-.0582	.0198	.0052
-2.11	.1145	-.1207	.0209	.0099
-2.84	.1145	-.1659	.0220	.0136
.03	.1145	.0070	.0206	-.0015
1.09	.1149	.0638	.0217	-.0063
2.21	.1151	.1347	.0225	-.0144
3.34	.1149	.1947	.0248	-.0170
4.41	.1149	.2623	.0305	-.0219
5.56	.1145	.3384	.0424	-.0271
6.71	.1145	.4082	.0570	-.0285
7.85	.1141	.4724	.0734	-.0307
8.99	.1139	.5282	.0914	-.0292
10.13	.1143	.5834	.1118	-.0284
11.31	.1143	.6379	.1346	-.0290
12.44	.1141	.6903	.1588	-.0295
13.66	.1147	.7392	.1860	-.0307
16.01	.1145	.8283	.2427	-.0368
18.14	.1136	.8941	.2983	-.0464
20.05	.1134	.9237	.3452	-.0591
22.28	.1157	.8927	.3782	-.1067

MODEL XV

ALPHA DEG.	MACH NO.	CL	CD	CM
-.02	.0819	.0071	.0235	-.0046
-.99	.0810	-.0506	.0248	.0315
-1.95	.0810	-.0959	.0245	.0028
-2.54	.0819	-.1508	.0259	.0134
-.02	.0819	.0081	.0242	-.0039
.99	.0819	.0665	.0255	-.0108
1.96	.0833	.1264	.0271	-.0175
2.99	.0822	.1912	.0274	-.0241
3.99	.0822	.2536	.0308	-.0301
4.99	.0822	.3232	.0400	-.0352
6.16	.0830	.3915	.0510	-.0382
7.17	.0833	.4486	.0650	-.0391
8.21	.0824	.5104	.0826	-.0399
9.23	.0819	.5614	.0999	-.0379
10.36	.0819	.6100	.1194	-.0363
11.41	.0830	.6568	.1400	-.0390
12.58	.0822	.7090	.1638	-.0375
14.86	.0850	.7944	.2152	-.0395
16.96	.0853	.8499	.2634	-.0449
19.06	.0841	.9131	.3212	-.0547
21.09	.0822	.9433	.3729	-.0695
22.64	.0833	.9014	.3931	-.1144

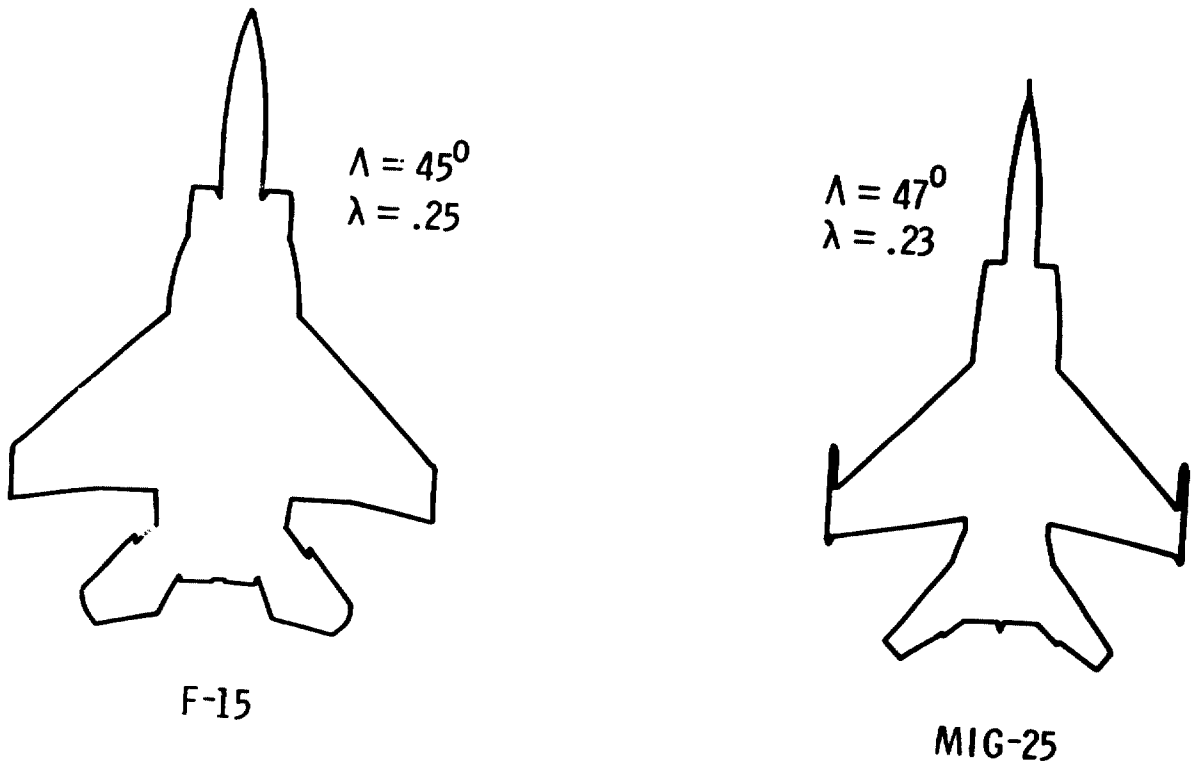


Figure 1. Current Fighter Aircraft.

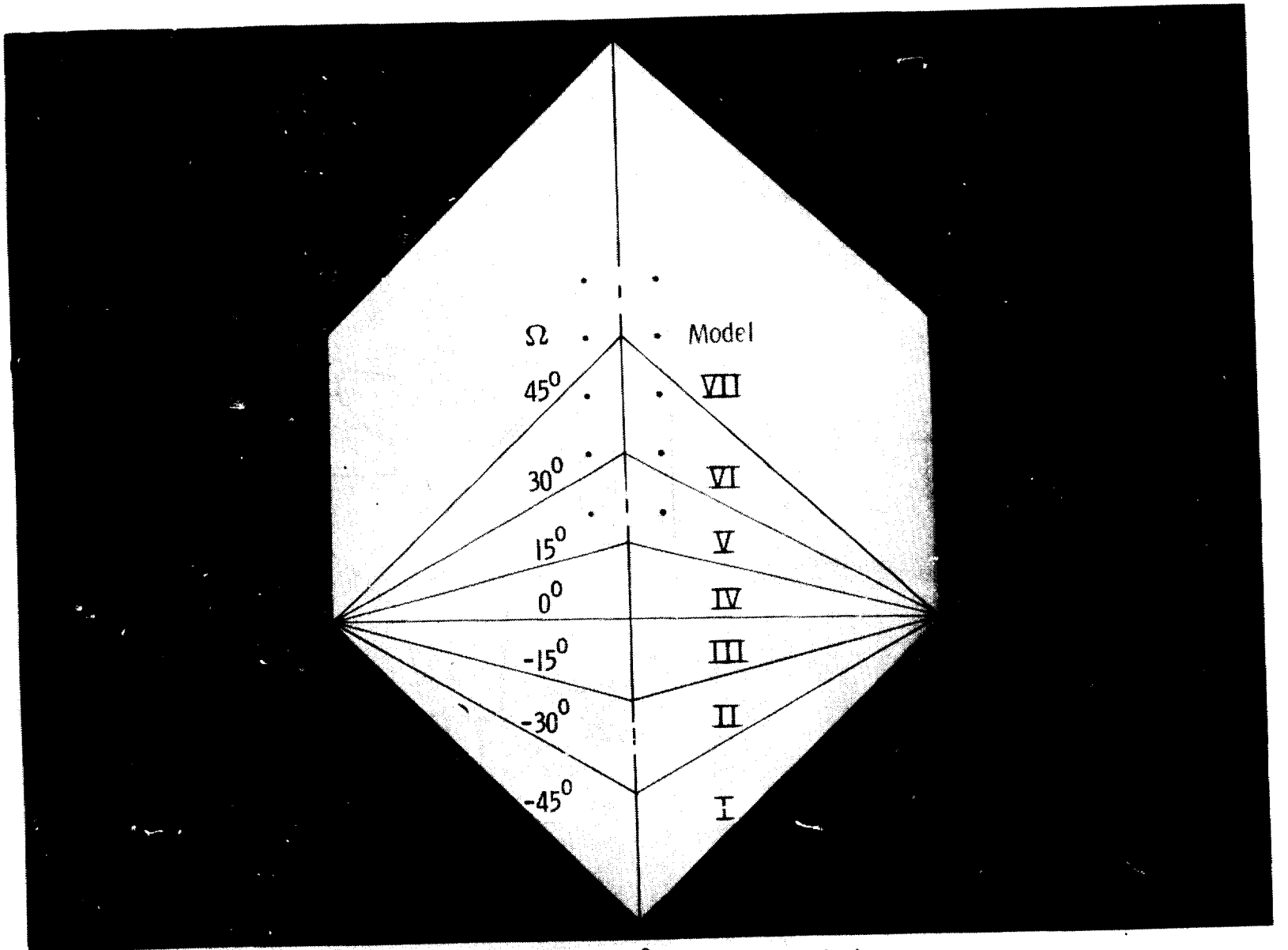


Figure 2. Basic 45° cropped diamond wing.

