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THE EFFECT OF BEAM LOADING ON WATER IMPACT

LOADS AND MOTIONS

By John S. Mixson

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SUMMARY

An investigation of the effect of beam loading on impact loads and motions has been conducted in the Langley impact basin. Water impact tests of flat-bottom 5-inch- and 8-inch-beam models having beam-loading coefficients C_Δ from 62.5 to 544 and a 30° dead-rise 5-inch-beam model having beam-loading coefficients from 208 to 530 are described and the results analyzed to show trends of these heavy-beam-loading data with initial flight-path angle, trim angle, dead-rise angle, and time throughout the impact. Data from flat-bottom model tests, $C_\Delta = 4.4$ to 36.5, and from 30° dead-rise model tests, $C_\Delta = 0.58$ and 18.8, are included, along with the heavy-beam-loading data; and variations of these data with beam-loading coefficients are shown. Each of the load and motion coefficients is found to be directly proportional to a power factor of C_Δ. For instance, the maximum impact lift coefficient $C_{L,max}$ is found to be directly proportional to $C_\Delta^{0.33}$ for the flat-bottom model and $C_\Delta^{0.45}$ for the 30° dead-rise model. These variations of $C_{L,max}$ with C_Δ are found to be in agreement with theoretical variations.

Finally, an empirical equation for the prediction of $C_{L,max}$ is presented and is shown to give good agreement with experimental $C_{L,max}$ for about 500 fixed-trim smooth-water impacts. The range of variables included dead-rise angles from 0° to 30°, beam-loading coefficients from 0.48 to 544, trim angles from 3° to 45°, and initial flight-path angles from about 2° to about 27°.

INTRODUCTION

At the Langley impact basin a program has been under way to determine the effects of model configuration on water impact loads and motions of chine-immersed bodies for a range of landing conditions. This program has included investigations of the effects of longitudinal and transverse

shape, including curvature and dead rise, at beam-loading coefficients up to 36 (refs. 1 to 6). Narrow hydro-skis having very high beam loading have become of interest for applications requiring impact-load alleviation, for example, on high-speed water-based aircraft. Therefore, an investigation of the effect of very high beam loading on water impact loads and motions has been made, and the results are reported herein.

In order to extend the range of beam-loading coefficient C_Δ above 36, water-landing tests of $0°$ and $30°$ dead-rise narrow-beam models were conducted. A $30°$ dead-rise 5-inch-beam model was tested with C_Δ from 208 to 530, and flat-bottom ($0°$ dead rise) 5-inch- and 8-inch-beam models were tested with C_Δ from 62.5 to 544. Time histories of the loads and motions were measured as the models impacted at fixed trim on smooth water.

In this report the tests of the narrow-beam models are described and the results are analyzed to show trends of these high beam-loading data with time, initial flight-path angle, and dead-rise angle. Data are then included for beam-loading coefficients from 0.58 to 544, and variations of impact loads and motions for this range of beam-loading coefficients are shown. Theoretical variations of maximum impact lift coefficient with beam-loading coefficient are shown and compared with the experimental variations. Finally, an empirical equation for the prediction of maximum impact lift coefficient is developed and compared with a large amount of experimental data.

SYMBOLS

b	model beam, ft
F_V	vertical component of resultant hydrodynamic force normal to undisturbed water surface, lb
g	acceleration due to gravity, 32.2 ft/sec^2
l_{cp}	distance from step-keel point to center of pressure, ft
M_Y	pitching moment about the step-keel point, ft-lb
n_i	impact-load factor normal to undisturbed water surface, F_V/W
t	time after water contact, sec

V resultant velocity, ft/sec

W dropping weight, lb

$\dot{x}$ velocity of model parallel to undisturbed water surface, ft/sec

z draft of step-keel point normal to undisturbed water surface, ft

$\dot{z}$ velocity of model normal to undisturbed water surface, ft/sec

β dead-rise angle, deg

γ flight-path angle, relative to undisturbed water surface, deg

ρ mass density of water, 1.938 slugs/cu ft

τ trim angle, deg

C_L impact lift coefficient, $\dfrac{F_V}{\frac{1}{2}\rho V_o^2 b^2}$

C_d draft coefficient, z/b

C_t time coefficient, $V_o t/b$

$C_{\dot{z}}$ vertical-velocity coefficient, $\dot{z}/\dot{z}_o$

C_m pitching-moment coefficient, $\dfrac{M_Y}{\frac{1}{2}\rho V_o^2 b^3}$

C_{cp} center-of-pressure coefficient, $\dfrac{l_{cp}}{b}$

C_Δ beam-loading coefficient, $\dfrac{W}{\rho g b^3}$

Subscripts:

o instant of initial contact with water surface

max   maximum

APPARATUS AND TEST PROCEDURE

These tests were conducted in the Langley impact basin which is described in reference 7 along with its basic instrumentation. The equipment consists of a catapult, a testing carriage to which the model is attached, associated instrumentation for measuring loads and motions of the model, and an arresting gear. The model is attached to the carriage at all times by a boom mounted on a parallel linkage which permits the model to move freely relative to the carriage in the vertical direction.

Models

Drawings and pertinent dimensions of the three models used in these tests are shown in figure 1(a), and photographs of the models mounted on the impact basin carriage are shown in figure 1(b). The models were basically of sheetmetal construction and were designed so that any deflection under load could be considered negligible. The chines were sharp enough to insure flow separation, and the parts of the models above the chines therefore had no effect on the test results. The nose shapes were determined by operational considerations and had no effect on the test results.

The 30° dead-rise model was 14 feet in overall length with a beam of 5 inches. In plan form it had a transverse step, a prismatic section 12 feet long, and a nose 2 feet long which tapered to a point. A Fiberglas covered wooden bottom with a constant 30° dead-rise angle was attached to the sheetmetal body. With this model the range of C_Δ covered was 208 to 530.

The flat-bottom 5-inch-beam model consisted of the same sheetmetal body used in the 30° dead-rise model with a flat steel sheet replacing the wooden dead-rise bottom. With this model a range of C_Δ from 208 to 544 was covered.

The flat-bottom 8-inch-beam model was used to cover a range of C_Δ from 62.5 to 133.7. This model had a rectangular plan form, a 12-foot-long flat bottom, and a 1-foot-long pulled-up nose giving an overall length of 13 feet.

Instrumentation

The instrumentation for each test consisted of an accelerometer, a dynamometer, a water-contact indicator, and electrical pickups for

measuring displacements and velocities. The data from these instruments, together with timing at intervals of 0.01 second, were recorded on a multi-channel oscillograph.

Accelerations were measured in the vertical direction by unbonded strain-gage-type accelerometers. For each test the range of the accelerometer and the flat frequency response of the circuit incorporating the accelerometer were as follows:

Model		Accelerometer	
β, deg	Beam, in.	Range, g	Frequency, cps
30	5	±2	13
0	5	±2	40
0	8	±3	13

Pitching moments M_Y about the step were obtained from a strain-gage-type dynamometer mounted between the model and the carriage boom. (Moments were measured about the front attachment point and were transferred to the step.) Moments due to the acceleration of the mass below the dynamometer were calculated and were found to be negligible.

Model contact with the water was indicated by means of an electric circuit completed by the water. Horizontal and vertical displacements were obtained from a photoelectric cell and slide wire, respectively, as described in reference 7. Vertical velocity of the model was determined by electrically differentiating the displacement measured by the slide wire.

In general, the apparatus used in the tests yields measurements that are believed to be correct within the following limits:

Horizontal velocity, ft/sec . . . . ±0.5
Vertical velocity, ft/sec . . . . ±0.2
Vertical displacement, in. . . . . ±0.2
Acceleration, g . . . . ±0.05
Weight, lb . . . . ±10
Time, sec . . . . ±0.002

The time at which maximum values occurred is less precise than the ±0.002 second given in this table because of difficulty in choosing the point at which the maximum occurred, although the time of the chosen point can be determined within ±0.002 second.

Test Procedure

A series of impacts were made, at fixed trim in smooth water for a range of trim, velocity, flight-path angle, and dropping weight. The dropping weight ranged from 933 pounds to 2,472 pounds, beam-loading coefficient from 62.5 to 544, trim angle from 3° to 30°, and initial flight-path angle from about 2^O to about 20°. The resultant velocity at contact ranged from about 30 feet per second to about 90 feet per second. Throughout each impact a force equal in magnitude and opposite in direction to the total weight of the model and drop linkage was applied to simulate wing lift. A summary of the flight-path angles covered at each test condition of trim and beam loading with each model is presented in table I.

RESULTS

The results of the tests of the heavy-beam-loading models are presented in tables II to IV. Data from tests of the 5-inch-beam 30° dead-rise model are presented in table II as basic measured quantities, and in table III in coefficient form. Basic measured quantities and coefficient data from tests of flat-bottom 5- and 8-inch-beam models are presented in table IV. Data are presented in these tables for the instants of maximum lift, maximum moment, maximum draft, and exit during rebound.

Typical variations of very high beam-loading water-impact data with time and with initial flight-path angle are presented in figures 2 and 3. In figure 2 typical time histories of coefficients of impact lift, moment, velocity, draft, and center of pressure are shown for three flight path angles for the 30° dead-rise model at 15° trim, and beam-loading coefficient of 208. It can be seen that the load and moment have been very gradually applied and have sustained flat peaks especially at the lower flight-path angles. These flat peaks, along with small superposed instrument or structural vibrations which have been faired out, made determination of the time of the peaks somewhat uncertain. Because of this uncertainty, more scatter appears, in general, in those coefficients which are read at the time of a peak of some other quantity. In figure 3 typical variations of coefficient data with initial flight-path angle γ_o are shown for the instants of maximum impact lift, maximum moment, maximum draft, and exit during rebound. The data presented are for a dead-rise angle of 30°, a beam-loading coefficient of 208, and a trim of 9°. Coefficients of impact lift and moment are shown to change very little (generally about 10 percent for the trims and beam loadings of these tests) between the instants of maximum lift and maximum moment. This small change can be explained by observing that the maximums occur at nearly the same time. In figure 3, when C_t is plotted against γ_o,

maximum moment occurs slightly after maximum lift. Also, in figure 2, it is observed that the rates of change of these coefficients are small in the region of their maximums. The variations shown in figures 2 and 3 are similar in character to those shown in references 1 to 6 for beam-loading coefficients from 4.4 to about 36.0. This similarity indicates that no change of trends with initial flight-path angle occurs even with large changes of beam loading.

DISCUSSION

Effect of Beam Loading

The changes of the load and motion coefficients caused by a change of beam loading can be seen from figures 4 and 5, where variations of the coefficients are shown as functions of time (fig. 4) and of initial flight-path angle (fig. 5) for a range of beam-loading coefficients. Included in these and subsequent plots are data for beam loadings obtained from previous investigations (refs. 1 to 6 and 8 to 11). Time histories of C_L, C_m, C_d, and $C_{\dot{z}}$ are presented in figure 4 for the 30° dead-rise model at a trim of 15° and C_Δ of 208 and 530. Variations of the coefficients with initial flight-path angle are presented in figure 5 for 30° dead-rise models at a trim of 15° and C_Δ of 0.58, 18.8, 300, and 530. Both figures show noticeable increases with increasing C_Δ of all the coefficients except $C_{\dot{z}}$ in figure 5.

Beam-loading reduction factors.- Analysis of the experimental data indicated that for a given dead-rise angle, flight-path angle, and trim angle, each of the coefficients is proportional to C_Δ^p, where the value of the exponent p depends on the coefficient under consideration and the dead-rise angle β. Values of p were determined by empirical trial and error means and are given in the following table:

Coefficient	C_Δ^p factors	
	$\beta = 0^\circ$	$\beta = 30^\circ$
Impact lift coefficient, C_L	$C_\Delta^{0.33}$	$C_\Delta^{0.45}$
Pitching-moment coefficient, C_m	C_Δ	C_Δ
Draft coefficient, C_d	$C_\Delta^{0.67}$	$C_\Delta^{0.55}$
Time coefficient, C_t	$C_\Delta^{0.67}$	$C_\Delta^{0.55}$
Vertical-velocity coefficient, $C_{\dot{z}}$	C_Δ^{0}	C_Δ^{0}

Figure 6 shows the time histories pres∍nted in figure 4 reduced by the appropriate C_Δ^p factor. From this fi⅃ure it can be concluded that C_Δ^p factors reduce the coefficients to sub⅂tantially a single variation at least to the stage of maximum draft. Figure 7 shows reduced data for a 0° dead-rise model at trims of 3°, 6°, 15°, and 30°, initial flight-path angles from 2° to about 22°, and beam-loading coefficients from 1 to 544. Figure 8 shows data for a 30° dead-rise angle at trims of 6°, 9°, 15°, and 30°, initial flight-path angles from about 2° to about 27°, and beam loading coefficients from 0.58 to 530. It may be concluded from figures 7 and 8 that the empirically devised factors reduce the data for a large range of beam-loading coefficients to essentially a single variation for each trim angle.

In figure 9 the empirically determined trends of $C_{L,max}$ with C_Δ are compared with trends predicted by the theory of reference 12. Maximum impact lift coefficient is shown for 0^c and 30° dead-rise angles, C_Δ from 1 to 600, trim of 15°, and flight-path angle of 20°. As shown by figure 9, the trend cf $C_{L,max}$ with C_Δ predicted by reference 12 is not a simple power function of C_Δ; however, for the range of C_Δ shown, a simple power function is a good a⟩proximation. The empirically determined trends are seen to approximate ʧhe theoretical curves reasonably well, so that agreement between the theoretical and empirical trends with beam loading is indicated.

Lift reduction due to dead rise.- The effect of a change of beam loading on the reduction of lift caused by an increase of dead-rise angle can be seen from figures 9 and 10. ʧhe theoretical curves of figure 9 show that an increase of dead-risᵉ angle from 0° to 30° decreases the maximum impact lift coefficiᵉnt by about 30 percent at C_Δ of 19 and by about 20 percent at C_Δ of 530. In figure 10 experimental maximum impact lift coefficient is ⅃hown for 0° and 30° dead-rise angles at C_Δ of 18.8 and about 530. The experimental data of figure 10 show that an increase in dead-rise angle f⸲om 0° to 30° decreases maximum impact lift coefficient by about 35 percen⅃ at C_Δ of 18.8 and by only about 15 percent at C_Δ of about 530. It may be concluded therefore that the importance of dead-rise angle variations as a means of varying impact lift decreases as beam loading incr∍ases.

Empirical $C_{L,max}$ Eq⅃ation

The large amount of experimental data covering large ranges of trim, dead rise, flight-path angle, and beam loading available in tables III and IV and in references 1 to 11 suggested the possibility

of establishing empirically an equation for the prediction of maximum impact lift coefficient $C_{L,max}$. A form which may be assumed for such an equation can be inferred from figures 8 and 9. The $C_{L,max}$ curves of figure 8 indicate that $C_{L,max}$ may be considered as proportional to $(\gamma_0)^s$, where the constant of proportionality and the exponent s both depend on the trim angle τ. The curves of figure 9 indicate that $C_{L,max}$ is proportional to C_Δ^p, where this constant of proportionality and the exponent p depend on the dead-rise angle β. Based on these considerations, an equation has been assumed in the following form:

$$C_{L,max} = f_1(\tau)f_2(\beta)\gamma_0^{f_3(\tau)}C_\Delta^{f_4(\beta)}$$

Analysis of the experimental data yielded the following empirical expressions for the unknown functions:

$$f_1(\tau) = 0.0125 + 0.000963\tau$$
$$f_2(\beta) = 1.0 - 0.0806\beta^{0.56}$$
$$f_3(\tau) = 1.8 - 0.29\tau^{0.3}$$
$$f_4(\beta) = 0.333 + 0.0141\beta^{0.566}$$

In figure 11, $C_{L,max}$ predicted by this equation is compared with experimental $C_{L,max}$ for about 500 fixed trim, smooth-water impacts. The range of variables includes dead-rise angles from $0°$ to $30°$, beam-loading coefficients from 0.48 to 544, trim angles from $3°$ to $45°$, and flight-path angles from about $2°$ to about $27°$. Figure 11 shows that the empirical equation gives values of $C_{L,max}$ generally within about 15 percent of the experimental value.