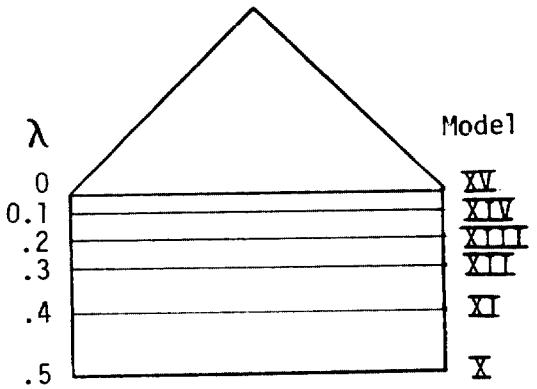
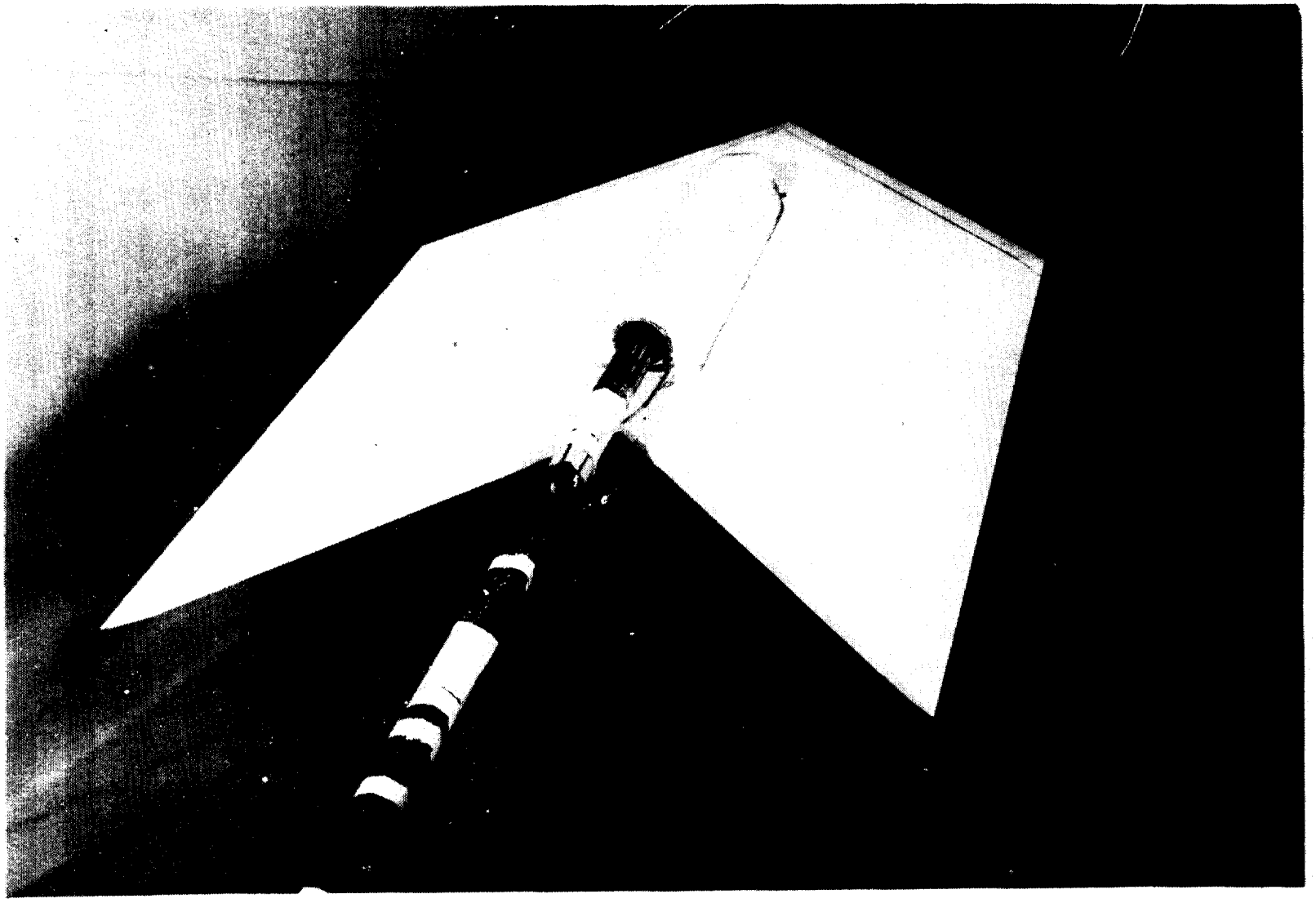
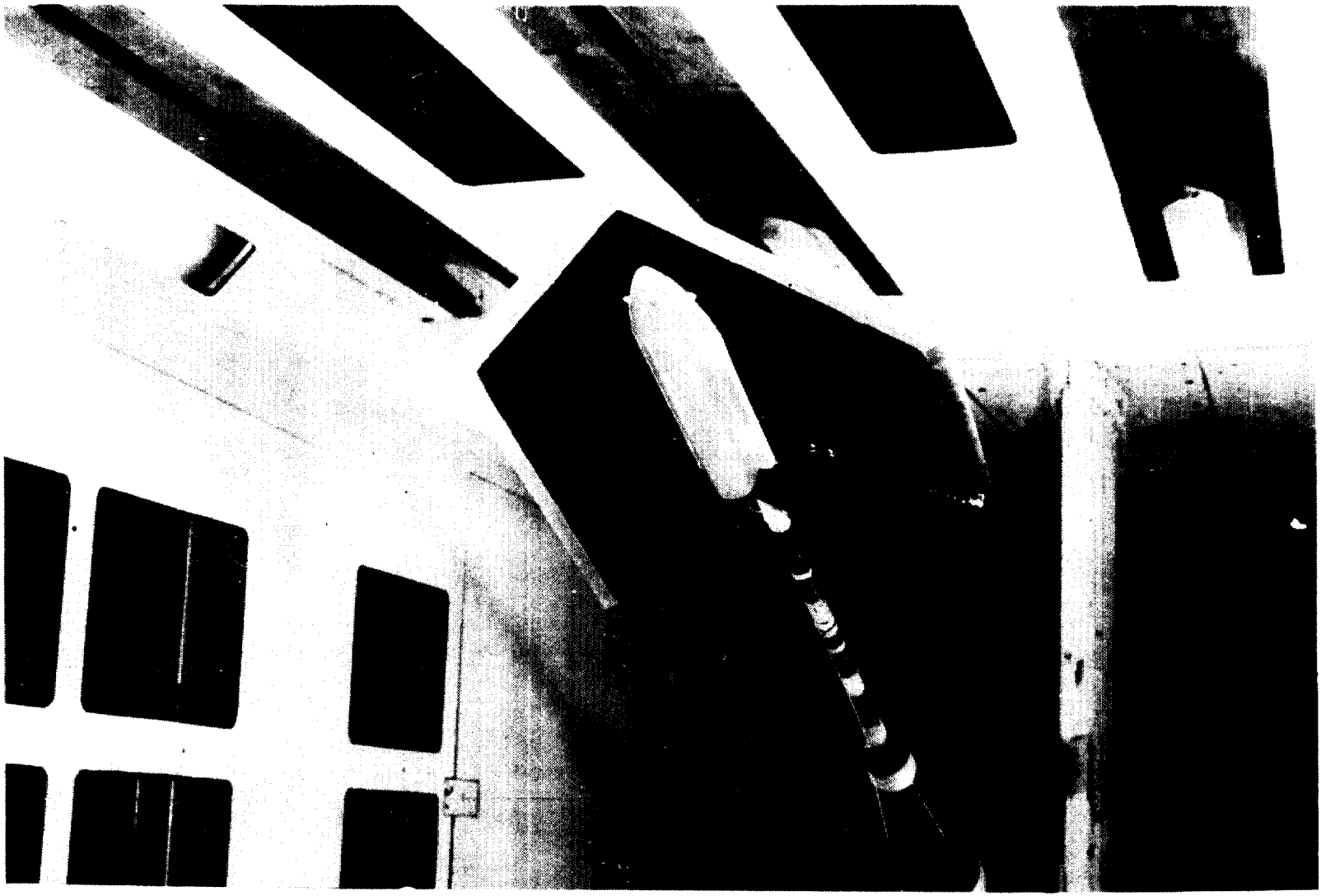


Figure 3. Basic 45° cropped delta wing



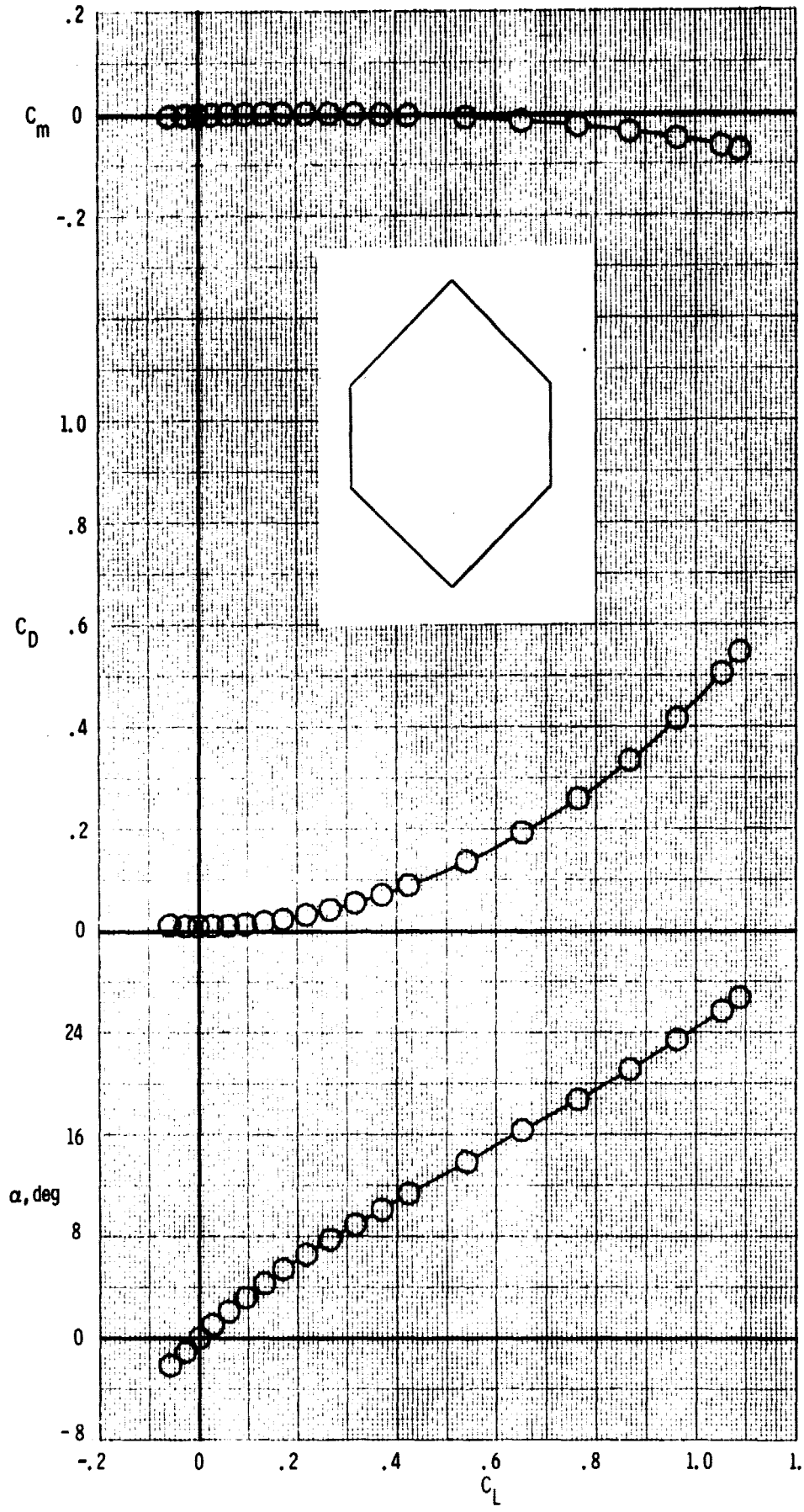
(a) Active balance housing shown

Figure 4. Typical model installation in the wind tunnel (Model VIII).



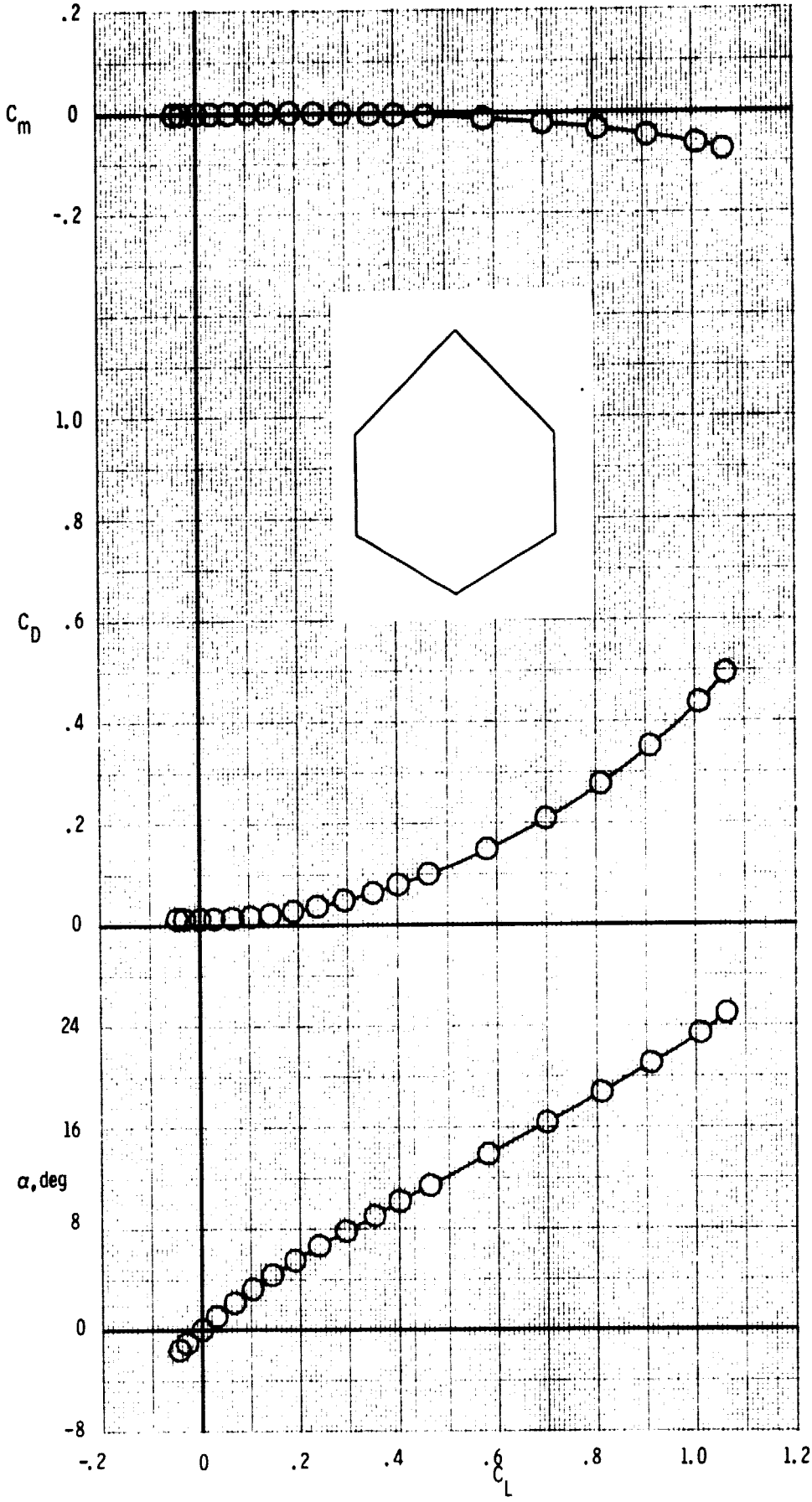
(b) Dummy balance housing shown

Figure 4. Concluded.

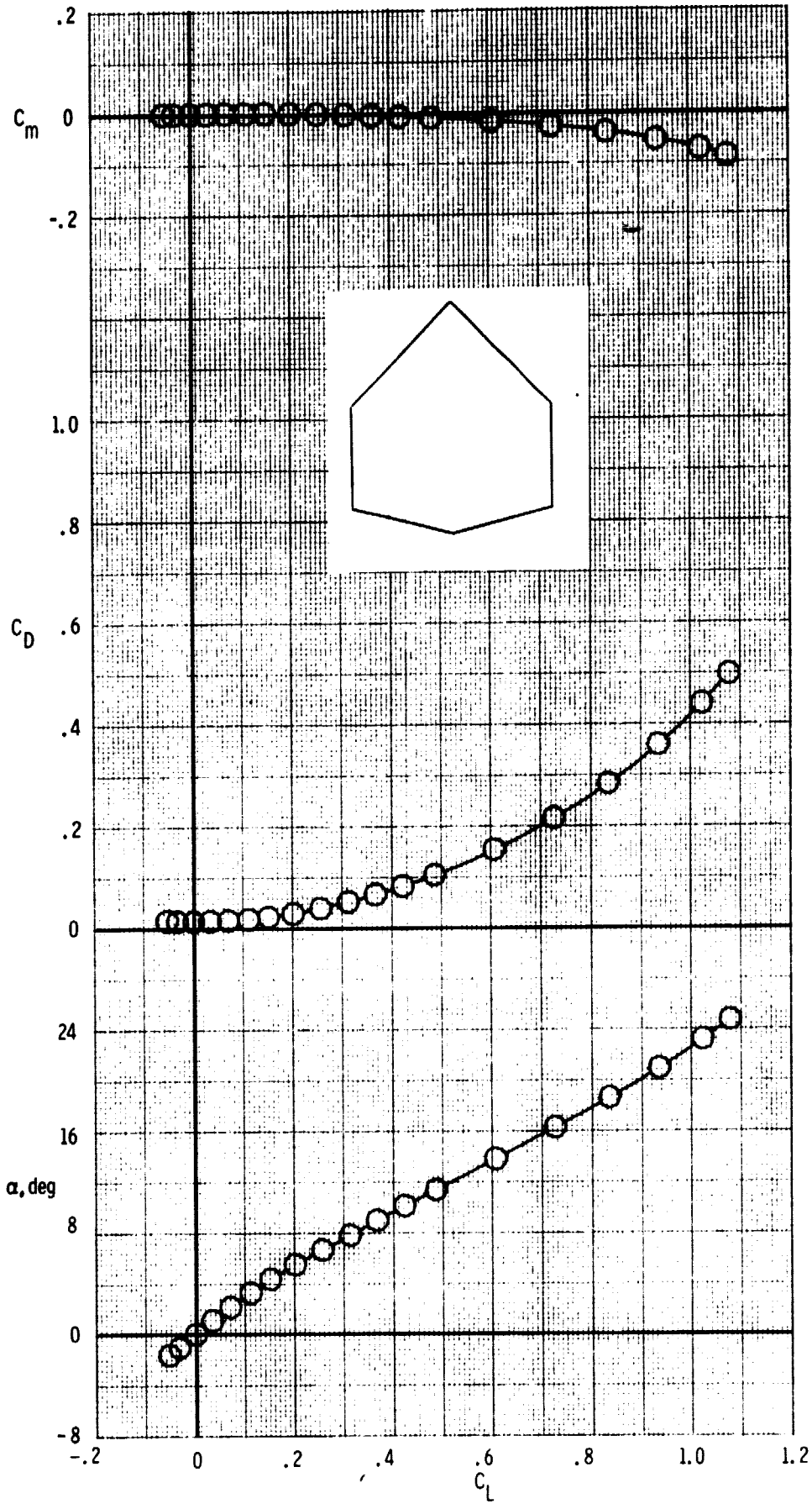


(a) Model 1, Ω=-45°

Figure 5. Longitudinal aerodynamic characteristics for Λ=45° cropped wings with constant tip chord and variable trailing edge