CONCLUSIONS

An investigation of the effect of beam loading on impact loads and motions has been conducted in the Langley impact basin. Landing impact-loads data were included for $0°$ dead-rise models having beam-loading coefficients C_Δ from 1 to 544 and $30°$ dead-rise models having beam-loading coefficients from 0.58 to 530; the following conclusions were reached:

1. The following beam-loading coefficient C_Δ factors were found to reduce the data to essentially a single variation with initial flight-path angle for a given trim angle τ and dead-rise angle, β:

Coefficient	C_Δ^P factors	
	$\beta = 0°$	$\beta = 30°$
Impact lift coefficient, C_L	$C_\Delta^{0.33}$	$C_\Delta^{0.45}$
Moment coefficient, C_m	C_Δ	C_Δ
Draft coefficient, C_d	$C_\Delta^{0.67}$	$C_\Delta^{0.55}$
Time coefficient, C_t	$C_\Delta^{0.67}$	$C_\Delta^{0.55}$
Vertical-velocity coefficient, $C_{\dot{z}}$	C_Δ^0	C_Δ^0

2. The importance of increasing dead-rise angle as a means of reducing impact lift is shown theoretically and experimentally to decrease as beam loading increases. Experimentally, an increase of dead-rise angle from 0° to 30° is shown to decrease maximum impact lift coefficient by about 35 percent at a beam-loading coefficient of 18.8 and by only about 15 percent at a beam-loading coefficient of about 530.

3. The following equation for the prediction of maximum impact lift coefficient $C_{L,max}$ was determined empirically and was shown to give good agreement with experimental data over a range of dead-rise angle β from 0° to 30°, trim angle τ from 3° to 45°, beam-loading coefficient C_Δ from 0.48 to 544, and initial flight-path angle γ_0 from about 2° to about 27°:

$$C_{L,max} = f_1(\tau)f_2(\beta)\gamma_0^{f_3(\tau)}C_\Delta^{f_4(\beta)}$$

where

$$f_1(\tau) = 0.0125 + 0.000965\tau$$
$$f_2(\beta) = 1.0 - 0.0806\beta^{0.55}$$
$$f_3(\tau) = 1.8 - 0.29\tau^{0.3}$$
$$f_4(\beta) = 0.333 + 0.0141\beta^{0.566}$$

Langley Research Center,
National Aeronautics and Space Administration,
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TABLE I.- SUMMARY OF TEST CONDITIONS

τ, deg	C_Δ	W, lb	γ_o, deg
$\beta = 30°$; b = 5 in.			
3	208	933	2.48 to 8.06
6	208	933	2.64 to 12.36
9	208	933	3.16 to 17.88
9	530	2,350	2.52 to 10.00
15	208	933	2.62 to 20.55
15	300	1,315	3.21 to 18.54
15	400	1,767	3.15 to 13.29
15	530	2,350	2.16 to 12.04
30	208	933	2.75 to 20.91
30	530	2,350	2.22 to 12.97
$\beta = 0°$; b = 8 in.			
3	62.5	1,156	2.29 to 7.38
3	133.7	2,472	1.97 to 5.45
6	62.5	1,156	2.54 to 10.31
6	103.4	1,912	2.65 to 10.13
6	133.7	2,472	2.26 to 11.71
15	62.5	1,156	2.55 to 20.06
15	85.1	1,574	2.37 to 18.81
15	103.4	1,912	2.55 to 17.51
15	133.7	2,472	2.48 to 19.58
30	1		3.59
30	62.5	1,156	2.54 to 21.79
30	133.7	2,472	2.48 to 18.95
$\beta = 0°$; b = 5 in.			
6	208	933	2.71 to 14.80
6	544	2,455	3.13 to 8.08
15	208	933	2.85 to 15.66
15	544	2,455	3.17 to 16.04

TABLE II.- BASIC MEASURED QUANTITIES FROM TESTS OF A 5-INCH-BEAM, 30° DEAD-RISE MODEL

At contact				At maximum load					At maximum moment					At maximum draft				At exit	
x_o, fps	$\dot{z}_o$, fps	V_o, fps	γ_o, deg	t, sec	n_1	M_γ, ft-lb	z, ft	$\dot{z}$, fps	t, sec	M_γ, ft-lb	n_1	z, ft	$\dot{z}$, fps	t, sec	z, ft	n_1	M_γ, ft-lb	t, sec	$\dot{z}$, fps
$\tau = 3°$; W = 933 lb																			
87.7	3.8	87.8	2.48	0.13	0.38	1,402	0.41	2.7	0.23	1,924	0.35	0.60	1.5	0.41	0.72	0.08	362	----	-----
75.8	3.7	75.8	2.76	.14	.31	1,272	.43	2.6	.23	1,841	.31	.59	1.7	.40	.72	.20	936	----	-----
69.0	4.6	69.1	3.76	.14	.40	1,979	.52	3.0	.22	2,563	.38	.71	2.0	.44	.91	.27	1,231	----	-----
69.0	5.8	69.2	4.82	.10	.57	3,619	.52	4.3	.15	4,281	.56	.70	3.5	.43	1.18	.31	1,744	----	-----
62.1	6.0	62.4	5.54	.14	.56	3,678	.60	4.4	.14	3,678	.56	.72	3.8	.47	1.27	.28	598	----	-----
54.8	6.0	55.1	6.26	.11	.53	2,764	.58	4.3	.14	3,233	.51	.70	3.9	.49	1.30	.29	895		-----
51.2	7.2	51.7	8.06	.12	.66	4,855	.68	5.4	.12	4,855	.66	.73	5.2	.41	1.55	.44	1,949	----	-----
$\tau = 6°$; W = 933 lb																			
85.5	3.9	85.6	2.64	0.17	0.49	1,743	0.49	2.0	0.17	1,743	0.49	0.49	2.0	0.32	0.63	0.34	1,078	----	-----
82.0	3.8	82.1	2.74	.18	.45	1,497	.57	2.1	.24	1,590	.43	.66	1.2	.35	.72	.28	957	----	-----
59.5	10.6	60.4	6.05	.15	.57	4,984	.97	6.2	.23	5,518	.51	1.22	3.7	.34	1.38	.32	3,502	----	-----
56.0	7.7	56.6	7.81	.14	.76	3,747	.95	5.3	.23	4,330	.67	1.30	3.1	.44	1.59	.33	1,700	----	-----
61.9	9.7	62.7	8.93	.13	1.07	5,487	1.07	6.3	.16	6,630	1.03	1.23	5.2	.42	1.77	.43	2,288	----	-----
64.5	10.3	65.3	9.09	.13	1.18	6,346	1.10	6.9	.17	7,462	1.10	1.36	5.3	.39	1.86	.48	2,389	----	-----
52.6	9.4	53.5	10.09	.14	.90	4,444	1.05	6.5	.17	5,425	.85	1.24	5.5	.47	1.93	----	1,889	----	-----
52.6	10.7	53.7	11.48	.14	1.08	6,489	1.24	6.7	.17	7,017	.99	1.42	5.9	.40	2.05	----	4,509	----	-----
48.8	10.6	49.9	12.27	.15	1.04	6,280	1.27	6.9	.18	7,080	.98	1.45	6.0	.41	2.14	----	5,031	----	-----
42.7	9.4	43.8	12.36	.17	.81	5,002	1.34	5.8	.19	5,185	.80	1.44	5.5	.45	2.12	----	3,927	----	-----
$\tau = 9°$; W = 933 lb																			
86.2	4.7	86.3	3.16	0.17	0.65	1,751	0.60	2.1	0.17	1,751	0.65	0.60	2.1	0.29	0.71	0.50	1,409	----	-----
75.2	8.4	75.7	6.36	.15	.98	3,613	.99	4.6	.22	3,783	.87	1.20	2.4	.30	1.79	.61	2,478	----	-----
62.1	10.6	63.0	9.64	.13	1.15	4,297	1.13	6.9	.21	5,675	1.02	1.54	4.0	.36	1.79	.57	3,475	----	-----
52.1	8.9	52.8	9.69	.15	.84	3,234	1.13	5.8	.22	3,746	.75	1.47	4.2	.43	1.84	.40	2,251	----	-----
43.6	9.9	44.7	12.84	.17	.84	3,805	1.31	6.5	.23	4,121	.78	1.62	4.7	.45	2.09	.42	2,286	----	-----
44.8	10.6	46.1	13.25	.14	.96	3,781	1.22	7.4	.23	4,857	.82	1.75	4.9	.46	2.21	.41	2,425	----	-----
33.8	8.6	34.9	14.26	.19	.62	2,734	1.28	5.4	.26	2,962	.57	1.59	4.0	.55	2.08	.33	1,408	1.63	-1.55
39.2	10.5	54.2	15.04	.13	1.64	3,671	1.20	7.7	.22	5,058	1.48	1.76	5.1	.49	2.30	.77	2,343	1.39	-2.53
33.3	10.8	35.0	17.88	.14	.83	3,459	1.29	7.5	.24	4,497	.73	1.91	5.3	.51	2.52	----	2,371	----	-----
$\tau = 9°$; W = 2,390 lb																			
86.2	3.7	86.3	2.52	0.28	0.29	2,208	0.79	2.1	0.39	2,562	0.28	0.93	0.7	0.49	0.97	0.24	2,083	----	-----
74.1	5.7	74.3	4.40	.25	.39	4,310	1.18	3.4	.32	4,999	.39	1.38	2.6	.54	1.65	.29	4,097	----	-----
67.1	6.0	67.4	5.10	.27	.36	15,843	1.22	3.3	----	-----	----	-----	---	.61	1.77	----	18,637	----	-----
68.5	7.8	68.9	6.47	.26	.53	7,491	1.63	4.9	.36	8,240	.49	1.99	3.2	.57	2.33	----	7,358	----	-----
57.3	8.4	57.9	8.29	.27	.48	7,254	1.83	5.4	.33	7,820	.46	2.09	4.4	.61	2.70	----	7,297	----	-----
63.5	9.7	64.2	8.63	.24	.64	10,133	1.88	6.1	.27	10,788	.63	2.06	5.6	.53	2.80	----	10,915	----	-----
56.4	10.0	57.3	10.00	.23	.57	5,802	1.86	6.5	----	------	----	-----	---	.57	2.94	----	2,425	----	-----
$\tau = 15°$; W = 933 lb																			
85.5	3.9	85.6	2.62	0.13	0.67	1,894	0.41	2.1	0.16	1,477	0.67	0.46	1.6	0.22	0.51	0.63	1,711	0.53	-2.4
83.0	3.9	83.1	2.71	.16	.67	1,313	.44	1.6	.16	1,313	.67	.44	1.6	.25	.49	.54	462	.55	-2.0
81.3	4.2	81.4	2.94	.17	.62	1,537	.48	1.7	.23	1,467	.62	.54	.5	.25	.54	.57	1,706	.58	-2.3
87.0	5.3	87.1	3.44	.16	.85	1,459	.59	2.6	.18	1,644	.83	.62	1.5	.25	.66	.71	1,058	.55	-3.1
83.3	6.2	83.6	4.20	.16	.94	1,816	.75	2.8	.22	1,675	.92	.84	1.2	.25	.85	.82	1,937	.58	-3.6
74.6	8.2	75.1	6.26	.15	1.04	2,571	.85	4.1	.23	2,983	.96	1.07	1.5	.27	1.10	.85	2,532	.71	-3.5
75.8	8.4	76.2	6.35	.16	1.15	1,725	1.05	4.1	.16	1,725	1.15	1.05	4.1	.27	1.26	.94	1,479	----	-----
73.5	8.8	74.1	6.87	.18	1.20	3,065	1.15	3.4	.22	3,191	1.10	1.25	1.9	.28	1.28	.85	2,165	.70	-3.6
69.4	8.4	70.0	6.89	.16	1.09	1,317	1.06	4.3	.23	777	1.02	1.25	1.8	.28	1.28	.85	1,201	.74	-4.1
56.8	7.2	57.3	7.27	.18	.80	1,375	1.03	3.9	.23	990	.75	1.18	2.5	.33	1.29	.57	653	.88	-3.0
62.5	8.8	63.1	8.05	.16	1.06	1,128	1.12	4.8	.21	843	1.03	1.30	3.1	.31	1.46	.75	701	.82	-3.9
52.0	8.4	52.6	9.22	.16	.89	965	1.40	5.3	.23	404	.83	1.40	3.5	.37	1.60	.58	195	1.02	-3.0
61.7	10.1	62.6	9.27	.15	1.24	3,666	1.25	5.8	.22	4,146	1.11	1.54	3.1	.32	1.68	.82	2,817	.86	-3.7
62.1	10.2	63.0	9.35	.17	1.28	956	1.38	5.1	.24	180	1.10	1.62	2.7	.32	1.70	.83	9	.84	-4.1
62.1	10.6	63.0	9.69	.13	1.24	2,138	1.15	7.0	.20	723	1.20	1.50	3.8	.31	1.68	.82	391	.82	-4.4
61.9	10.7	62.8	9.81	.15	1.25	3,790	1.34	6.4	.22	4,276	1.15	1.69	3.6	.34	1.88	.73	2,611	----	-----
59.2	10.4	60.1	9.92	.15	1.24	4,038	1.25	6.1	.22	4,515	1.15	1.55	3.5	.35	1.72	.68	2,706	.95	-3.3
61.5	10.8	62.5	9.97	.15	1.24	3,826	1.32	6.0	.22	4,318	1.13	1.64	3.2	.34	1.81	.70	2,569	----	-----
59.5	10.6	60.4	10.00	.15	1.10	16,744	1.19	6.3	----	-----	----	----	---	.34	1.65	.65	10,602	.92	-3.3
61.0	11.1	62.0	10.30	.16	1.28	4,638	1.31	6.3	.24	5,073	1.14	1.68	3.1	.32	1.80	.87	3,984	.90	-4.3
52.0	10.6	53.0	11.54	.15	1.10	985	1.33	6.6	.22	208	1.03	1.70	4.2	.39	1.98	.60	35	1.05	-3.4
50.0	10.9	51.2	12.29	.15	1.12	3,352	1.35	7.0	.23	3,587	1.00	1.77	4.2	.40	2.07	.58	1,739	1.19	-2.8
48.0	11.3	49.3	13.23	.12	1.18	3,339	1.27	8.6	.19	4,405	1.15	1.73	5.9	.39	2.24	.66	2,912	1.19	-3.0
43.5	10.5	44.7	13.65	.19	.97	592	1.60	5.9	.23	47	.59	1.80	4.7	.44	2.22	.49	19	1.30	-3.1
42.1	10.8	43.5	14.29	.16	1.02	2,942	1.42	7.2	.18	3,281	1.01	1.56	6.8	.44	2.28	.50	1,892	1.43	-2.3
43.5	11.4	45.0	14.69	.17	1.14	3,869	1.68	7.1	.19	4,067	1.07	1.81	6.4	.41	2.44	.89	2,786	1.37	-2.3
38.9	11.5	40.6	16.48	.16	1.05	3,517	1.56	7.7	.31	3,991	.83	2.34	3.2	.45	2.52	.49	2,354	1.48	-2.3
35.2	10.7	36.8	16.95	.20	.84	295	1.70	6.8	.23	65	.79	1.88	5.9	.50	2.59	.43	300	1.70	-2.2
33.7	10.4	35.2	17.20	.16	.83	409	1.47	7.2	.21	58	.82	1.79	6.2	.51	2.57	.41	235	1.67	-2.1
34.1	11.5	36.0	18.61	.17	.99	3,622	1.69	7.9	.24	4,043	.90	2.14	5.8	.48	2.76	.51	2,522	1.64	-2.0
28.7	10.8	30.7	20.55	.16	.76	420	1.50	7.6	.23	220	.71	1.95	6.0	.57	2.81	.35	94	1.86	-1.7