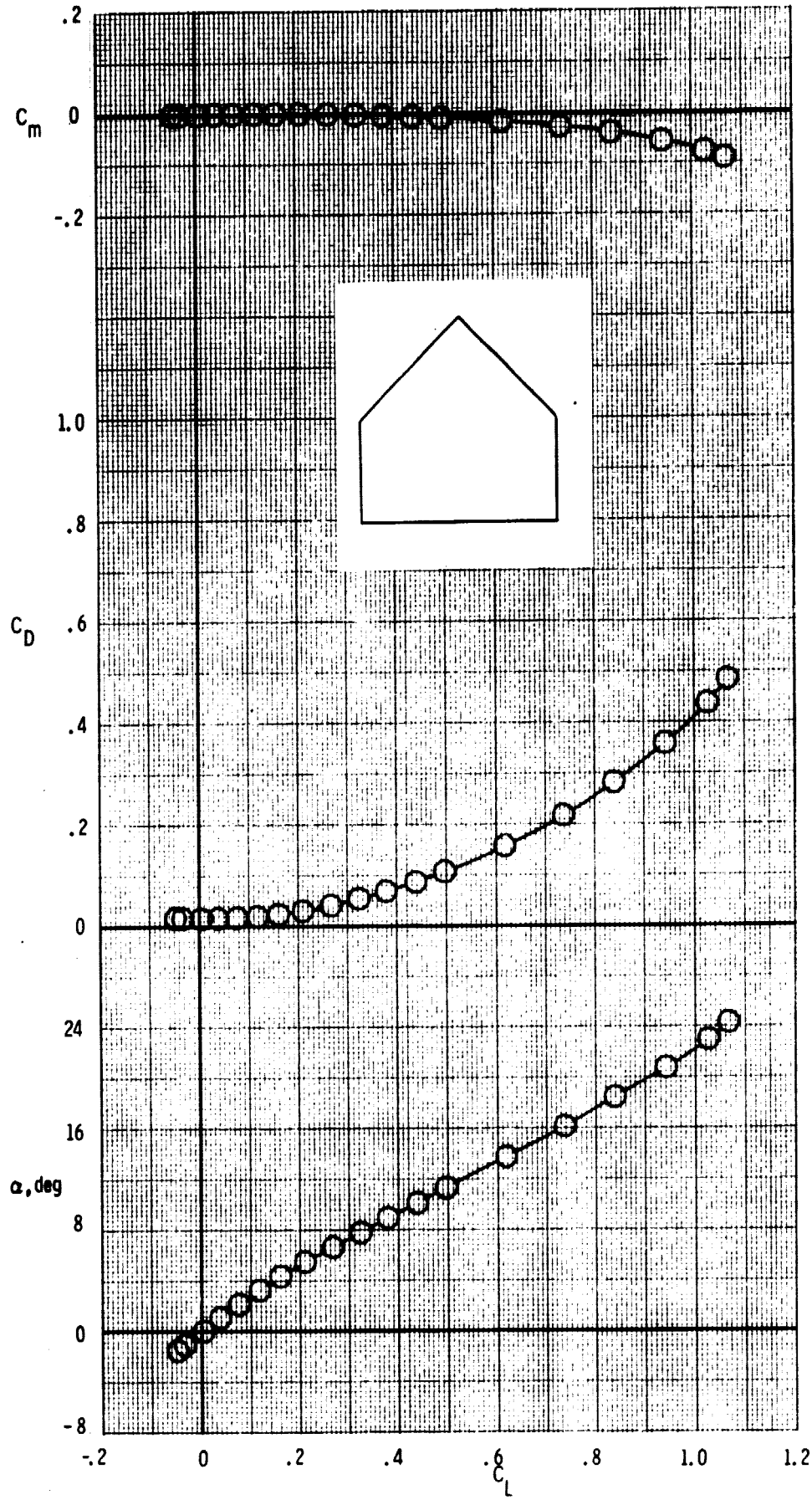


(b) Model II , $\Omega = -30^{\circ}$



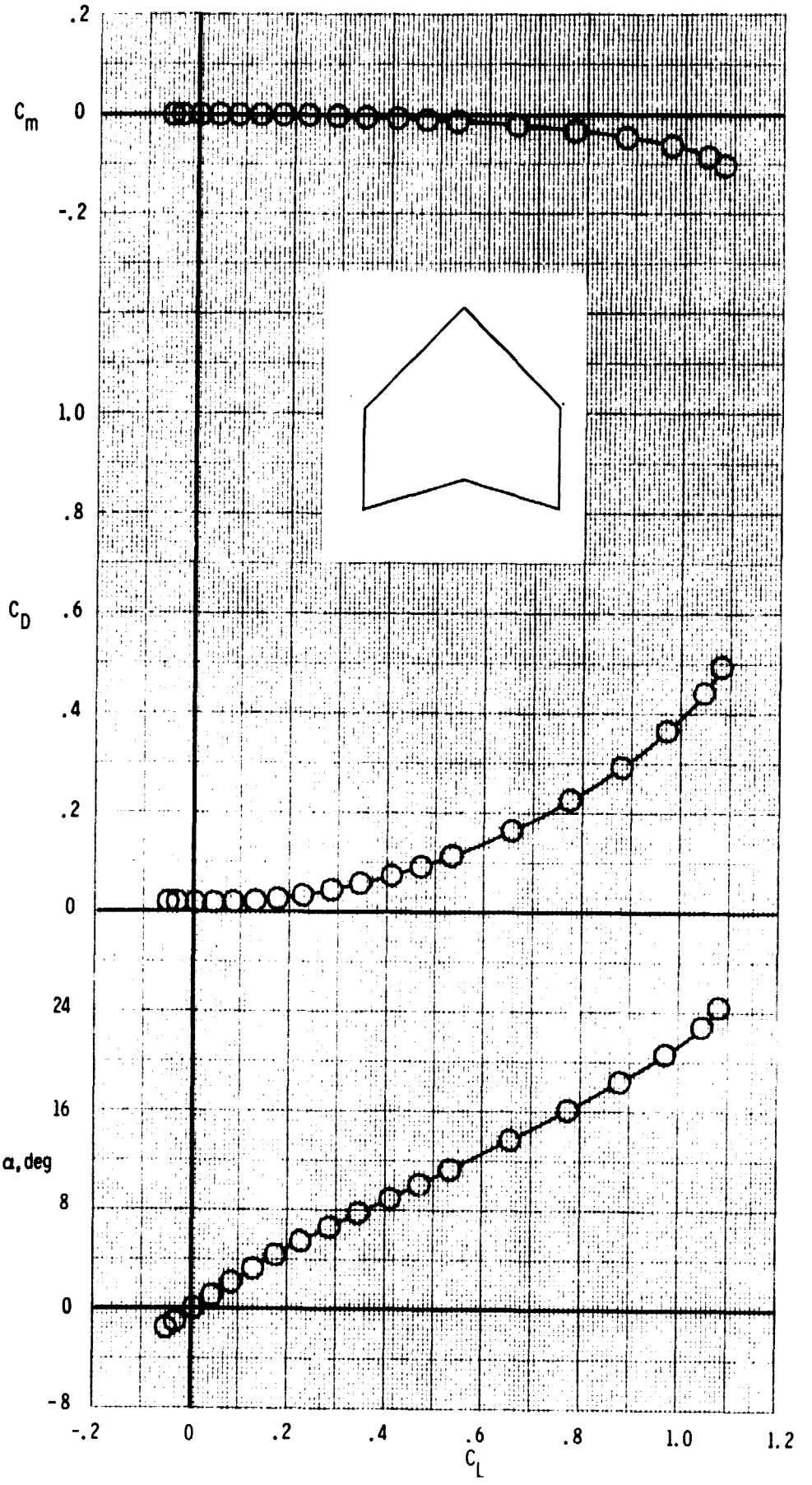
(c) Model III , $\Omega = -15^0$

Figure 5. Continued



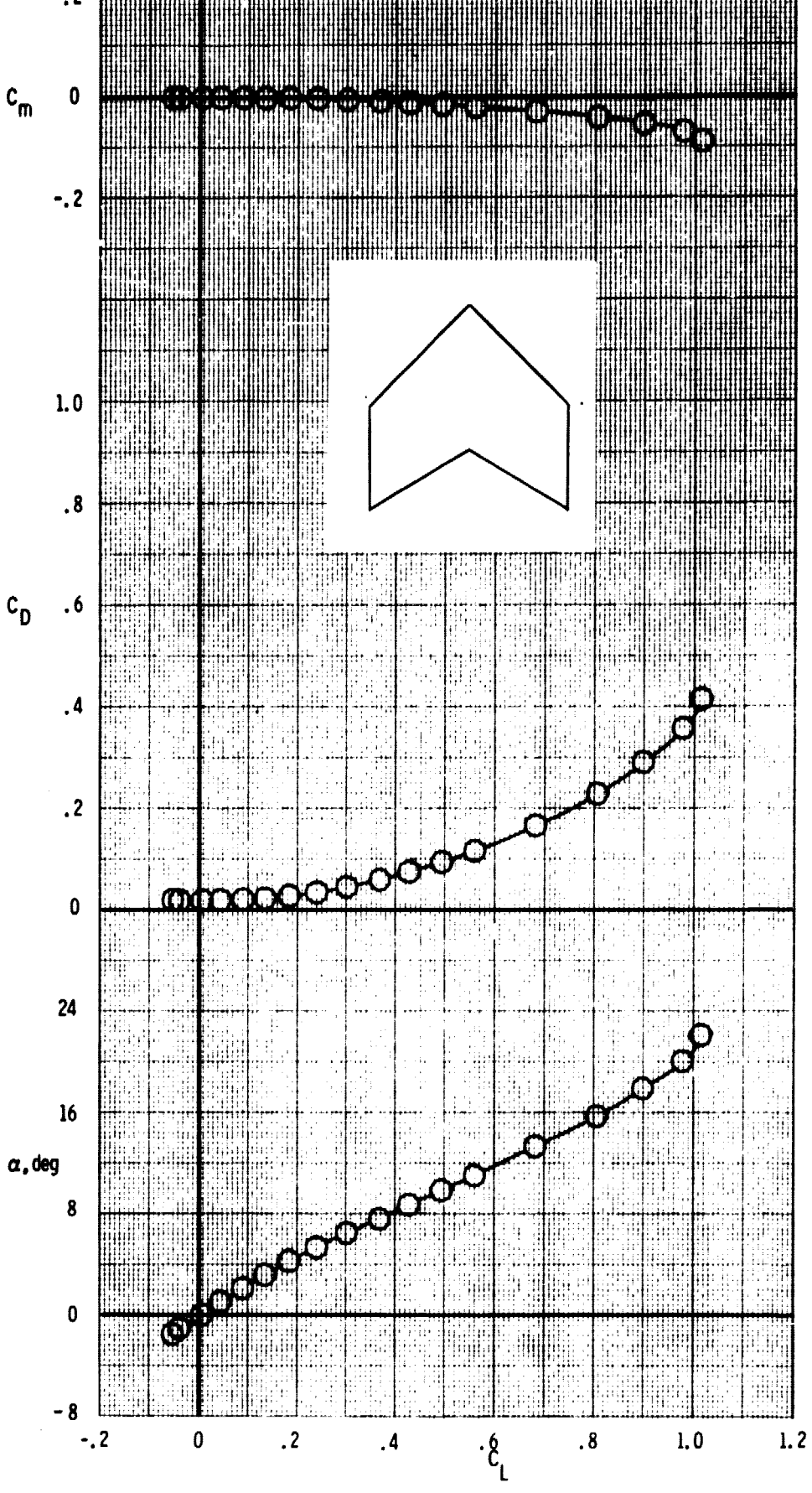
(d) Model IV , $\Omega = 0^0$