TABLE II.- BASIC MEASURED QUANTITIES FROM TESTS OF A 5-INCH-BEAM, 30° DEAD-RISE MODEL - Concluded

At contact				At maximum load					At maximum moment					At maximum draft				At exit	
x_o, fps	$\dot{z}_o$, fps	V_o, fps	γ_o, deg	t, sec	n_i	M_Y, ft-lb	z, ft	$\dot{z}$, fps	t, sec	M_Y, ft-lb	n_i	z, ft	$\dot{z}$, fps	t, sec	z, ft	n_i	M_Y, ft-lb	t, sec	$\dot{z}$, fps
$\tau = 15°$; $W = 1,315$ lb																			
78.1	4.3	78.2	3.21	0.19	0.52	1,150	0.65	2.3	0.22	1,110	0.50	0.70	1.7	0.34	0.78	0.39	483	----	----
76.3	7.2	76.7	5.42	.16	.91	3,400	.98	4.2	.23	3,380	.85	1.20	2.3	.31	1.29	.67	2,647	----	----
66.4	10.3	67.2	8.76	.21	1.10	5,814	1.67	4.8	.21	5,814	1.10	1.67	4.8	.37	2.02	.73	4,252	----	----
59.9	10.8	60.8	10.19	.15	1.02	4,753	1.37	7.3	.24	6,158	.98	1.91	4.6	.41	2.27	.64	4,660	----	----
52.9	10.3	53.9	11.00	.21	.90	5,014	1.79	5.8	.21	5,014	.90	1.79	5.8	.46	2.44	.51	3,342	----	----
42.2	10.3	43.4	13.73	.29	.71	4,603	2.31	4.8	.36	5,164	.68	2.59	3.6	.57	2.88	.34	2,582	----	----
37.6	10.4	39.0	15.42	.21	.71	4,004	1.90	6.9	.30	5,108	.71	2.44	4.9	.58	3.09	----	3,123	----	----
32.9	11.0	34.7	18.54	.23	.65	3,881	2.11	7.3	.35	4,978	.61	2.80	4.5	.62	3.36	----	3,086	----	----
$\tau = 15°$; $W = 1,767$ lb																			
85.5	4.7	85.6	3.15	0.26	0.51	1,882	0.89	1.8	0.35	2,050	0.48	0.97	0.3	0.36	0.98	0.45	1,776	0.86	-2.7
74.9	4.7	75.1	3.59	.24	.45	----	.88	2.4	----	----	---	---	---	.38	1.05	.38	----	1.00	-2.3
70.4	6.1	70.7	4.94	.24	.55	2,903	1.18	2.9	.32	3,195	.53	1.36	1.7	.41	1.44	.45	2,640	1.10	-2.8
45.2	4.9	45.5	6.09	.34	.25	915	1.35	2.8	.39	950	.25	1.47	2.5	.66	1.82	.18	481	----	----
66.0	7.9	66.5	6.84	.23	.64	3,746	1.43	4.7	.33	4,307	.60	1.75	2.3	.48	1.88	.39	2,534	----	----
48.2	6.1	48.6	7.17	.28	.35	1,686	1.49	4.0	.37	2,030	.35	1.80	2.9	.66	2.21	.20	1,035	----	----
50.8	7.8	51.4	8.76	.24	.52	3,398	1.61	4.9	.28	3,680	.51	1.79	4.3	.58	2.35	.27	2,062	----	----
63.7	10.9	64.6	9.71	.21	.89	6,512	1.89	6.2	.32	7,268	.79	2.41	3.2	.49	2.65	.48	4,224	----	----
36.8	6.4	37.3	9.92	.33	.33	2,499	1.65	3.7	.33	2,499	.33	1.85	3.7	.83	2.37	.10	467	----	----
51.3	9.7	52.2	10.73	.22	.64	3,914	1.75	6.0	.24	4,924	.64	1.85	5.6	.60	2.85	.29	2,335	----	----
48.3	9.6	49.2	11.23	.23	.59	4,160	1.80	6.2	.47	5,145	.49	2.70	1.8	.58	2.80	.32	3,184	----	----
44.6	9.6	45.7	12.18	.22	.54	3,816	1.78	6.6	.39	5,063	.51	2.60	3.6	.67	3.01	.26	2,816	----	----
41.2	9.7	42.4	13.29	.23	.52	3,931	1.84	6.5	.42	5,201	.49	2.76	3.6	.69	3.16	----	-----	----	----
$\tau = 15°$; $W = 2,350$ lb																			
86.2	3.2	86.3	2.16	0.27	0.30	5,957	0.63	1.4	0.27	5,957	0.50	0.63	1.4	0.41	0.71	0.25	4,784	0.94	-2.0
87.0	3.5	87.0	2.22	.19	.33	1,258	.53	2.3	.25	1,226	.52	.63	1.6	.40	.73	.27	871	.95	-2.5
80.6	3.6	80.7	2.58	.30	.37	2,249	.80	1.3	.30	2,249	.57	.80	1.3	.43	.86	.26	1,054	1.01	-1.7
76.6	5.0	76.8	3.65	.29	.39	3,055	1.02	1.8	.36	3,097	.57	1.11	1.1	.45	1.15	.30	2,482	----	----
78.1	5.0	78.3	3.67	.19	.40	2,378	.74	3.2	.36	2,602	.58	1.06	.9	.47	1.10	.24	557	1.09	-2.6
72.7	5.5	72.9	4.38	.31	.47	3,611	1.31	2.3	.35	3,822	.46	1.38	1.8	.45	1.49	.41	3,575	1.26	-2.5
71.7	5.8	71.9	4.57	.21	.43	3,004	.95	3.8	.27	3,576	.43	1.13	2.8	.48	1.37	.29	1,589	1.21	-2.6
67.8	7.1	68.2	6.01	.25	.51	4,275	1.33	4.0	.32	4,408	.48	1.53	2.6	.49	1.75	.35	3,120	----	----
45.7	4.9	45.9	6.06	.28	.25	2,195	1.05	3.0	.33	2,333	.25	1.19	2.6	.66	1.59	.17	1,485	----	----
67.8	7.6	68.2	6.45	.26	.58	5,143	1.50	4.2	.29	5,534	.57	1.61	3.6	.50	1.96	.39	3,660	----	----
60.6	8.2	61.2	7.71	.24	.53	4,852	1.57	4.7	.33	5,530	.51	1.91	3.2	.54	2.20	.33	3,581	----	----
63.3	9.6	64.0	8.67	.21	.66	6,549	1.68	6.5	.38	7,378	.56	2.42	3.2	.56	2.65	.42	5,541	----	----
61.7	9.7	62.5	8.96	.22	.64	6,357	1.76	6.2	.35	6,878	.56	2.35	3.6	.58	2.67	.33	4,186	----	----
54.4	9.8	55.2	10.25	.23	.58	5,844	1.83	6.3	.39	6,666	.51	2.54	3.3	.64	2.88	.27	3,530	----	----
49.1	9.9	50.1	11.35	.22	.54	5,608	1.78	7.0	.43	6,252	.44	2.76	3.4	.71	3.09	.20	2,879	----	----
45.9	9.8	46.9	12.04	.32	.57	7,318	2.44	9.6	.40	7,889	.54	2.78	7.2	.68	3.27	----	4,411	----	----
$\tau = 30°$; $W = 933$ lb																			
80.3	3.8	80.4	2.75	0.16	0.79	966	0.45	1.6	0.16	966	0.79	0.45	1.6	0.20	0.48	0.73	28	0.47	-2.4
75.2	8.2	75.6	6.24	.19	1.47	2,160	1.04	2.1	.23	2,667	1.43	1.07	.3	.23	1.07	1.43	2,667	.51	-5.7
63.1	10.6	64.0	9.50	.20	1.46	2,588	1.46	3.5	.20	2,588	1.46	1.46	3.5	.26	1.55	1.33	2,118	.63	-6.3
43.7	10.1	44.8	13.07	.22	.98	2,270	1.71	4.9	.22	2,270	.98	1.71	4.9	.40	2.08	.67	1,242	.98	-4.9
33.3	10.7	35.0	17.85	.22	.86	2,383	1.92	6.1	.28	2,203	.81	2.21	4.4	.49	2.58	.44	1,006	1.36	-3.4
27.9	10.7	29.9	20.91	.22	.69	1,852	1.96	6.6	.34	2,105	.65	2.56	4.0	.56	2.96	.44	1,380	1.81	-2.1
$\tau = 30°$; $W = 2,350$ lb																			
87.0	3.5	87.0	2.22	0.25	0.48	830	0.63	1.3	0.28	1,001	0.48	0.66	0.8	0.31	0.68	0.46	625	0.70	-2.6
78.1	4.8	78.3	3.59	.25	.55	2,009	.95	2.0	.27	2,044	.55	.98	1.6	.37	1.06	.49	1,304	.82	-3.8
68.5	8.5	69.0	7.11	.28	.74	4,470	1.75	3.9	.34	4,593	.73	1.93	2.4	.45	2.05	.71	5,369	1.13	-5.2
62.1	9.6	62.8	8.80	.24	.79	5,104	1.93	6.2	.30	5,368	.78	2.22	4.3	.49	2.60	.59	4,029	----	----
55.2	9.7	56.1	9.97	.32	.65	-----	2.38	4.7	----	-----	---	----	---	.56	2.87	.49	-----	----	----
49.0	9.8	50.0	11.33	.32	.60	4,214	2.52	5.2	.48	4,642	.55	3.10	2.4	.63	3.24	.42	3,315	----	----
43.5	10.0	44.6	12.97	.38	.51	3,817	2.91	5.1	.55	4,942	.50	3.49	2.5	.55	3.49	.50	4,942	----	----