Figure 5 . Continued



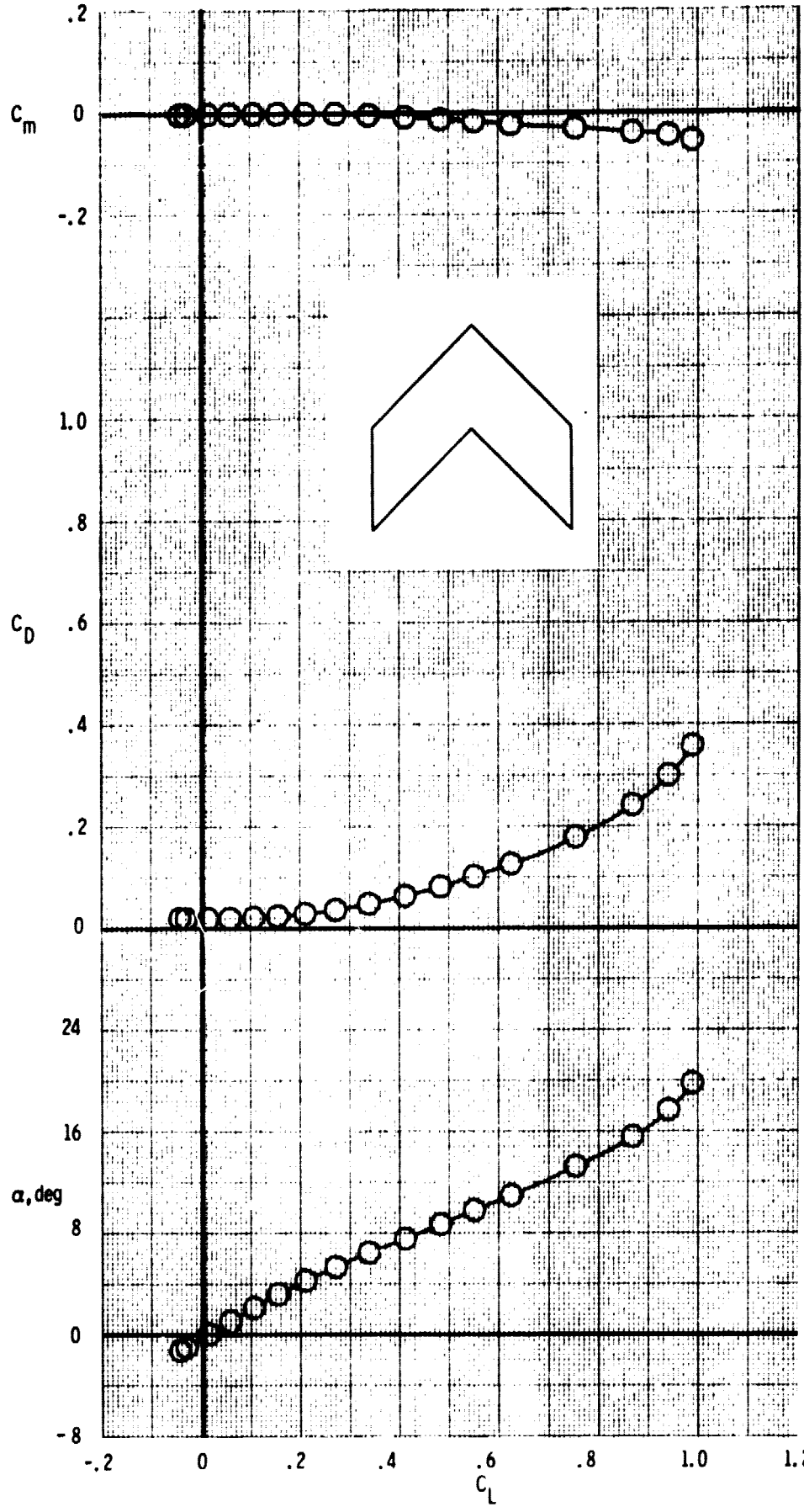
(e) Model V , $\Omega = 15^0$

Figure 5. Continued



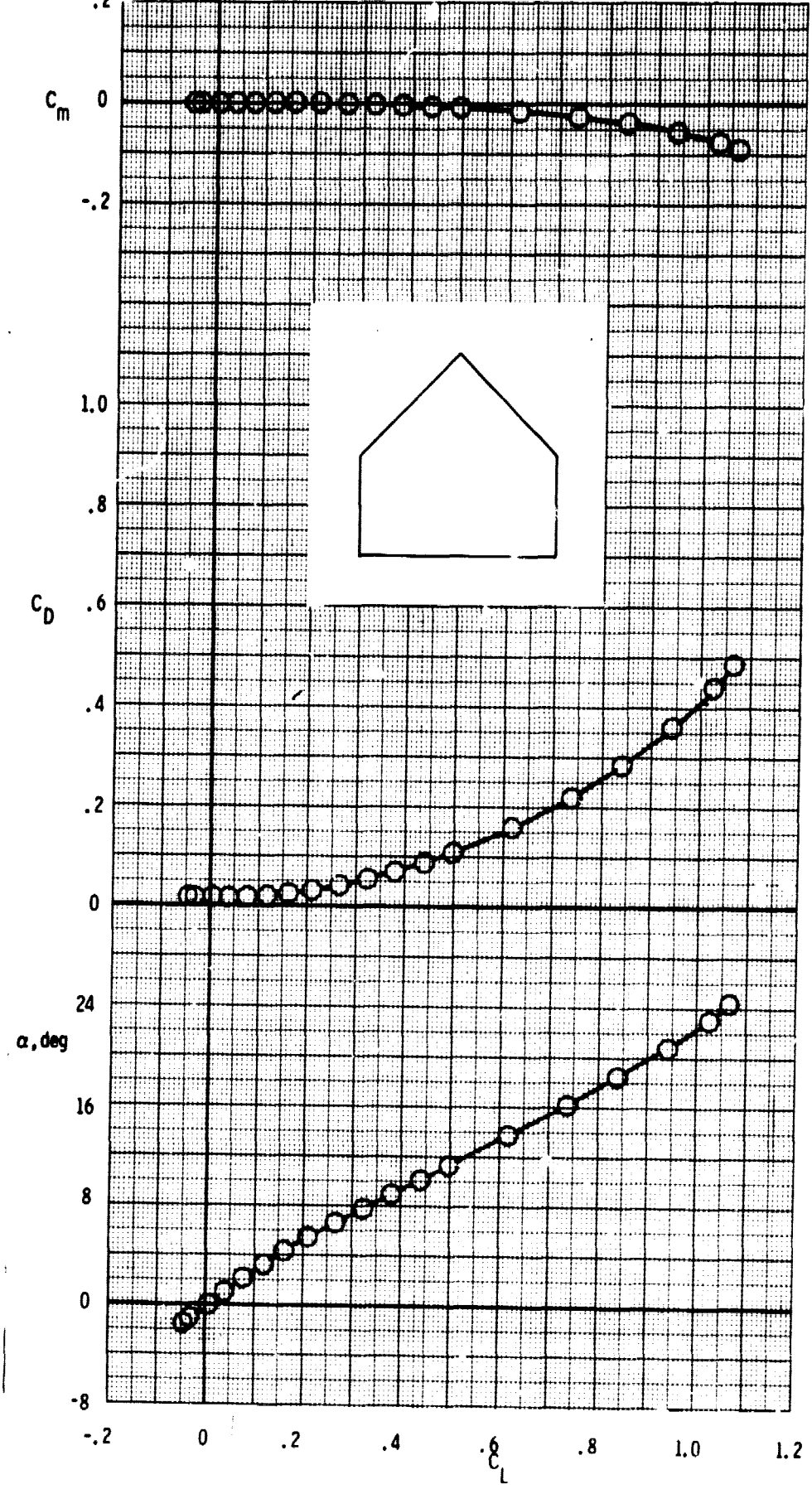
(f) Model VI , $\Omega = 30^0$

Figure 5. Continued



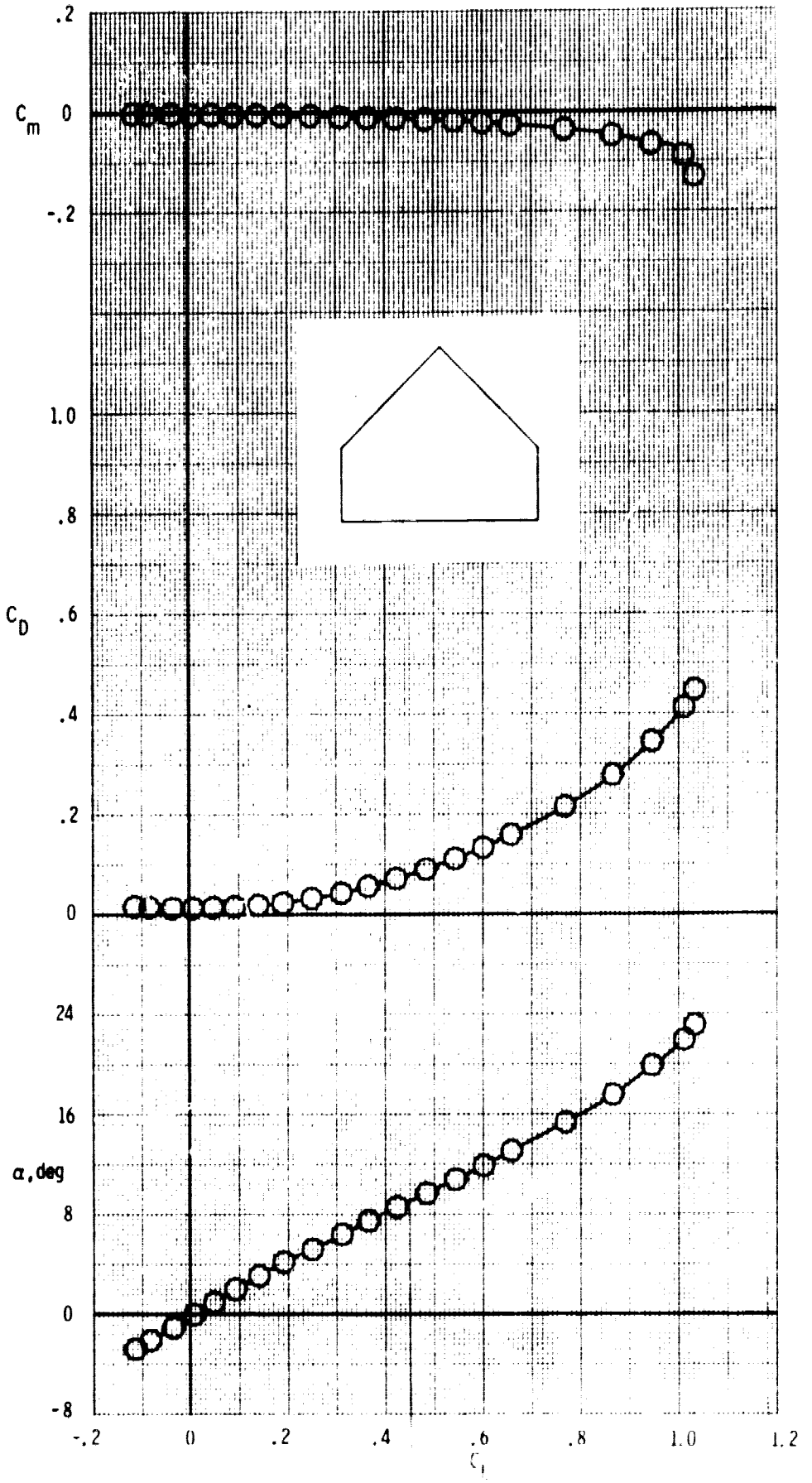
(g) Model VII, $\Omega = 45^0$