TABLE III.- COEFFICIENT DATA FROM TESTS OF A 5-INCH-BEAM, 30° DEAD-RISE MODEL

γ_0, deg	At maximum load						At maximum moment						At maximum draft					At exit	
	c_t	c_L	c_m	c_d	$c_{\dot z}$	c_{cp}	c_t	c_m	c_L	c_d	$c_{\dot z}$	c_{cp}	c_t	c_d	c_L	c_m	c_{cp}	c_t	$c_{\dot z}$
$\tau = 3°$; $C_\Delta = 208$																			
2.48	27.4	0.27	2.6	0.98	0.71	9.7	48.5	3.6	0.25	1.45	0.40	14.5	86.4	1.72	0.06	0.7	11.6	-----	-----
2.76	25.5	.30	3.2	1.02	.71	10.5	41.9	4.6	.30	1.42	.45	15.2	72.8	1.73	.19	2.3	12.0	-----	-----
3.76	23.2	.46	5.9	1.25	.66	12.7	36.5	7.7	.44	1.71	.43	17.3	73.0	2.18	.31	3.7	11.7	-----	-----
4.82	16.6	.66	10.8	1.25	.75	16.6	24.9	12.8	.65	1.69	.60	19.6	71.4	2.82	.36	5.2	12.8	-----	-----
5.54	21.0	.80	11.1	1.44	.73	15.2	21.0	13.5	.80	1.73	.63	17.8	70.4	3.05	.40	2.2	5.5	-----	-----
6.26	14.6	.97	13.0	1.38	.72	14.8	18.5	15.2	.93	1.67	.65	16.3	64.8	3.13	.53	4.2	8.8	-----	-----
8.06	14.9	1.37	23.0	1.63	.74	16.0	14.9	26.0	1.37	1.76	.72	16.9	50.8	3.73	.91	10.4	11.4	-----	-----
$\tau = 6°$; $C_\Delta = 208$																			
2.64	34.9	0.37	3.4	1.18	0.51	9.1	34.9	3.4	0.37	1.18	0.51	9.1	65.7	1.50	0.26	2.1	8.1	-----	-----
2.74	35.4	.37	3.2	1.36	.55	8.5	47.3	3.4	.35	1.58	.32	9.7	68.9	1.72	.23	2.0	8.7	-----	-----
6.05	28.4	.87	11.4	2.33	.59	13.1	43.5	12.7	.78	2.93	.35	16.2	64.4	3.32	.49	8.0	16.3	-----	-----
7.81	19.0	1.32	16.7	2.27	.69	12.6	31.2	19.3	1.16	3.13	.40	16.5	59.7	3.81	.57	7.6	13.2	-----	-----
8.93	19.6	1.51	19.9	2.56	.65	13.1	24.1	24.1	1.45	2.96	.53	16.5	63.2	4.25	.61	8.3	15.6	-----	-----
9.09	20.4	1.53	21.2	2.65	.67	13.8	26.7	25.0	1.43	3.26	.51	17.4	61.2	4.47	.62	8.0	12.8	-----	-----
10.09	18.0	1.75	22.2	2.52	.69	12.6	21.8	27.1	1.65	2.97	.59	16.3	60.3	4.62	----	----	----	-----	-----
11.48	18.0	2.08	32.1	2.98	.63	15.4	21.9	34.7	1.90	3.40	.55	18.1	51.6	4.91	----	----	----	-----	-----
12.27	18.0	2.32	36.0	3.04	.65	15.4	21.6	40.6	2.18	3.48	.57	18.5	49.1	5.14	----	----	----	--- ..	-----
12.36	17.9	2.35	37.3	3.21	.62	15.8	20.0	38.7	2.32	3.46	.59	16.6	47.3	5.08	----	----	----	-----	-----
$\tau = 9°$; $C_\Delta = 208$																			
3.16	35.2	0.48	3.4	1.44	0.45	6.9	35.2	3.4	0.48	1.44	0.45	6.9	60.1	1.70	0.37	2.7	7.2	-----	-----
6.36	27.2	.95	9.0	2.37	.54	9.4	39.9	9.4	.84	2.88	.29	11.0	54.5	3.10	.59	6.2	10.3	-----	-----
9.64	19.7	1.61	15.5	2.71	.65	9.5	31.8	20.4	1.43	3.70	.38	14.1	54.4	4.30	.80	12.5	15.5	-----	-----
9.69	19.0	1.67	16.5	2.71	.65	9.8	27.9	19.2	1.49	3.52	.47	12.7	54.5	4.42	.80	11.5	14.3	-----	-----
12.84	18.2	2.33	27.2	3.14	.65	11.5	24.7	29.5	2.17	3.89	.47	13.4	48.3	5.01	1.17	16.3	13.8	-----	-----
13.25	15.5	2.51	25.4	2.93	.70	10.0	25.4	32.7	2.14	4.19	.46	15.0	50.9	5.30	1.07	16.3	15.0	-----	-----
14.26	15.9	2.83	32.1	3.06	.63	11.2	21.7	34.8	2.60	3.82	.46	13.2	46.0	4.99	1.51	16.6	10.8	136.3	-0.18
15.04	12.7	3.09	31.8	2.88	.73	10.1	21.4	43.8	2.79	4.22	.48	15.5	47.8	5.53	1.45	20.3	13.9	135.7	-.24
17.88	11.8	3.75	40.3	3.09	.70	10.6	20.2	52.3	3.30	4.58	.49	15.6	42.9	6.04	----	----	----	-----	-----
$\tau = 9°$; $C_\Delta = 530$																			
2.52	58.0	0.55	4.2	1.90	0.57	7.5	80.8	4.9	0.53	2.23	0.18	9.1	101.5	2.32	0.46	4.0	8.6	-----	-----
4.40	44.6	1.00	11.2	2.83	.60	11.0	57.1	12.9	1.00	3.31	.45	12.7	96.3	3.96	.75	10.6	14.0	-----	-----
5.10	43.7	1.13	----	2.93	.55	----	----	----	----	----	----	----	98.6	4.24	----	----	----	-----	-----
6.47	43.0	1.59	22.5	3.91	.63	14.0	59.6	24.8	1.47	4.78	.41	16.7	94.3	5.58	----	----	----	-----	-----
8.29	37.5	2.03	30.9	4.38	.64	15.0	45.9	33.3	1.95	5.02	.53	16.9	84.8	6.47	----	----	----	-----	-----
8.63	37.0	2.21	35.1	4.52	.63	15.7	41.6	37.3	2.17	4.94	.58	17.0	81.7	6.73	----	----	----	-----	-----
10.00	31.6	2.47	----	4.47	.65	----	----	----	----	----	----	----	78.4	7.06	----	----	----	-----	-----
$\tau = 15°$; $C_\Delta = 208$																			
2.62	26.7	0.51	1.6	0.99	0.54	3.1	32.9	2.4	0.51	1.11	0.41	4.7	45.2	1.23	0.48	1.6	3.2	108.0	-0.60
2.71	31.9	.54	2.7	1.06	.42	4.8	31.9	2.7	.54	1.06	.42	4.8	49.9	1.18	.43	1.0	2.2	109.7	-.52
2.94	33.2	.52	2.0	1.16	.41	3.7	44.9	2.2	.52	1.30	.11	1.3	48.8	1.30	.48	1.2	2.5	112.5	-.54
3.44	33.5	.62	2.7	1.41	.49	4.3	37.6	3.1	.61	1.49	.29	4.9	52.3	1.58	.52	2.0	3.7	115.6	-.59
4.20	32.1	.75	4.0	1.79	.45	5.2	44.1	4.2	.73	2.02	.19	5.5	50.1	2.05	.65	2.8	4.2	115.7	-.58
6.26	27.0	1.02	6.5	2.03	.50	6.1	41.4	7.6	.94	2.56	.18	7.8	48.7	2.63	.84	6.4	7.4	127.9	-.43
6.35	29.3	1.10	7.1	2.53	.49	6.2	29.3	7.1	1.10	2.53	.49	6.2	49.4	3.03	.90	5.6	6.0	-----	-----
6.87	32.0	1.21	8.0	2.75	.38	6.4	39.1	8.3	1.11	2.99	.21	7.2	49.8	3.06	.86	5.6	6.3	124.4	-.42
6.89	26.9	1.24	8.8	2.53	.51	6.9	38.6	9.7	1.15	2.99	.21	6.6	47.0	3.08	.96	6.5	6.6	123.4	-.42
7.27	24.7	1.35	8.1	2.47	.54	5.8	31.6	9.0	1.27	2.82	.35	6.8	45.4	3.10	.96	7.1	7.1	121.0	-.42
8.05	24.2	1.48	11.3	2.69	.54	7.4	31.8	11.9	1.43	3.13	.35	8.0	47.0	3.50	1.04	8.4	7.8	124.7	-.44
9.22	20.2	1.78	13.5	2.63	.63	7.3	29.1	15.0	1.66	3.35	.42	8.7	46.7	3.85	1.16	11.1	9.2	128.7	-.35
9.27	22.5	1.76	13.4	2.99	.57	7.3	33.0	15.1	1.57	3.69	.31	9.3	48.0	4.02	1.16	10.3	8.5	129.5	-.37
9.35	25.7	1.79	15.0	3.31	.50	8.1	36.3	15.2	1.54	3.90	.26	9.6	48.3	4.09	1.16	12.0	9.9	127.0	-.40
9.69	19.7	1.73	10.3	2.76	.66	5.7	30.2	14.7	1.68	3.61	.36	8.5	46.9	4.04	1.15	10.5	8.9	124.1	-.41
9.81	22.6	1.76	13.7	3.22	.60	7.5	33.2	15.5	1.62	4.05	.34	9.2	51.3	4.51	1.03	9.4	8.9	-----	-----
9.92	21.6	1.91	16.0	2.99	.59	8.1	31.7	17.9	1.77	3.73	.34	9.7	50.5	4.12	1.04	10.7	9.9	136.5	-.32
9.97	22.5	1.76	14.0	3.16	.56	7.7	33.0	15.8	1.61	3.94	.30	9.5	51.0	4.34	.99	9.4	9.1	-----	-----
10.0	21.8	1.67	----	2.86	.60	----	----	----	----	----	----	----	49.3	3.97	.98	----	----	133.9	-.31
10.3	23.8	1.85	17.2	3.15	.57	9.0	35.7	18.9	1.65	4.02	.28	11.0	47.6	4.31	1.26	14.8	11.4	133.9	-.39
11.54	19.1	2.17	17.4	3.20	.62	7.7	28.0	20.0	2.03	4.07	.40	9.5	49.6	4.74	1.18	12.0	9.8	134.0	-.32
12.29	18.4	2.38	21.9	3.24	.64	8.9	28.3	22.0	2.12	4.25	.39	10.1	49.1	4.96	1.24	13.0	10.1	146.0	-.26
13.23	14.2	2.70	19.6	3.04	.76	7.0	22.5	25.9	2.63	4.29	.52	9.5	46.1	5.38	1.51	17.1	11.0	140.7	-.27
13.65	20.4	2.69	23.6	3.85	.56	8.5	24.7	25.8	2.47	4.33	.45	10.1	47.3	5.32	1.36	14.0	10.0	139.8	-.29
14.29	16.7	3.00	22.2	3.41	.67	8.0	18.8	24.8	2.97	3.74	.63	8.6	45.9	5.47	1.46	14.3	10.6	149.1	-.21
14.69	18.3	3.13	27.3	4.03	.62	8.4	20.5	28.7	2.94	4.34	.56	9.4	44.2	5.85	1.62	19.7	11.7	147.4	-.20
16.48	15.6	3.54	30.5	3.74	.67	8.3	30.2	34.6	2.80	5.61	.28	11.9	43.8	6.06	1.65	20.4	12.0	144.0	-.20
16.95	17.7	3.44	32.4	4.08	.63	9.1	20.3	34.2	3.23	4.51	.55	10.2	44.2	6.22	1.76	20.9	11.5	150.3	-.20
17.20	13.5	3.71	34.1	3.53	.69	8.9	17.8	37.4	3.66	4.29	.59	9.9	43.1	6.16	1.85	21.3	11.2	141.0	-.20
18.61	14.7	4.23	39.9	4.06	.69	9.1	20.7	44.5	3.85	5.14	.51	11.2	41.5	6.62	2.18	27.8	12.3	141.4	-.17
20.55	11.8	4.48	39.9	3.61	.71	8.6	16.9	46.6	4.18	4.68	.56	10.8	42.0	6.75	2.06	20.2	9.4	137.4	-.16

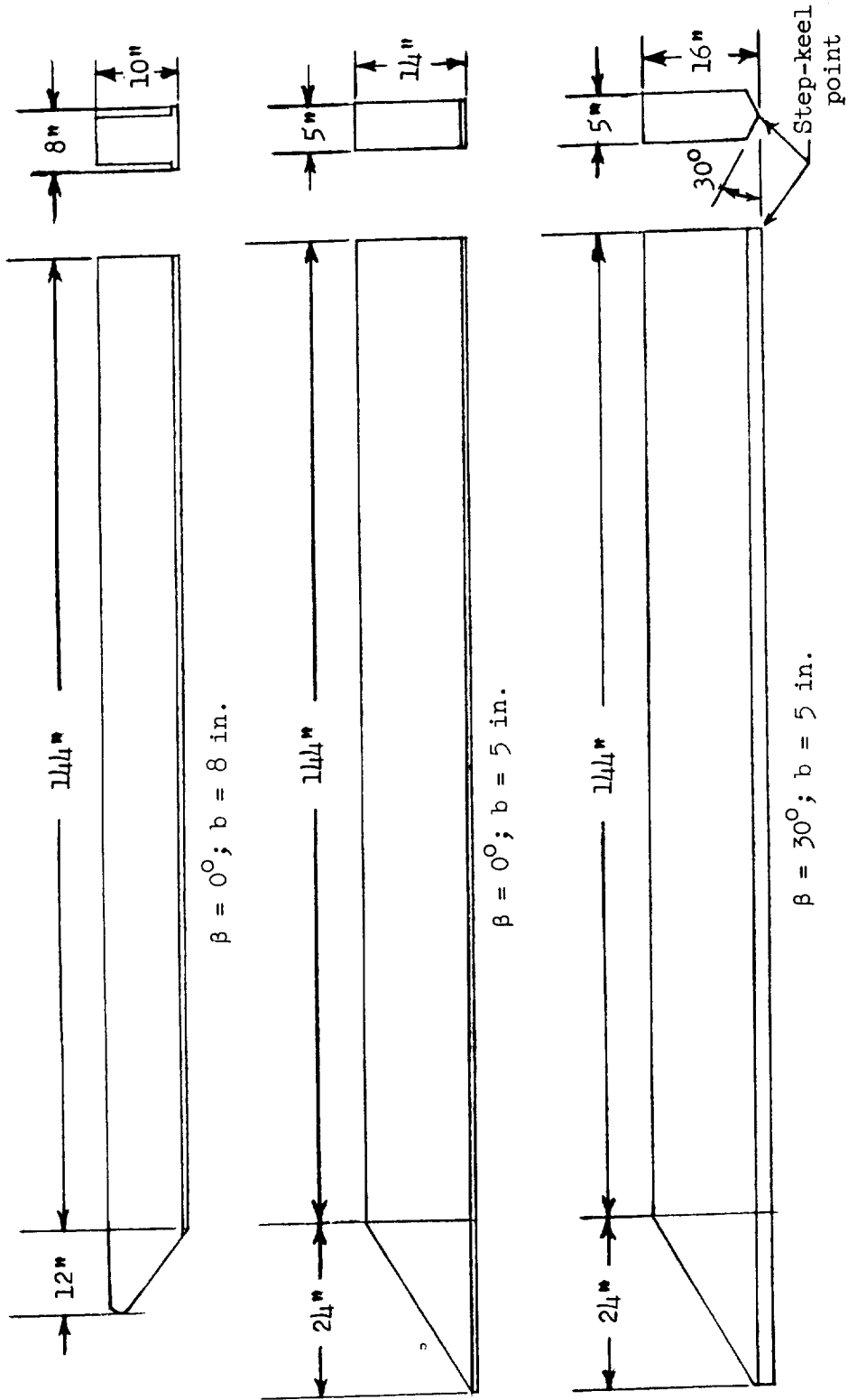TABLE III.- COEFFICIENT DATA FROM TESTS OF A 5-INCH-BEAM, 30° DEAD-RISE MODEL - Concluded

γ_0, deg	At maximum load						At maximum moment						At maximum draft					At exit	
	c_t	c_L	c_m	c_d	$c_{\dot z}$	c_{cp}	c_t	c_m	c_L	c_d	$c_{\dot z}$	c_{cp}	c_t	c_d	c_L	c_m	c_{cp}	c_t	$c_{\dot z}$
$\tau = 15°$; $C_\Delta = 300$																			
3.21	35.7	0.68	2.7	1.56	0.54	3.8	41.3	2.6	0.66	1.69	0.40	3.8	63.9	1.88	0.51	1.1	2.1	-----	-----
5.42	29.4	1.25	8.3	2.36	.58	6.4	42.3	8.2	1.16	2.89	.32	6.8	57.0	3.09	.92	6.4	6.6	-----	-----
8.76	33.9	1.96	18.4	4.01	.47	9.0	33.9	18.4	1.96	4.01	.47	9.0	59.7	4.85	1.30	13.4	10.0	-----	-----
10.19	21.9	2.22	18.3	3.29	.68	8.0	35.0	23.8	2.13	4.59	.43	10.8	59.9	5.45	1.39	18.0	12.5	-----	-----
11.00	27.2	2.50	24.6	4.30	.56	9.5	27.2	24.6	2.50	4.30	.56	9.5	59.5	5.86	1.41	16.4	11.2	-----	-----
13.73	30.2	3.03	34.8	5.54	.47	11.1	37.5	39.1	2.90	6.21	.35	13.0	59.4	6.91	1.45	19.5	13.0	-----	-----
15.42	19.7	3.76	37.6	4.56	.67	9.7	28.1	48.0	3.76	5.86	.47	12.7	54.3	7.41	----	----	----	-----	-----
18.54	19.1	4.35	46.0	5.06	.66	10.2	29.1	59.1	4.08	6.72	.41	14.0	51.6	8.07	----	----	----	-----	-----
$\tau = 15°$; $C_\Delta = 400$																			
3.15	53.4	0.75	3.7	2.13	0.37	4.7	71.9	4.0	0.70	2.33	0.06	5.5	74.0	2.35	0.66	3.5	5.1	176.5	-0.58
3.59	43.2	.86	----	2.10	.50	----	----	----	----	----	----	----	68.4	2.52	.73	----	----	180.1	-.48
4.94	40.7	1.18	8.3	2.82	.48	6.8	54.3	9.1	1.14	3.26	.28	7.7	69.5	3.46	.97	7.5	7.5	186.1	-.47
6.09	37.1	1.30	6.3	3.23	.58	4.7	42.6	6.6	1.30	3.53	.51	4.9	72.1	4.37	.93	3.3	3.4	-----	-----
6.84	36.7	1.56	12.1	3.44	.59	7.5	52.7	13.9	1.46	4.20	.29	9.2	76.6	4.50	.95	8.2	8.3	-----	-----
7.17	32.6	1.59	10.2	3.58	.66	6.2	43.1	12.3	1.59	4.31	.48	7.?	76.9	5.30	.91	6.3	6.6	-----	-----
8.76	29.6	2.12	18.4	3.86	.63	8.4	34.5	19.9	2.08	4.29	.55	9.?	71.5	5.65	1.10	11.2	9.8	-----	-----
9.71	32.6	2.29	22.3	4.54	.57	9.4	49.6	24.9	2.03	5.79	.29	11.3	76.0	6.35	1.24	14.4	11.3	-----	-----
9.92	29.6	2.55	25.6	3.95	.57	9.7	29.6	25.6	2.55	3.95	.57	9.?	74.3	5.68	.77	4.8	6.0	-----	-----
10.73	27.6	2.52	20.5	4.20	.62	8.7	30.1	25.8	2.52	4.45	.58	10.?	75.2	6.84	1.14	12.2	11.5	-----	-----
11.23	27.2	2.61	24.5	4.31	.65	9.0	55.6	30.3	2.17	6.47	.19	13.?	68.6	6.73	1.42	18.7	12.8	-----	-----
12.18	24.1	2.78	26.1	4.27	.69	9.1	42.7	34.7	2.63	6.23	.37	12.?	73.4	7.23	1.34	19.3	13.9	-----	-----
13.29	23.4	3.11	31.3	4.42	.67	9.7	42.7	41.4	2.93	6.63	.37	13.5	70.2	7.59	----	----	----	-----	-----
$\tau = 15°$; $C_\Delta = 530$																			
2.16	55.9	0.57	11.4	1.52	0.44	19.3	55.9	11.4	0.57	1.52	0.44	19.3	84.9	1.71	0.48	9.2	18.6	194.6	-0.61
2.22	39.7	.62	2.4	1.27	.66	3.7	52.2	2.9	.60	1.52	.47	4.4	83.5	1.75	.51	1.6	3.1	198.4	-.71
2.58	58.1	.81	4.9	1.91	.35	5.9	58.1	4.9	.81	1.91	.35	5.3	83.3	2.07	.57	2.3	3.9	194.7	-.48
3.65	53.4	.94	7.4	2.44	.37	7.6	66.3	7.5	.89	2.66	.22	8.1	82.9	2.76	.72	6.0	8.0	204.8	-.52
3.67	35.7	.93	5.5	1.78	.64	5.8	67.6	6.1	.88	2.55	.18	6.5	88.3	2.64	.56	1.3	2.3	220.2	-.45
4.38	54.3	1.26	9.7	3.15	.41	7.5	61.3	10.3	1.23	3.32	.32	8.1	78.8	3.57	1.10	9.6	8.5	209.0	-.45
4.57	36.2	1.18	8.3	2.28	.66	6.6	46.6	9.9	1.18	2.70	.48	7.5	82.8	3.28	.80	4.4	5.3	-----	-----
6.01	40.9	1.56	13.1	3.18	.56	8.1	52.4	13.5	1.47	3.67	.36	8.9	80.2	4.19	1.07	9.6	8.7	-----	-----
6.06	30.9	1.69	14.9	2.52	.63	8.5	36.4	15.8	1.69	2.85	.53	9.0	72.7	3.81	1.15	10.1	8.5	-----	-----
6.45	42.6	1.77	15.8	3.61	.55	8.6	47.5	17.0	1.74	3.86	.47	9.4	81.9	4.70	1.19	11.2	9.1	-----	-----
7.71	35.2	2.01	18.5	3.77	.57	3.9	48.4	21.1	1.94	4.58	.39	10.5	79.3	5.27	1.25	13.7	10.5	-----	-----
8.67	32.3	2.29	19.9	4.02	.67	9.1	58.4	23.4	2.01	5.81	.33	12.1	86.0	6.37	1.46	17.0	12.5	-----	-----
8.96	33.0	2.33	21.4	4.23	.64	9.3	52.5	25.7	2.04	5.65	.37	12.0	87.0	6.41	1.20	14.1	12.1	-----	-----
10.25	30.5	2.70	27.4	4.39	.64	9.8	51.7	31.2	2.38	6.10	.34	12.7	84.8	6.90	1.26	16.5	12.7	-----	-----
11.35	26.5	3.05	31.9	4.27	.71	10.1	51.7	40.2	2.49	6.63	.35	14.0	85.4	7.41	1.13	18.2	14.2	-----	-----
12.04	35.5	3.66	49.0	5.85	.98	12.9	44.3	52.8	3.46	6.67	.74	14.7	75.4	7.84	----	----	----	-----	-----
$\tau = 30°$; $C_\Delta = 208$																			
2.75	30.9	0.68	2.1	1.08	0.42	2.7	30.9	2.1	0.68	1.08	0.42	2.7	38.6	1.16	0.63	0.1	0.1	91.1	-0.62
6.24	34.5	1.42	5.4	2.49	.25	3.3	41.8	6.7	1.39	2.56	.04	4.2	41.8	2.56	1.39	6.7	4.2	92.6	-.69
9.50	30.7	1.98	9.0	3.50	.33	4.1	30.7	9.0	1.98	3.50	.33	4.1	39.9	3.73	1.80	7.4	3.8	96.4	-.60
13.07	23.7	2.71	16.1	4.16	.48	5.2	23.7	16.1	2.71	4.10	.33	5.2	43.0	4.98	1.85	8.8	4.1	105.9	-.48
17.85	18.5	3.89	27.8	4.61	.57	6.2	23.5	25.7	3.67	5.31	.41	6.1	41.2	6.19	2.13	11.7	4.8	114.4	-.32
20.91	15.8	4.28	29.6	4.70	.62	6.0	24.4	33.6	4.03	6.14	.38	7.2	40.2	7.10	2.73	22.0	7.0	130.0	-.20
$\tau = 30°$; $C_\Delta = 530$																			
2.22	52.2	0.90	1.6	1.52	0.37	1.5	58.5	1.9	0.90	1.58	0.24	1.8	64.7	1.62	0.86	1.2	1.2	146.2	-0.73
3.59	47.0	1.28	4.7	2.27	.41	3.2	50.7	4.8	1.28	2.35	.33	3.2	69.5	2.54	1.14	3.0	2.3	154.1	-.79
7.11	46.4	2.21	13.4	4.21	.46	5.3	56.3	13.8	2.18	4.63	.28	5.5	74.5	4.92	2.12	16.1	6.6	187.8	-.61
8.80	36.2	2.84	18.5	4.62	.64	5.6	45.2	19.4	2.81	5.32	.45	6.0	73.9	6.23	2.12	14.6	5.9	-----	-----
9.97	43.1	2.94	----	5.70	.48	----	----	----	----	----	----	----	75.4	6.89	2.21	----	----	-----	-----
11.33	38.5	3.40	24.0	6.04	.53	6.1	57.7	26.4	3.12	7.43	.24	7.3	75.7	7.77	2.38	18.9	6.9	-----	-----
12.97	40.7	3.64	27.4	6.98	.51	6.5	58.9	35.4	3.57	8.37	.25	8.6	58.9	8.37	3.57	35.4	8.6	-----	-----

TABLE IV.- EXPERIMENTAL DATA FROM TESTS OF FLAT-BOTTOM (0° DEAD RISE) 5-INCH- AND 8-INCH-BEAM MODELS

Column groups: **At contact** (V_o, $\dot{z}_o$, $\dot{x}_o$, γ_o) — **At maximum load** (t, C_t, n_i, C_L, z, C_d, $\dot{z}$, $C_{\dot{z}}$, M_Y, C_m, C_{cp}) — **At maximum draft** (t, C_t, n_i, C_L, z, C_d) — **At exit** (t, $\dot{z}$)

| V_o, fps	$\dot{z}_o$, fps	$\dot{x}_o$, fps	γ_o, deg	t, sec	C_t	n_i	C_L	z, ft	C_d	$\dot{z}$, fps	$C_{\dot{z}}$	M_Y, ft-lb	C_m	C_{cp}	t, sec	C_t	n_i	C_L	z, ft	C_d	t, sec	$\dot{z}$, fps
$\tau = 3°$; W = 1,156 lb; $C_\Delta = 62.5$; b = 8 in.																						
82.3	3.3	82.3	2.29	0.077	9.5	0.54	0.21	0.19	0.28	2.1	0.65	1,771	0.9	4.3	0.247	30.5	0.27	0.11	0.38	0.58	0.767	-0.7
52.8	4.5	52.6	4.89	.086	6.8	.52	.50	.34	.50	3.1	.70	2,762	3.4	6.9	.359	28.4	.28	.27	.71	1.07	-----	----
68.8	6.7	68.5	5.61	.079	8.1	1.02	.58	.42	.63	4.3	.64	5,863	4.3	7.5	.274	28.2	.57	.32	.80	1.19	-----	----
57.5	7.3	57.1	7.25	.075	6.5	1.12	.91	.46	.68	5.0	.68	6,728	7.1	7.8	.291	25.1	.56	.46	.95	1.42	.931	-.9
54.2	7.0	53.8	7.38	.078	6.3	1.07	.98	.47	.70	4.7	.68	6,572	7.8	8.0	.303	24.6	.56	.51	.98	1.47	.529	-1.3
$\tau = 3°$; W = 2,472 lb; $C_\Delta = 133.7$; b = 8 in.																						
85.3	2.9	85.3	1.97	0.053	6.8	0.30	0.24	0.14	0.22	2.6	0.89	2,384	1.1	4.8	0.393	50.3	0.19	0.15	0.55	0.82	-----	----
84.0	2.9	84.0	2.20	.093	11.7	.27	.22	.26	.39	2.2	.75	2,151	1.1	4.8	.363	45.8	.17	.14	.53	.80	-----	----
84.3	4.3	84.2	2.94	.162	20.5	.40	.29	.54	.80	2.4	.56	5,534	2.7	9.3	.162	20.5	.36	.29	.76	1.28	-----	----
68.1	3.9	68.0	3.31	.084	8.6	.33	.41	.29	.43	3.3	.83	3,299	2.5	6.1	.419	42.8	.25	.31	.79	1.19	-----	----
68.0	4.2	67.9	3.51	.091	9.3	.36	.45	.33	.49	3.3	.80	4,362	3.3	7.4	.411	42.0	.27	.34	.85	1.24	-----	----
60.6	4.0	60.5	3.77	.091	8.3	.31	.48	.33	.50	3.2	.81	3,518	3.3	6.9	.091	8.3	.23	.36	.88	1.31	-----	----
67.5	4.9	67.4	4.17	.090	9.1	.43	.54	.39	.58	3.6	.74	5,710	4.4	8.0	.090	9.1	.32	.40	.97	1.46	-----	----
69.8	6.7	69.4	5.50	.091	9.5	.68	.80	.53	.79	4.7	.71	11,964	8.6	10.7	.091	9.5	.44	.52	1.13	1.70	-----	----
$\tau = 6°$; W = 1,156 lb; $C_\Delta = 62.5$; b = 8 in.																						
81.0	3.6	81.0	2.54	0.098	11.9	0.74	0.30	0.28	0.42	1.9	0.54	2,599	1.4	4.5	0.188	15.2	0.53	0.22	0.36	0.54	0.455	-1.8
65.1	6.6	64.7	5.84	.080	7.8	1.07	.68	.45	.68	---	----	3,928	3.2	4.7	.249	16.2	.60	.38	.78	1.16	.684	----
64.6	8.1	64.1	7.21	.074	7.2	1.32	.85	.52	.78	5.2	.65	5,229	4.4	5.1	.265	17.1	.60	.39	.95	1.43	.772	-2.3
52.8	9.4	52.0	10.31	.077	6.1	1.30	1.25	.64	.95	6.9	.73	5,276	6.6	5.2	.327	17.3	.53	.51	1.38	2.07	1.130	-2.0
$\tau = 6°$; W = 1,912 lb; $C_\Delta = 103.4$; b = 8 in.																						
82.4	3.8	82.3	2.65	0.109	13.5	0.52	0.34	0.35	0.53	2.5	0.66	3,314	1.7	5.0	0.268	33.1	0.40	0.26	0.53	0.80	0.689	-1.7
59.2	5.9	58.9	5.76	.098	8.7	.63	.80	.52	.79	4.6	.77	4,742	4.7	5.9	.383	34.0	.33	.42	1.07	1.60	1.135	-1.2
52.7	7.4	52.2	8.10	.093	7.4	.75	1.20	.64	.96	5.7	.76	6,305	7.9	6.6	.423	33.4	.34	.54	1.43	2.14	1.402	-1.0
46.6	8.2	45.8	10.13	.088	6.1	.79	1.62	.66	.99	6.3	.77	6,703	10.8	6.6	.468	32.7	.35	.72	1.69	2.53	1.488	-1.2
$\tau = 6°$; W = 2,472 lb; $C_\Delta = 133.7$; b = 8 in.																						
83.6	3.3	83.5	2.26	0.109	13.7	0.39	0.32	0.32	0.47	2.3	0.70	2,628	1.3	4.1	0.294	36.8	0.33	0.26	0.51	0.76	0.792	-1.4
42.0	3.4	41.8	4.63	.180	11.3	.23	.75	.53	.80	2.4	.72	2,379	4.7	6.3	.570	35.9	.15	.50	.95	1.93	-----	----
62.2	5.8	61.9	5.33	.111	10.4	.44	.65	.54	.82	4.2	.73	4,021	3.6	5.5	.431	40.2	.27	.40	1.13	1.70	1.320	-2.1
68.1	6.6	67.8	5.51	.102	10.4	.63	.78	.60	.89	4.8	.73	6,384	4.8	6.1	.397	40.6	.35	.44	1.22	1.83	1.233	-1.4
56.6	6.0	56.3	6.03	.115	9.7	.53	.95	.60	.90	4.5	.75	6,166	6.7	7.0	.452	38.4	.28	.51	1.24	1.86	-----	----
52.4	6.2	52.1	6.80	.120	9.4	.49	1.02	.65	.97	4.6	.75	6,115	7.7	7.5	.510	40.1	.28	.60	1.45	2.18	-----	----
57.1	7.2	56.7	7.25	.107	9.2	.65	1.14	.70	1.04	5.5	.77	7,550	8.1	7.0	.477	40.9	.32	.56	1.55	2.33	-----	----
56.1	9.1	55.4	9.34	.100	8.4	.83	1.51	.78	1.17	6.8	.74	10,428	11.5	7.6	.470	39.5	.37	.68	1.81	2.72	-----	----
49.4	8.4	48.7	9.83	.108	8.0	.62	1.46	.73	1.10	6.4	.76	7,276	10.4	7.1	.512	38.0	.31	.73	1.80	2.70	1.732	-.8
56.2	10.2	55.2	10.42	.109	9.2	.92	1.67	.92	1.38	7.1	.70	12,373	13.6	8.1	.469	39.5	.36	.66	1.97	2.96	-----	----
55.6	11.5	54.4	11.91	.087	7.3	1.07	2.00	.87	1.30	8.4	.73	13,910	15.6	7.8	.513	42.8	.39	.72	2.28	3.42	-----	----
$\tau = 6°$; W = 933 lb; $C_\Delta = 208$; b = 5 in.																						
89.4	4.2	89.3	2.71	0.090	19.3	0.62	0.43	0.12	0.28	2.9	0.68	1,806	3.2	7.5	0.290	62.2	0.23	0.16	0.30	0.71	0.677	-1.1
78.9	4.9	78.7	3.59	.085	16.1	.63	.56	.18	.43	3.6	.74	1,880	4.3	7.6	.295	55.9	.31	.28	.50	1.20	.890	-1.0
68.4	7.4	68.0	6.17	.083	13.6	.86	1.02	.34	.81	5.5	.74	3,118	9.5	9.3	.323	53.1	.40	.47	.88	2.12	-----	----
63.2	10.5	62.3	9.53	.069	10.5	1.31	1.82	.45	1.09	8.6	.82	6,122	21.9	12.0	.349	52.9	.48	.67	1.37	3.30	-----	----
39.5	10.1	38.2	14.80	.112	10.6	.95	3.37	.78	1.88	7.2	.71	4,827	44.0	13.0	.441	41.8	.56	1.97	1.76	4.23	1.325	-1.6
$\tau = 6°$; W = 2,455 lb; $C_\Delta = 544$; b = 5 in.																						
87.1	4.8	87.0	3.13	0.176	36.8	0.38	0.72	0.76	1.83	3.0	0.62	3,826	7.2	9.9	0.456	95.3	0.27	0.51	1.17	2.81	-----	----
77.7	5.5	77.5	4.07	.170	31.7	.38	.92	.82	1.97	3.7	.67	4,059	9.6	10.4	.515	96.1	.19	.47	1.38	3.31	-----	----
68.1	6.1	67.8	5.15	.205	33.5	.39	1.23	1.09	2.61	4.1	.67	5,545	17.1	13.8	-----	----	----		1.31	3.14	-----	----
46.5	6.2	46.1	7.70	.190	21.2	.27	1.82	1.09	2.62	4.8	.76	3,684	24.3	13.3	.670	74.8	.27	1.79	2.30	5.51	-----	----
62.3	8.8	61.7	8.08	.150	22.4	2.03	2.07	1.19	1.74	6.8	.77	------	----	----	.505	75.6	.79	2.96	2.42	5.80	-----	----
$\tau = 15°$; W = 1,156 lb; $C_\Delta = 62.5$; b = 8 in.																						
81.6	3.6	81.5	2.55	0.106	13.0	1.05	0.42	0.26	0.40	1.0	0.28	2,347	1.2	2.8	0.136	16.6	0.88	0.36	0.24	0.43	0.309	-2.6
69.3	5.4	69.1	4.50	.103	10.7	1.14	.64	.45	.67	2.7	.50	2,717	2.0	3.0	.178	18.5	1.03	.58	.54	.82	.418	-3.2
69.7	6.7	69.3	5.55	.102	10.7	1.37	.76	.55	.83	3.5	.52	3,431	2.5	3.1	.192	20.1	1.10	.61	.70	1.05	.435	-4.0
53.7	7.8	52.6	8.43	.105	8.5	1.16	1.08	.67	1.00	5.0	.64	3,259	3.9	3.5	.250	20.1	.84	.79	1.02	1.54	.640	-3.5
51.3	9.5	50.4	10.63	.103	8.2	1.38	1.41	.81	1.20	6.0	.64	4,781	6.3	4.3	.263	20.2	.89	.91	1.26	1.88	.685	-3.7
38.9	7.9	37.1	12.05	.119	7.0	.87	1.62	.82	1.22	5.5	.69	3,053	7.0	4.2	.349	20.4	.52	.63	1.36	2.05	.976	-2.4
41.7	10.4	40.4	14.48	.088	5.5	1.57	1.96	.80	1.21	7.3	.70	4,003	8.0	4.0	.323	20.2	.41	.63	1.51	2.27	.896	-3.5
40.7	11.0	39.2	15.72	.093	5.7	1.39	2.23	.85	1.28	7.1	.65	5,184	10.9	4.7	.323	19.7	.72	1.16	1.58	2.37	.917	-3.7
36.7	11.9	34.7	18.93	.085	4.5	1.36	2.77	.89	1.33	8.7	.73	4,603	11.9	4.1	.370	20.4	.52	1.04	1.88	2.82	1.117	-3.1
35.9	12.0	33.9	19.52	.084	4.5	1.27	2.83	.88	1.32	8.7	.73	4,637	12.5	4.3	.359	19.4	.55	1.14	1.88	2.82	1.104	-3.2
$\tau = 15°$; W = 1,574 lb; $C_\Delta = 85.1$; b = 8 in.																						
79.8	3.3	79.7	2.37	0.114	13.6	0.69	0.40	0.24	0.36	1.7	0.52	1,775	1.0	2.4	0.184	22.0	----	----	0.29	0.43	0.398	-1.7
68.6	6.6	68.3	5.53	.112	11.5	1.12	.87	.57	.86	3.8	.57	4,605	3.4	3.8	.224	23.0	----	----	.78	1.16	.529	-3.6
50.1	9.2	49.3	10.55	.114	8.6	1.11	1.62	.83	1.25	6.5	.71	5,453	7.6	4.5	.323	24.3	.61	.35	1.47	2.21	.844	-3.6
23.3	7.5	22.0	18.81	.159	5.6	.52	3.50	.98	1.46	5.9	.78	2,919	18.7	5.2	.638	22.3	.23	1.53	2.18	3.28	-----	----