Figure 5. Concluded

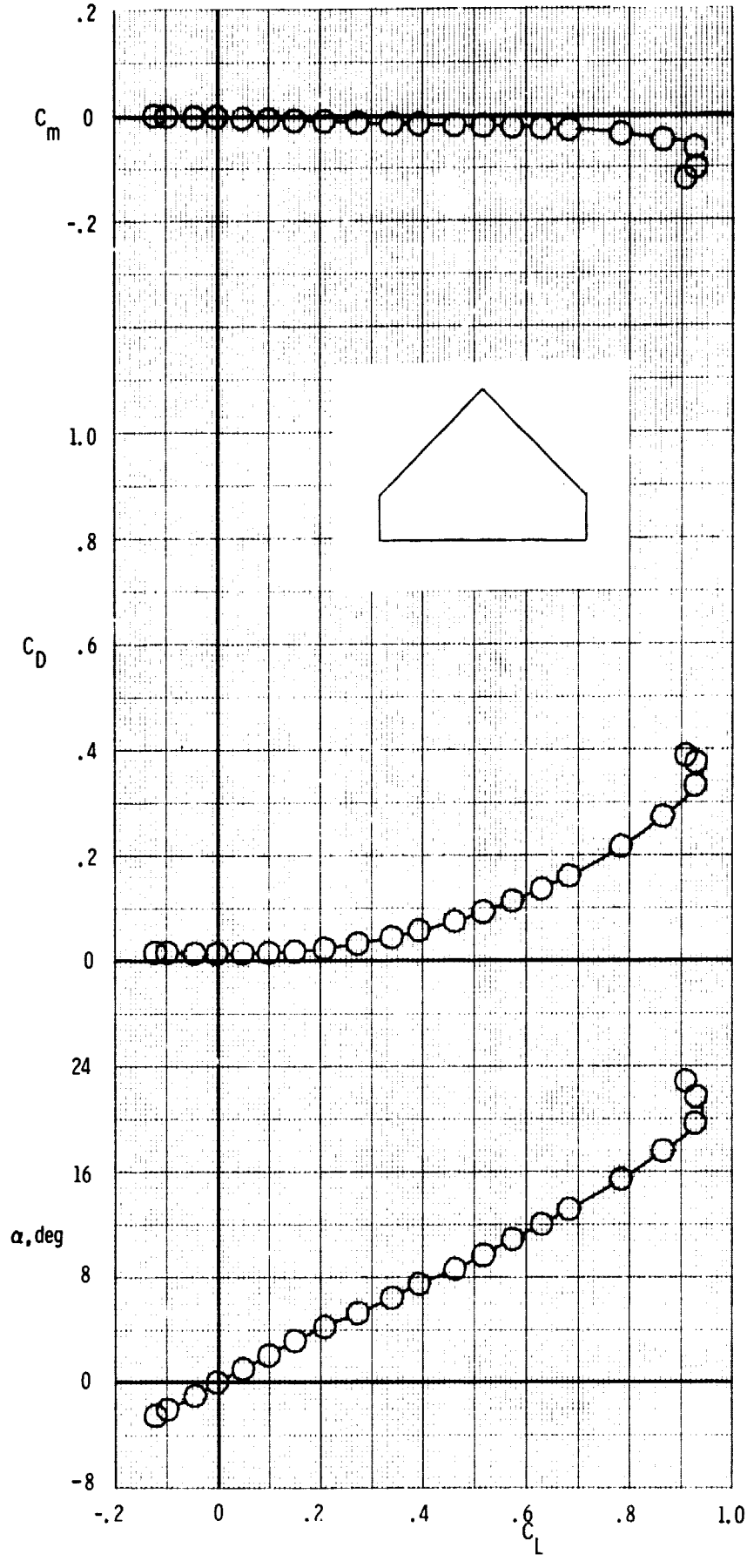


(a) Model X, λ =0.5 (Same data as for Model IV)

Figure 6. Longitudinal aerodynamic characteristics for $\Lambda = 45^0$ cropped delta wings with variable taper ratio at $M_{\infty}=0$.