TABLE IV.- EXPERIMENTAL DATA FROM TESTS OF FLAT-BOTTOM (0° DEAD RISE) 5-INCH- AND 8-INCH-BEAM MODELS - Concluded

At contact				At maximum load											At maximum draft						At exit	
V_o, fps	$\dot{z}_o$, fps	$\dot{x}_o$, fps	γ_o, deg	t, sec	C_t	n_1	C_L	z, ft	C_d	$\dot{z}$, fps	$C_{\dot{z}}$	M_Y, ft-lb	C_m	C_{cp}	t, sec	C_t	n_1	C_L	z, ft	C_d	t, sec	$\dot{z}$, fps

$\tau = 15°$; $W = 1,912$ lb; $C_\Delta = 103.4$; $b = 8$ in.

V_o	$\dot{z}_o$	$\dot{x}_o$	γ_o	t	C_t	n_1	C_L	z	C_d	$\dot{z}$	$C_{\dot{z}}$	M_Y	C_m	C_{cp}	t	C_t	n_1	C_L	z	C_d	t	$\dot{z}$
81.7	3.6	81.6	2.55	0.114	14.0	0.77	0.51	0.31	0.47	1.7	0.46	2,934	1.5	3.0	0.179	21.9	0.71	0.47	0.36	0.55	0.408	-2.4
69.4	6.9	69.1	5.68	1.112	11.7	1.01	.93	.63	.94	4.3	.63	4,790	3.5	3.6	.242	25.2	.84	.77	.89	1.34	.543	-3.6
55.0	9.4	54.2	9.89	.114	9.4	1.07	1.57	.92	1.38	6.5	.69	6,512	7.5	4.6	.334	27.6	.70	1.02	1.56	2.34	.879	-3.7
26.3	7.9	25.1	17.51	.159	6.3	.48	3.07	1.13	1.69	6.2	.78	3,014	15.1	4.8	.694	27.4	.20	1.29	2.48	3.72	----	----

$\tau = 15°$; $W = 2,472$ lb; $C_\Delta = 133.7$; $b = 8$ in.

V_o	$\dot{z}_o$	$\dot{x}_o$	γ_o	t	C_t	n_1	C_L	z	C_d	$\dot{z}$	$C_{\dot{z}}$	M_Y	C_m	C_{cp}	t	C_t	n_1	C_L	z	C_d	t	$\dot{z}$
83.2	3.6	83.2	2.48	0.120	15.0	0.59	0.50	0.33	0.50	1.9	0.53	2,985	1.5	3.0	0.220	27.5	0.60	0.50	0.41	0.62	0.469	-2.6
68.2	6.8	67.9	5.71	.118	12.1	.78	.96	.69	1.03	4.6	.68	4,856	3.6	3.6	.303	31.0	.66	.81	1.08	1.63	.724	-4.0
50.6	7.0	50.1	7.92	.176	13.4	.63	1.41	.99	1.48	4.3	.62	4,620	6.3	4.3	.407	30.9	.46	1.03	1.45	2.17	1.066	-2.9
56.9	9.7	56.1	9.78	.137	11.7	.91	1.61	1.12	1.68	6.5	.67	7,288	7.8	4.7	.372	31.8	.63	1.11	1.79	2.68	.988	-4.0
39.9	8.0	39.1	11.51	.170	10.2	.59	2.13	1.18	1.77	5.6	.71	4,746	10.4	4.7	.540	32.3	.31	1.12	2.07	3.10	1.550	-2.4
56.5	12.5	55.1	12.80	.165	14.0	1.32	2.37	1.59	2.39	7.4	.59	13,395	14.6	5.9	.375	31.8	.69	1.24	2.19	3.28	1.128	-3.1
50.4	12.0	49.0	13.80	.163	12.3	1.20	2.71	1.64	2.46	6.8	.57	12,419	17.0	6.1	.425	32.1	.53	1.20	2.39	3.59	1.317	-2.8
31.8	8.0	30.8	14.57	.190	9.1	.45	2.55	1.34	2.01	6.0	.75	3,786	13.0	4.9	.690	32.9	.21	1.17	2.63	3.94	2.623	-.8
44.7	12.2	43.0	15.77	.114	11.0	1.14	3.28	1.65	2.47	7.0	.58	12,401	21.6	6.4	.495	33.2	.45	1.29	2.63	3.95	1.599	-1.8
32.4	8.9	31.2	15.98	.184	9.0	.63	3.44	1.41	2.12	6.3	.70	6,199	20.5	5.8	.677	32.9	.24	1.31	2.64	3.96	----	----
40.8	11.4	39.2	16.15	.170	10.4	.96	3.30	1.62	2.43	7.2	.63	10,126	21.1	6.2	.540	33.1	.38	1.17	2.72	4.08	1.858	-1.3
32.0	9.6	30.5	17.43	.170	8.2	.60	5.37	1.45	2.17	7.0	.73	5,718	19.5	5.6	.680	32.6	.24	1.34	2.93	4.39	2.546	-.9
37.9	12.1	35.9	18.61	.164	9.3	1.02	4.08	1.67	2.50	7.8	.65	11,378	27.6	6.5	.528	30.0	.51	2.04	2.90	4.35	1.918	-1.3
37.4	12.2	35.4	19.01	.159	8.9	1.04	4.26	1.69	2.53	8.6	.70	11,367	28.2	6.4	.527	29.6	.51	2.09	3.01	4.51	2.056	-.8

$\tau = 15°$; $W = 933$ lb; $C_\Delta = 208$; $b = 5$ in.

V_o	$\dot{z}_o$	$\dot{x}_o$	γ_o	t	C_t	n_1	C_L	z	C_d	$\dot{z}$	$C_{\dot{z}}$	M_Y	C_m	C_{cp}	t	C_t	n_1	C_L	z	C_d	t	$\dot{z}$
88.6	4.4	88.5	2.85	0.095	20.2	0.89	0.62	0.36	0.86	2.7	0.61	897	1.6	2.5	0.180	38.3	0.73	0.52	0.44	1.06	0.412	-2.6
79.5	5.1	79.4	3.71	.137	26.2	.85	.74	.56	1.33	2.4	.46	1,394	3.1	4.1	.230	43.9	.63	.56	.64	1.53	.516	-3.1
68.4	7.5	68.0	6.28	.125	20.5	1.07	1.27	.76	1.81	4.3	.57	2,568	7.8	6.0	.273	44.8	.61	.72	1.00	2.39	.653	-3.0
62.4	10.5	61.5	9.72	.128	19.2	1.43	2.04	1.09	2.62	6.2	.59	4,364	16.0	7.6	.274	41.0	.86	1.22	1.45	3.47	.751	-3.9
39.6	10.7	38.2	15.66	.136	12.9	.99	3.48	1.25	3.00	7.4	.69	3,145	28.6	7.9	.431	41.0	.41	1.46	2.16	5.18	1.695	-5.6
3.6	3.6	0	90.00	.492	4.3	.10	----	----	----	2.6	.72	121	----	2.9	----	----	----	----	----	----	----	----
5.3	5.3	0	90.00	.513	6.5	.17	----	----	----	3.2	.61	389	----	5.8	----	----	----	----	----	----	----	----
7.3	7.3	0	90.00	.750	13.1	.63	----	----	----	.8	.11	3,910	----	15.3	----	----	----	----	----	----	----	----
9.1	9.1	0	90.00	.528	11.5	.85	----	----	----	3.1	.34	5,014	----	14.7	----	----	----	----	----	----	----	----
10.8	10.8	0	90.00	.525	13.6	1.22	----	----	----	2.0	.19	7,864	----	16.0	----	----	----	----	----	----	----	----

$\tau = 15°$; $W = 2,455$ lb; $C_\Delta = 544$; $b = $ in.

V_o	$\dot{z}_o$	$\dot{x}_o$	γ_o	t	C_t	n_1	C_L	z	C_d	$\dot{z}$	$C_{\dot{z}}$	M_Y	C_m	C_{cp}	t	C_t	n_1	C_L	z	C_d	t	$\dot{z}$
85.6	4.7	85.5	3.17	0.182	37.4	0.53	1.05	0.73	1.74	2.2	0.47	2,989	5.8	5.3	0.332	68.2	0.35	0.70	0.87	2.08	0.774	-2.7
76.8	5.6	76.6	4.14	.242	44.6	.51	1.27	1.04	2.49	2.6	.48	3,340	8.1	6.2	.422	77.8	.33	.82	1.20	2.87	1.016	-2.1
67.1	7.9	66.7	6.76	.236	38.0	.62	2.01	1.47	3.52	4.3	.54	5,628	17.8	8.6	.508	81.8	.30	.99	1.92	4.60	----	----
62.3	10.9	61.4	10.04	.215	32.2	.82	3.10	1.93	4.63	6.6	.61	9,019	33.2	10.3	.490	73.3	.46	1.71	2.72	6.54	----	----
39.1	10.8	37.6	16.04	.292	27.4	.60	5.73	2.57	6.17	6.4	.59	8,777	82.0	13.8	.676	63.5	.27	2.58	3.55	8.52	----	----

$\tau = 30°$; $C_\Delta = 1$

V_o	$\dot{z}_o$	$\dot{x}_o$	γ_o	t	C_t	n_1	C_L	z	C_d	$\dot{z}$	$C_{\dot{z}}$	M_Y	C_m	C_{cp}	t	C_t	n_1	C_L	z	C_d	t	$\dot{z}$
----	----	----	3.59	----	----	----	0.17	----	----	---	----	----	----	----	----	----	----	----	----	----	----	----

$\tau = 30°$; $W = 1,156$ lb; $C_\Delta = 62.5$; $b = 8$ in.

V_o	$\dot{z}_o$	$\dot{x}_o$	γ_o	t	C_t	n_1	C_L	z	C_d	$\dot{z}$	$C_{\dot{z}}$	M_Y	C_m	C_{cp}	t	C_t	n_1	C_L	z	C_d	t	$\dot{z}$
81.1	3.6	81.0	2.54	0.110	13.4	1.35	0.55	0.27	0.40	0.9	0.26	2,393	1.3	2.0	0.122	14.8	1.26	0.52	0.27	0.41	0.258	-3.2
68.9	5.4	68.7	4.48	.106	11.0	1.40	.79	.42	.63	2.2	.40	2,902	2.1	2.3	.154	15.9	1.30	.74	.47	.71	.333	-4.4
68.5	6.8	68.3	5.67	.107	11.0	1.57	.90	.53	.88	4.5	.44	3,535	2.6	2.5	.155	16.0	1.44	.82	.60	.91	.359	-5.1
51.9	7.9	51.3	8.74	.115	9.0	1.28	1.28	.74	1.11	4.8	.61	3,406	4.4	3.0	.222	17.3	1.12	1.12	.99	1.48	.517	-4.9
51.3	9.3	50.4	10.45	.110	8.5	1.45	1.48	.88	1.32	6.0	.64	3,853	5.1	3.0	.240	18.5	1.26	1.29	1.24	1.87	.558	-5.4
38.1	7.9	37.3	11.91	.153	8.7	.89	1.65	.97	1.45	4.8	.60	1,856	4.4	2.3	.308	17.6	.64	1.18	1.28	1.92	.769	-3.8
29.0	7.8	28.0	15.57	.152	6.6	.74	2.36	.96	1.44	4.9	.62	2,309	9.5	3.5	.387	16.8	.51	1.63	1.54	2.31	1.107	-3.4
40.7	11.2	39.1	15.95	.161	9.8	1.45	2.35	1.30	1.96	5.1	.45	4,460	9.4	3.4	.301	18.4	.97	1.57	1.63	2.44	.750	-5.0
35.5	10.1	34.0	16.56	.165	8.1	1.10	2.35	1.26	1.90	5.2	.52	3,264	9.0	3.3	.345	18.4	.77	1.64	1.73	2.59	.894	-4.2
35.8	11.7	33.8	19.11	.154	8.3	1.40	2.93	.82	1.26	6.3	.54	4,537	12.3	3.8	.339	18.2	.85	1.78	1.95	2.92	.899	-4.7
34.8	11.8	32.7	19.74	.158	8.2	1.42	3.15	1.48	2.22	6.1	.52	4,824	13.9	3.8	.333	17.4	.85	1.89	1.95	2.93	.694	-4.9

$\tau = 30°$; $W = 2,472$ lb; $C_\Delta = 133.7$; $b = 8$ in.

V_o	$\dot{z}_o$	$\dot{x}_o$	γ_o	t	C_t	n_1	C_L	z	C_d	$\dot{z}$	$C_{\dot{z}}$	M_Y	C_m	C_{cp}	t	C_t	n_1	C_L	z	C_d	t	$\dot{z}$
79.2	3.4	79.1	2.48	0.192	22.8	0.70	0.64	0.38	0.54	0.2	0.07	2,003	1.1	1.5	0.197	23.4	0.68	0.57	0.39	0.59	0.424	-2.5
63.8	6.3	63.5	5.63	.180	17.2	.88	1.24	.86	1.29	2.5	.40	3,703	3.2	2.6	.270	25.8	.83	1.17	.97	1.45	.598	-3.4
64.5	8.7	63.9	7.72	.183	17.7	1.15	1.59	1.20	1.79	3.5	.40	6,318	5.3	2.9	.278	26.9	1.04	1.44	1.35	2.02	.631	-5.6
44.0	6.4	43.5	8.47	.206	13.6	.60	1.78	1.36	2.04	1.7	.26	4,435	8.0	3.9	.401	26.4	.52	1.54	1.45	2.17	----	----
57.5	9.6	56.7	9.63	.187	16.1	1.07	1.86	1.38	2.06	6.9	.71	6,558	6.9	3.2	.322	27.8	.92	1.60	1.67	2.51	.752	-5.6
57.2	12.5	55.8	12.59	.170	14.6	1.49	2.62	1.63	2.45	7.0	.56	10,301	11.0	3.6	.321	27.5	1.10	1.93	2.11	3.17	.768	-6.8
51.4	12.1	49.9	13.63	.175	13.5	1.36	2.96	1.78	2.66	6.6	.54	10,257	13.5	4.0	.355	27.4	.97	2.11	2.31	3.46	.890	-6.2
50.6	12.2	49.1	13.92	.185	14.0	1.27	2.85	1.80	2.69	6.8	.56	9,693	13.2	4.0	.397	30.1	.79	1.77	2.45	3.67	.994	-5.7
45.1	11.2	43.7	14.42	.173	11.7	1.19	3.36	1.78	2.67	7.6	.68	9,024	15.4	4.0	.428	29.0	.71	2.00	2.61	3.92	1.106	-5.4
42.2	11.2	40.7	15.41	.181	11.5	1.12	3.61	2.44	3.66	7.0	.63	9,748	19.0	4.0	.451	28.6	.75	2.42	3.23	4.84	1.170	-5.0
33.5	9.2	32.2	16.00	.180	9.0	.63	3.22	1.42	2.13	6.8	.74	4,464	13.8	3.7	.590	29.7	.38	1.94	2.94	4.41	1.656	-2.9
39.0	12.1	37.1	18.01	.178	10.4	.98	3.70	1.87	2.80	7.9	.66	7,721	17.7	4.2	.483	28.2	.75	2.83	2.99	4.48	1.310	-4.7
38.4	12.1	36.5	18.34	.178	10.3	.98	3.80	1.87	2.81	8.1	.67	7,414	17.5	4.0	.588	33.9	.72	2.80	3.03	4.45	1.509	-3.9
43.0	11.7	41.3	20.53	.175	11.3	1.08	3.36	1.81	2.72	7.8	.66	8,216	15.5	4.0	.564	36.3	.63	1.96	2.82	4.23	1.350	-4.7

$\beta = 0^\circ$; b = 8 in.

$\beta = 0^\circ$; b = 5 in.

$\beta = 30^\circ$; b = 5 in.

(a) Lines and dimensions.
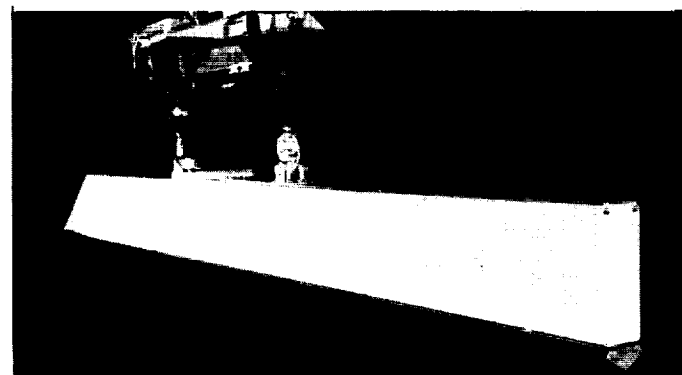
Figure 1.- Heavy beam-loading models.
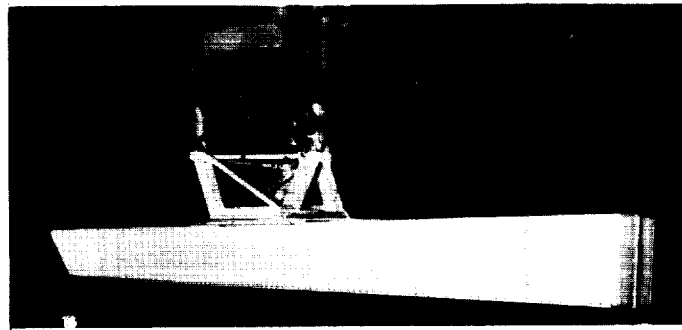
$\beta = 0^{\circ}$; $b = 8$ in.

$\beta = 0^{\circ}$; $b = 5$ in.

$\beta = 30^{\circ}$; $b = 5$ in.   L-58-2558

(b) Photographs of models mounted on the Langley impact-basin carriage boom.
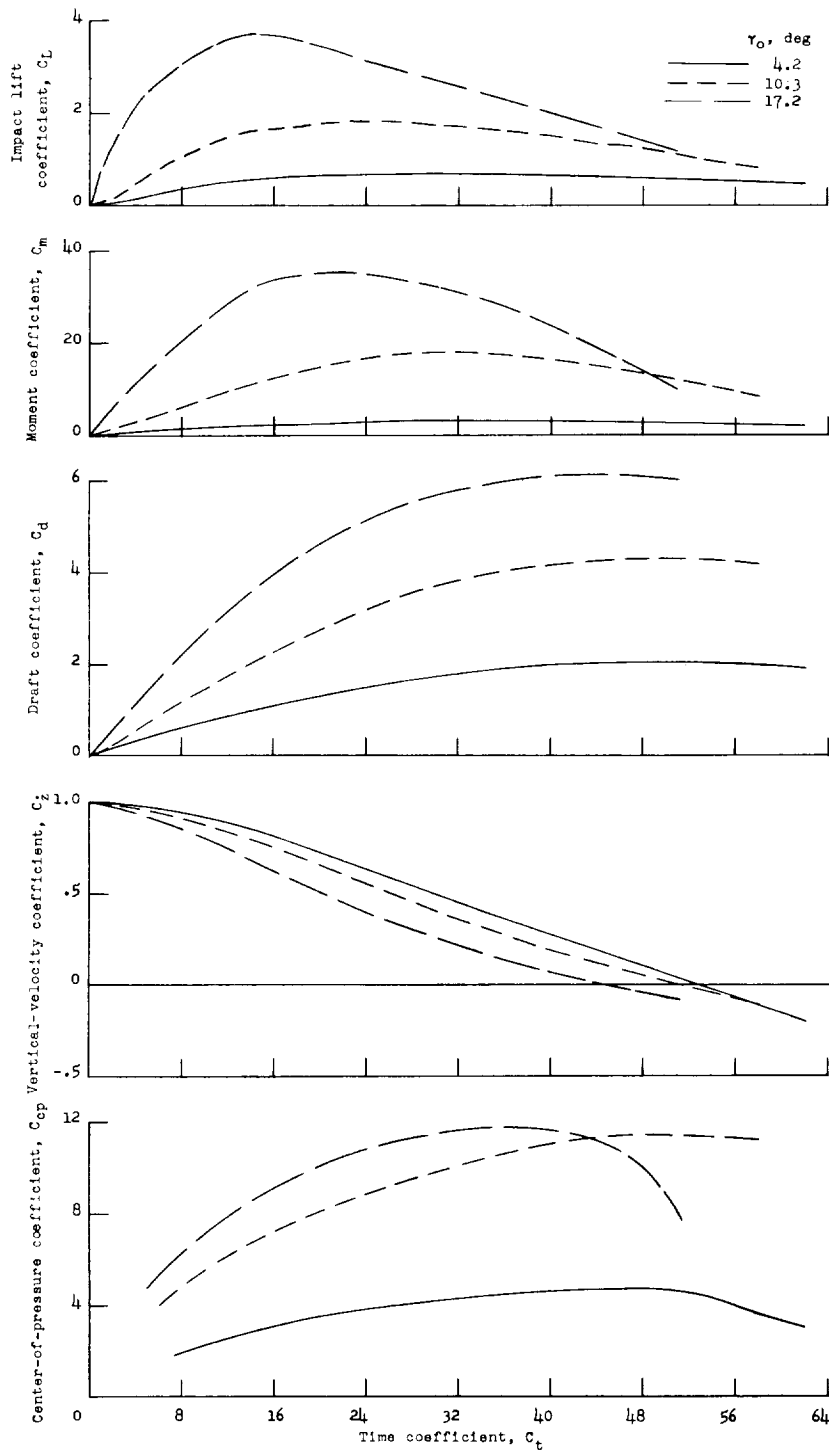
Figure 1.- Concluded.