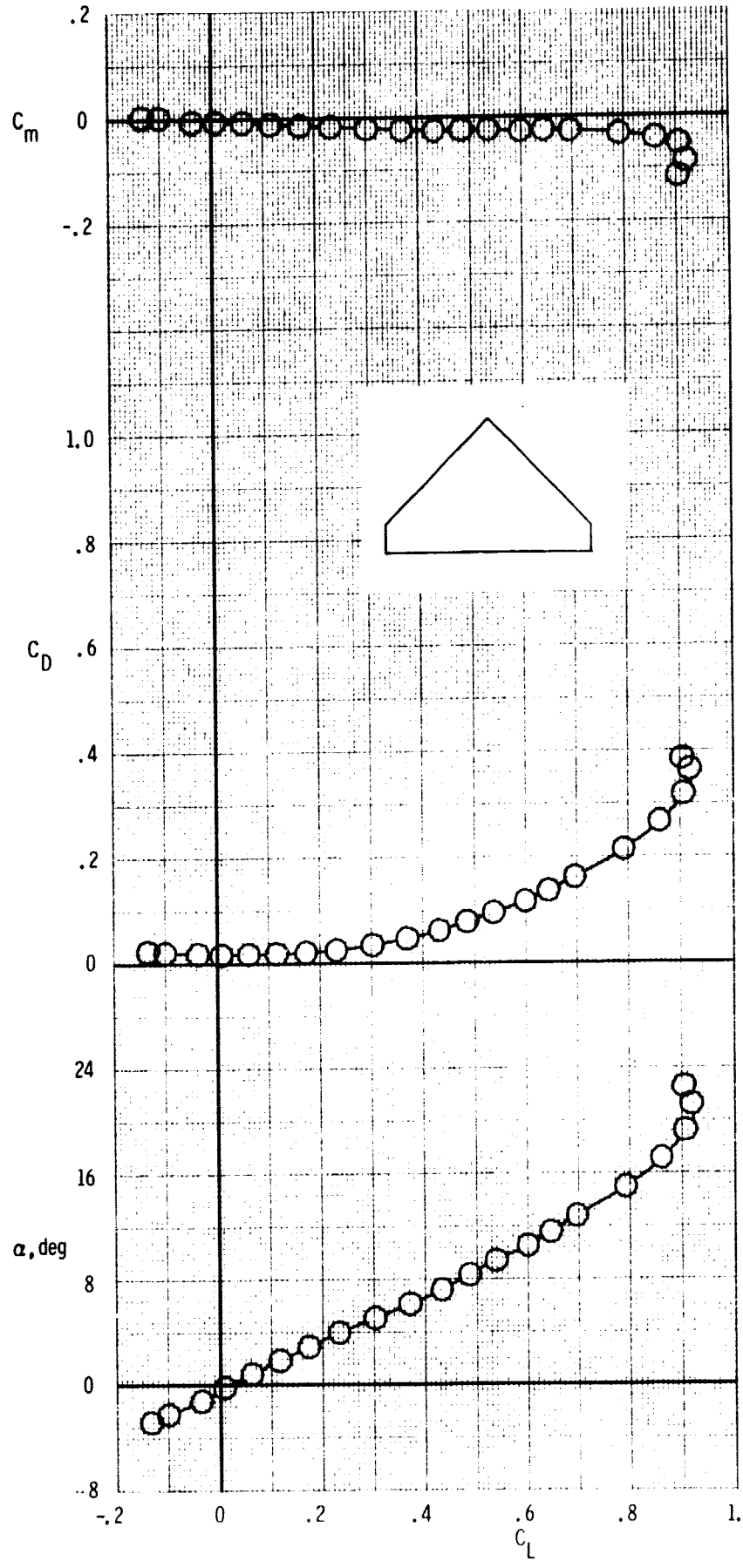


(b) Model X1 , λ = 0.4



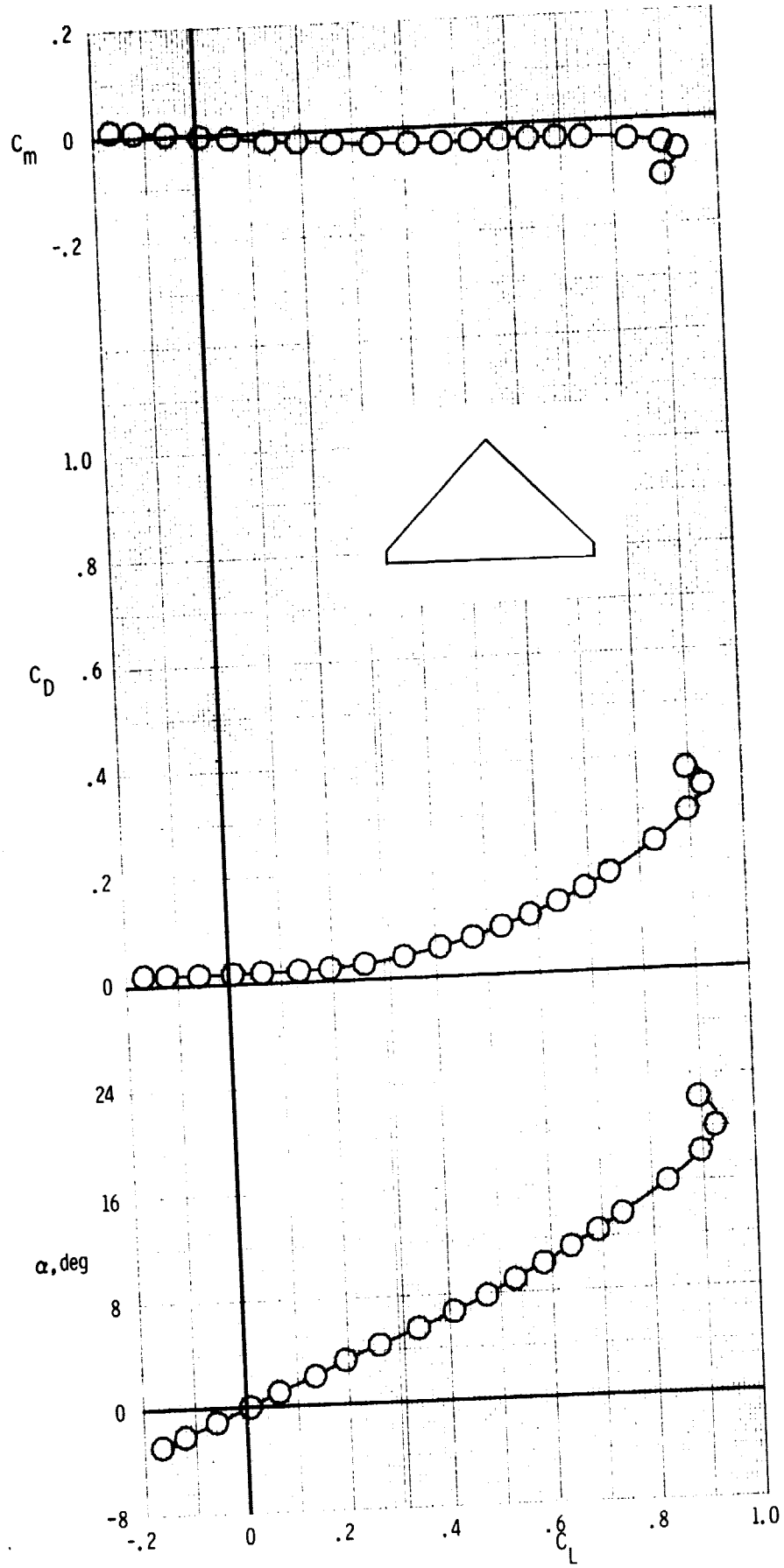
(c) Model XII, $\lambda = 0.3$

Figure 6 . Continued



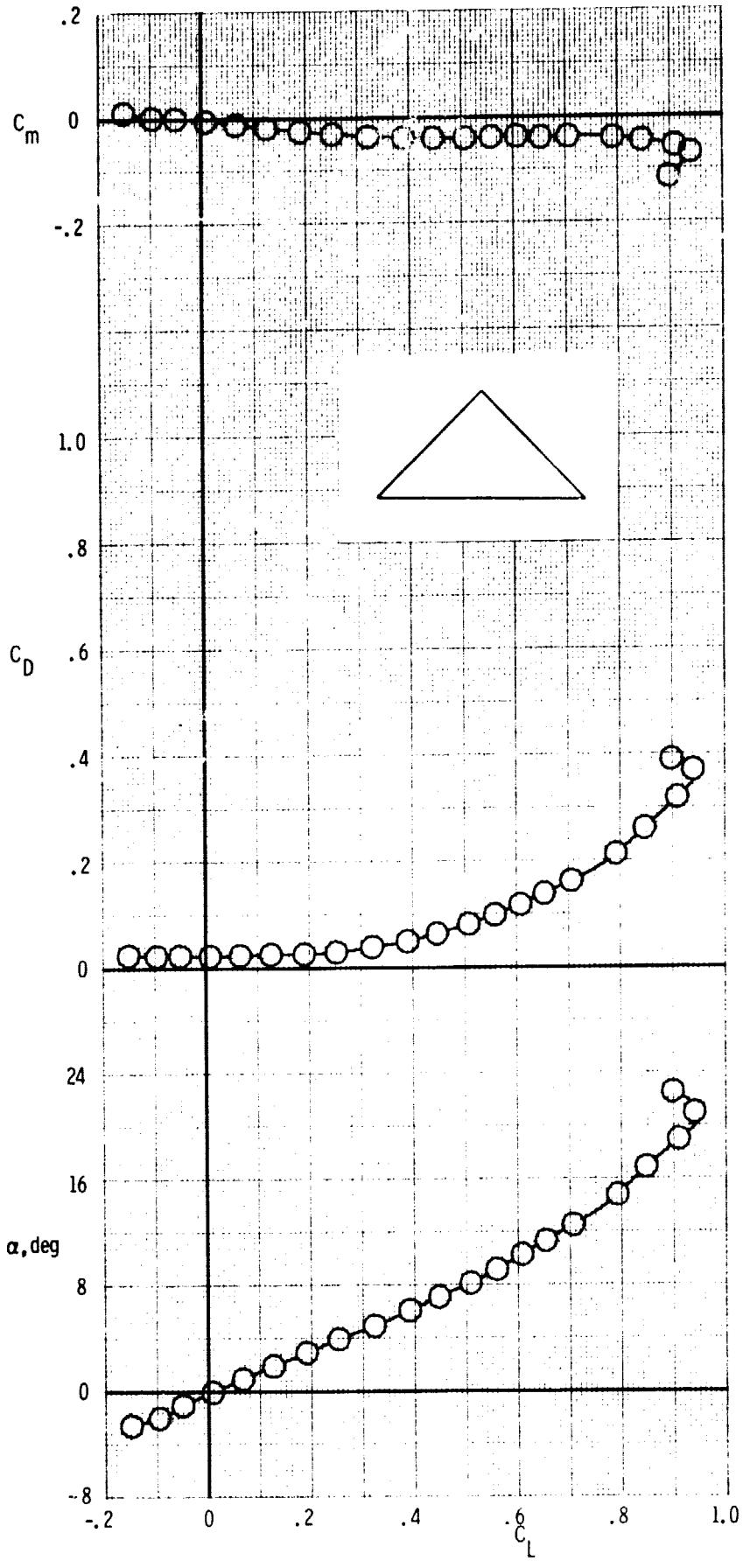
(d) Model XIII, $\lambda = 0.2$

Figure 6 . Continued



(e) Model XIV, $\lambda = 0.1$

Figure 6. Continued



(f) Model XV, $\lambda = 0$

Figure 6. Concluded

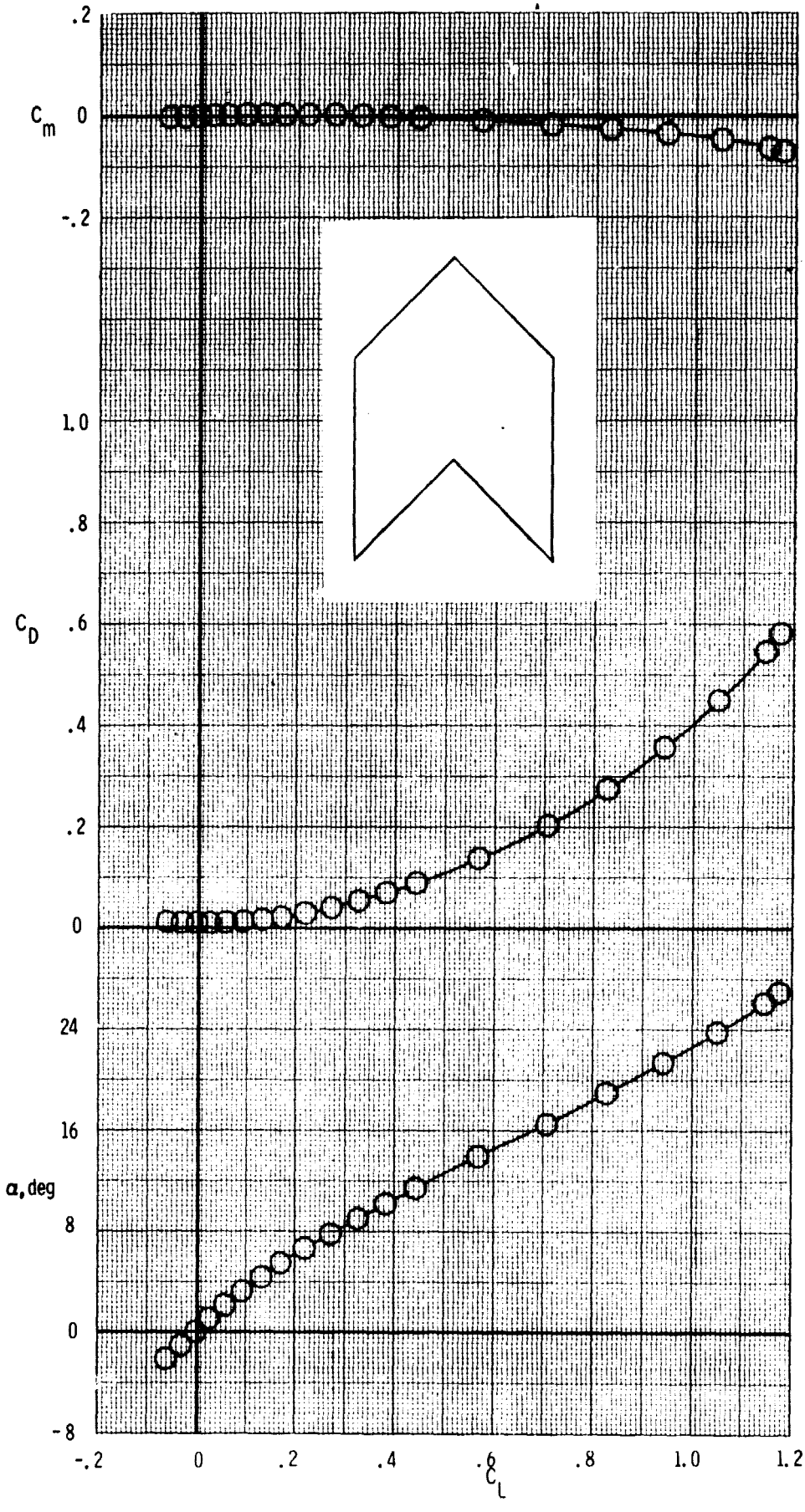


Figure 7. Longitudinal aerodynamic characteristics for Model VIII at $M_\infty \sim 0$.

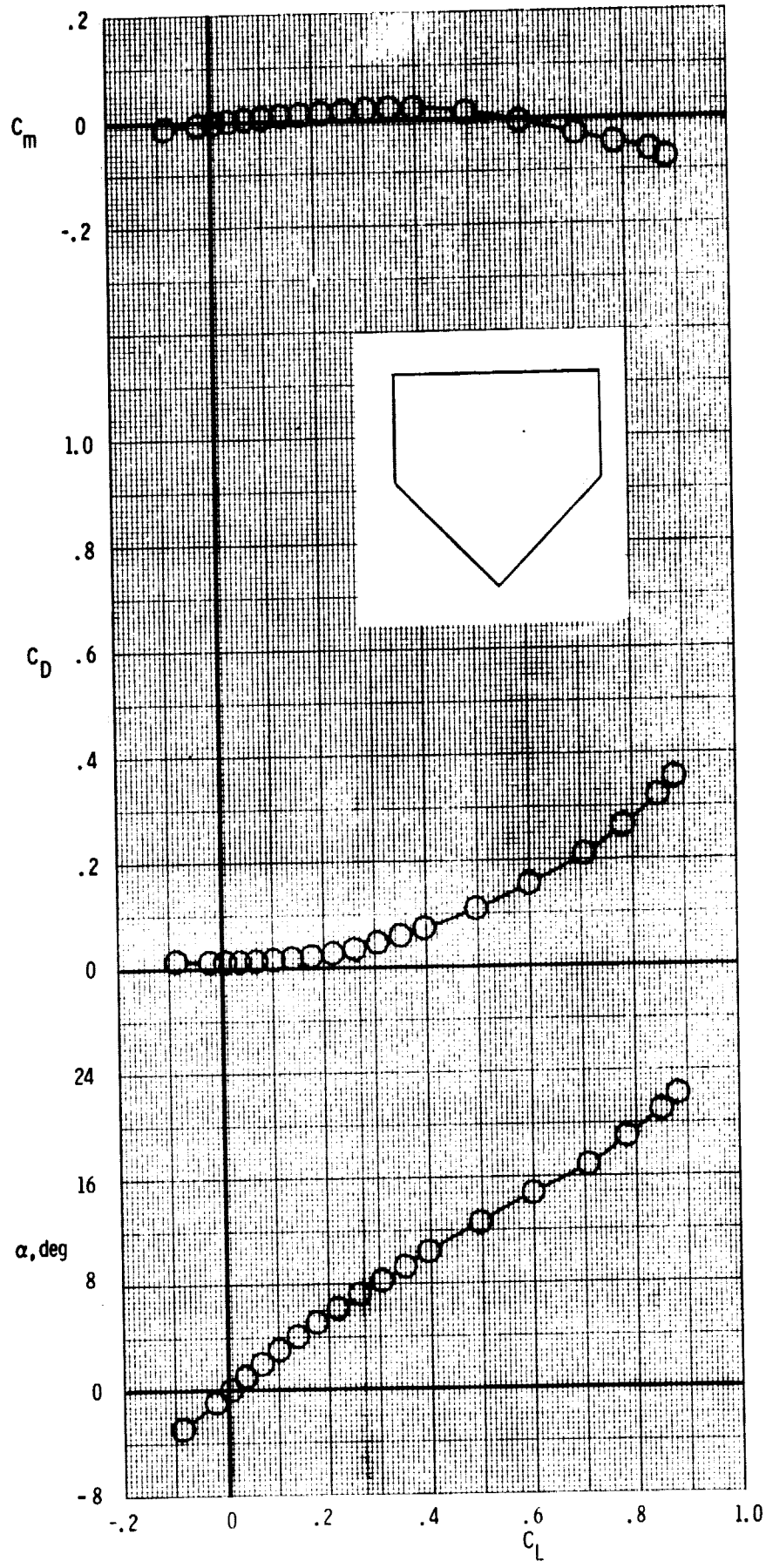


Figure 8 . Longitudinal aerodynamic characteristics for Model IX at $M_\infty \sim 0$.