Figure 2.- Typical time histories of impact loads and motions of a
30° dead-rise model. $C_{\Delta} = 208$; $\tau = 15^{\circ}$.
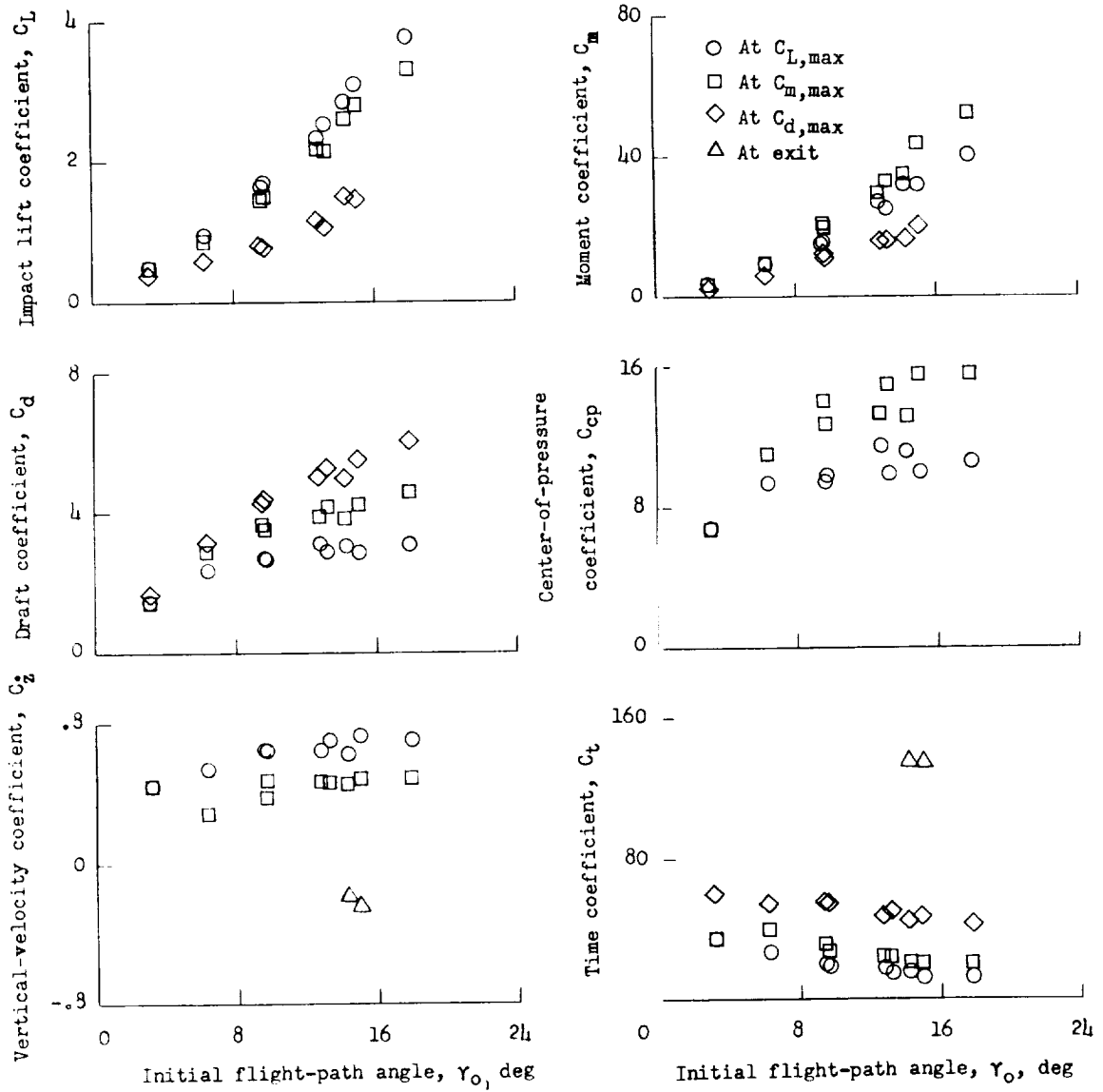
Figure 3.- Typical variations of coefficient data with initial flight-path angle. $\beta = 30^O$; $\tau = 9^O$; $C_\Delta = 208$.
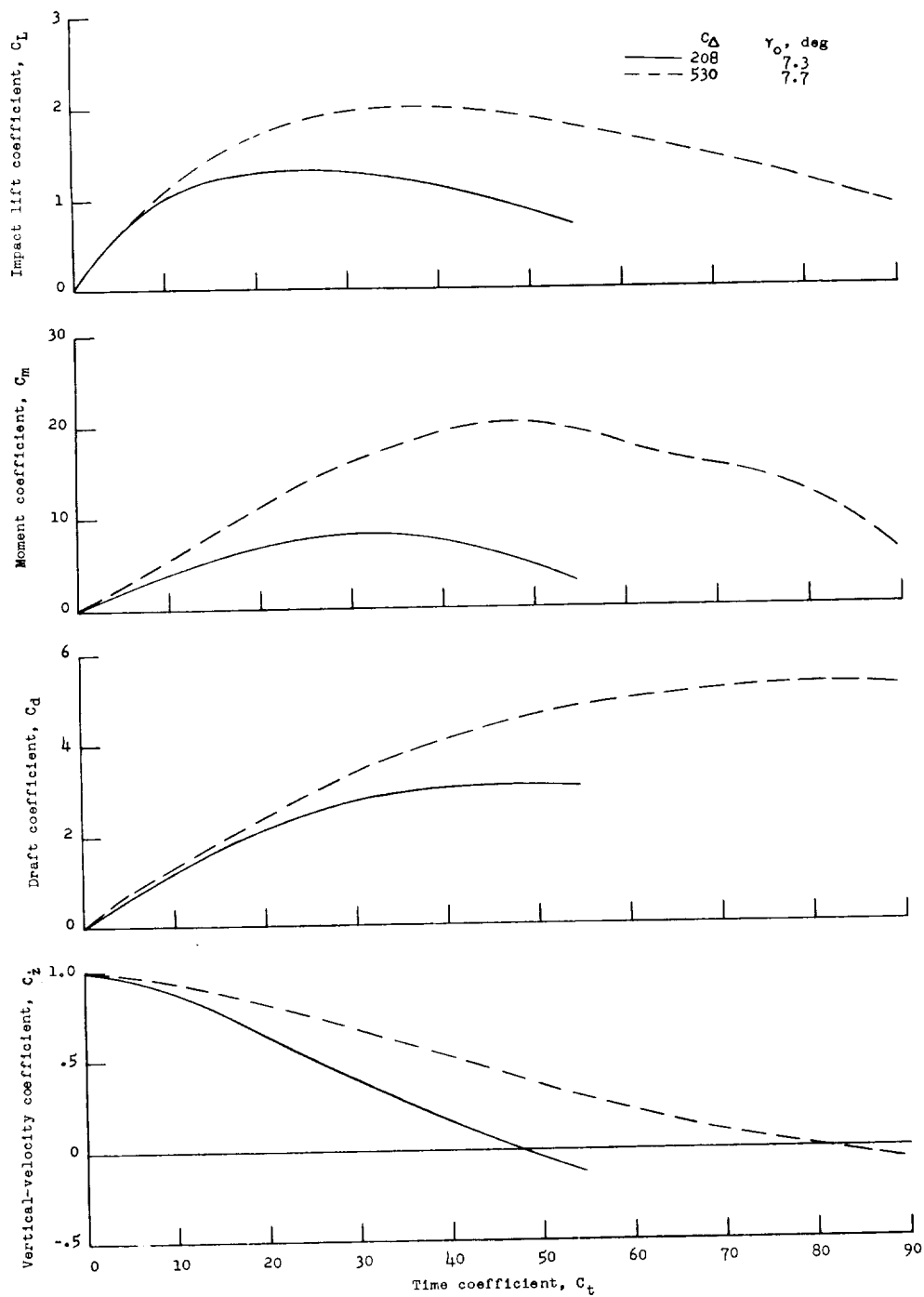
Figure 4.- Typical time histories of impact loads and motions of a 30° dead-rise model. τ = 15°.
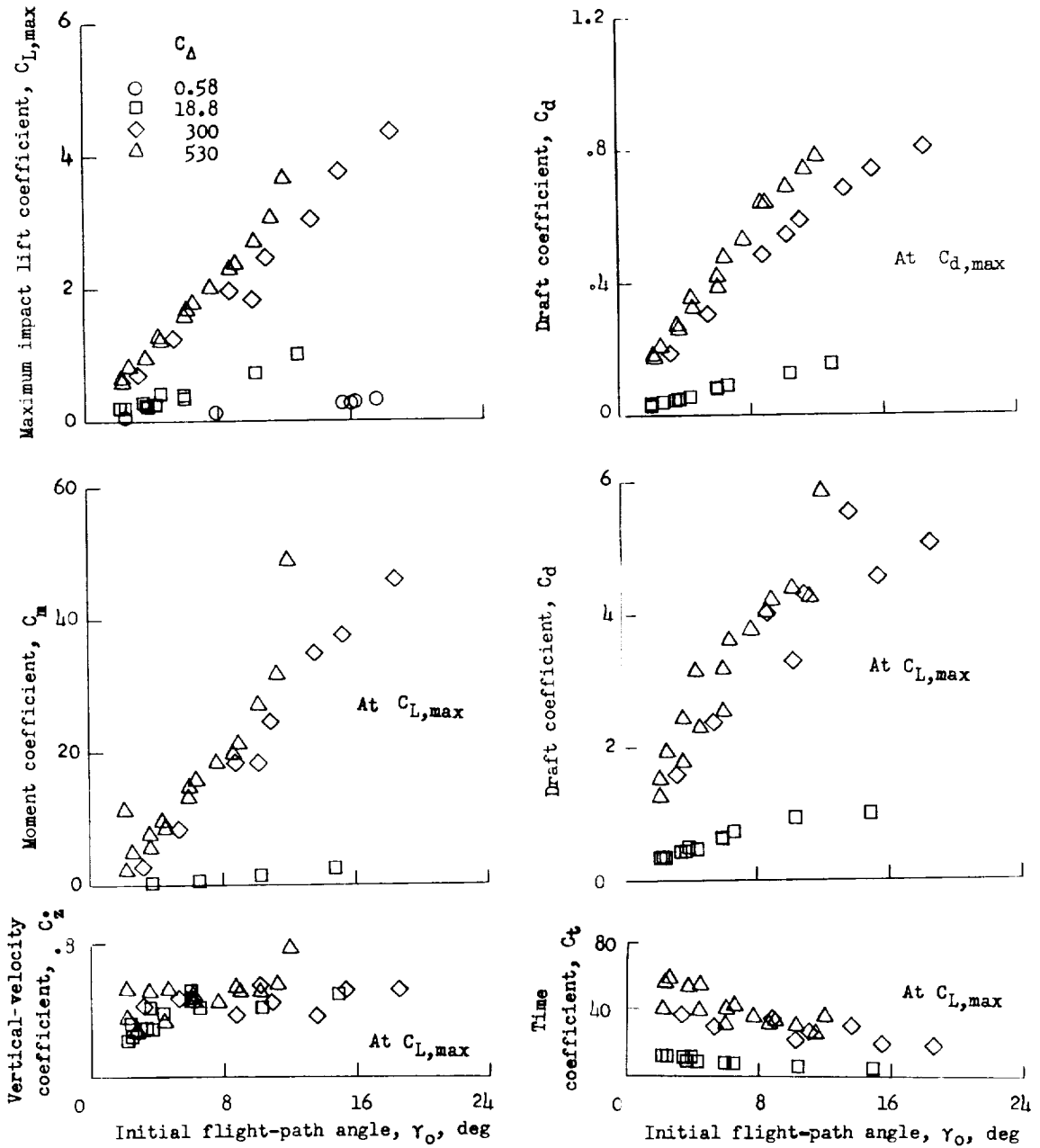
Figure 5.- Variation of coefficients with initial flight-path angle and various beam loading coefficients. $\beta = 30^\circ$; $\tau = 15^\circ$.
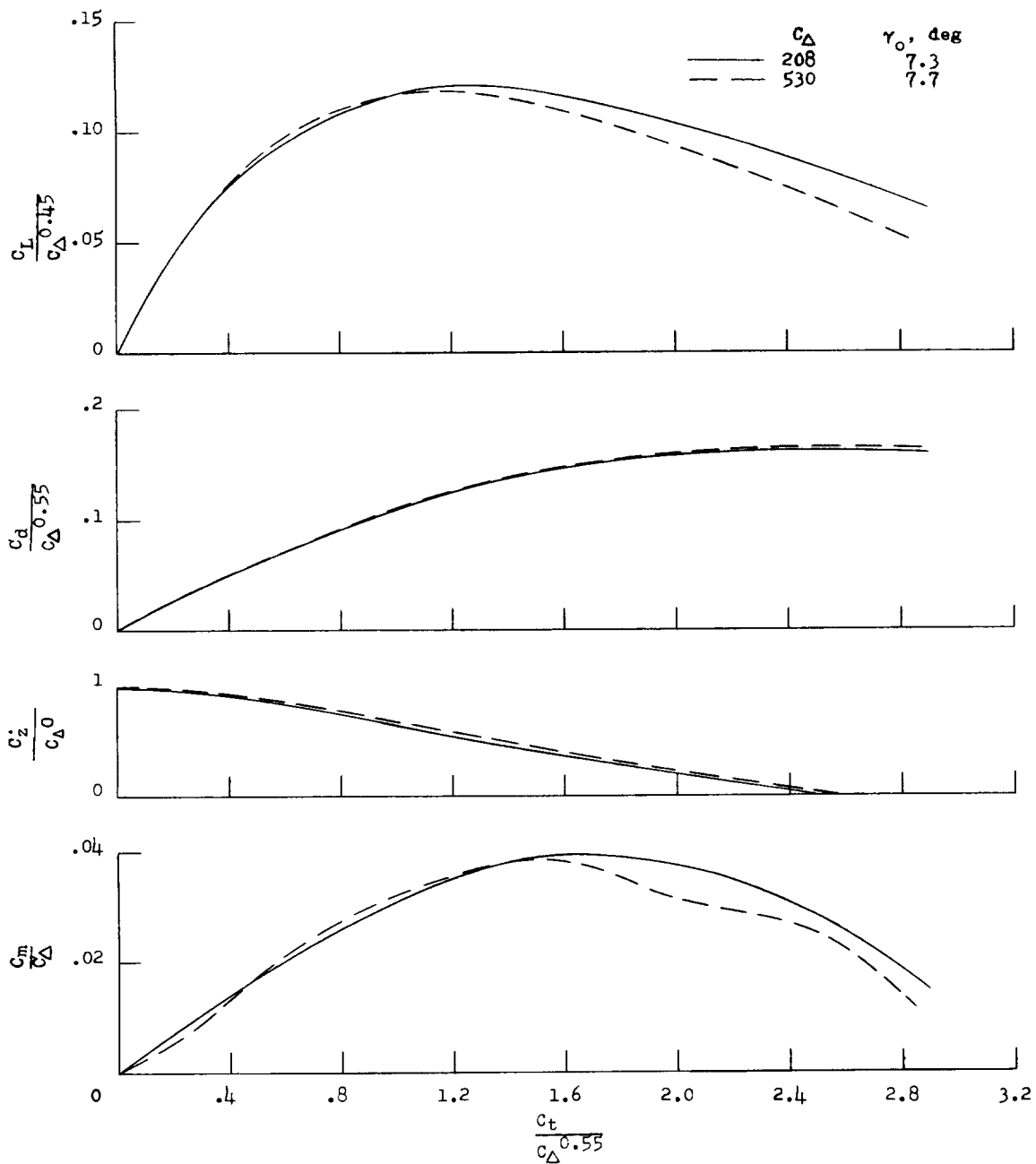
Figure 6.- Typical time histories of impact loads and motions of a
30° dead-rise model. Coefficients reduced by C_Δ factors. $\tau = 15°$.
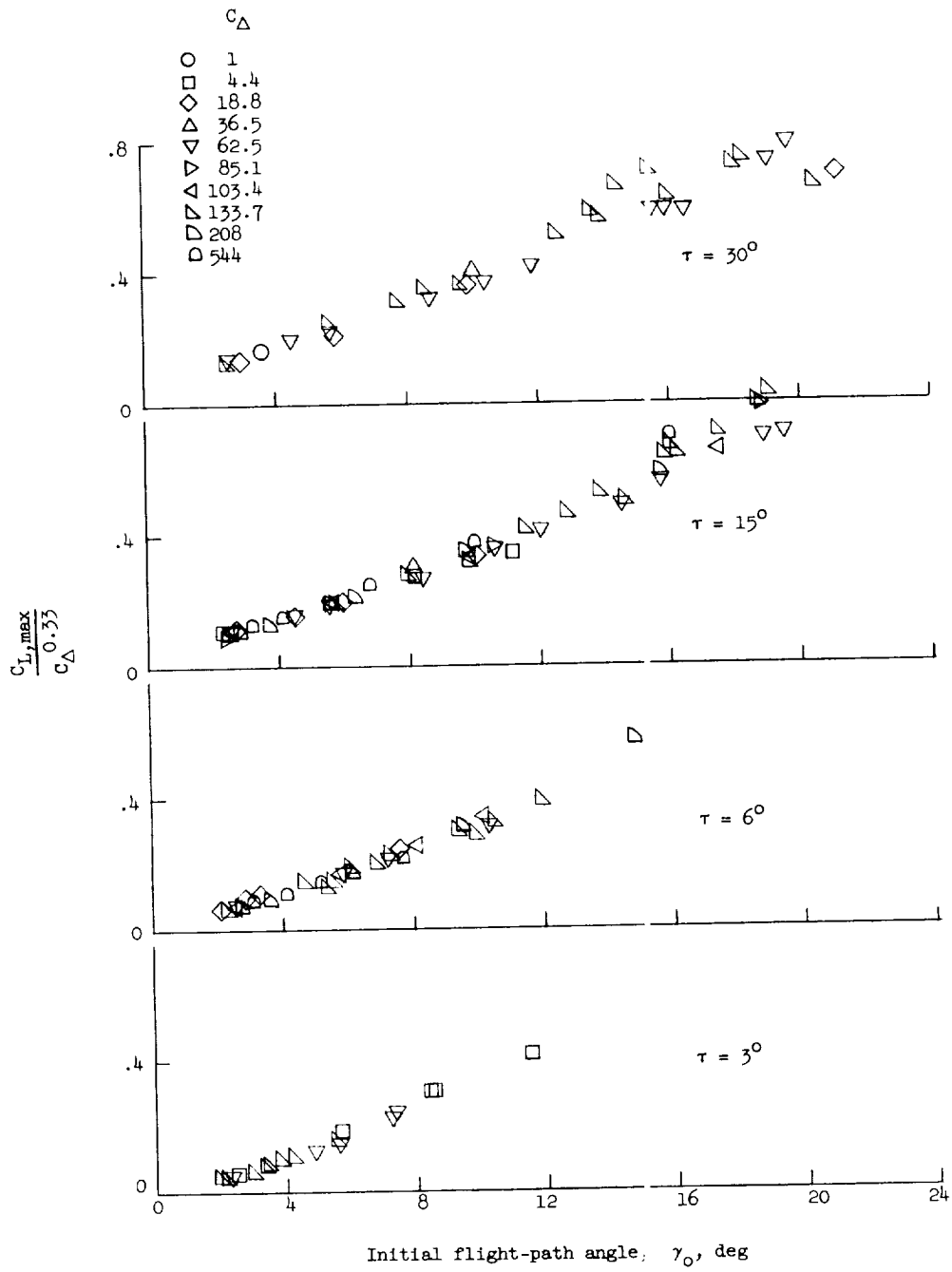
(a) $C_{L,max}$.

Figure 7.- Variation of coefficients reduced by beam-loading factors with initial flight-path angle. $\beta = 0^{\circ}$.

(b) C_m at $C_{L,max}$.

Figure 7.- Continued.

Initial flight-path angle, γ_o, deg
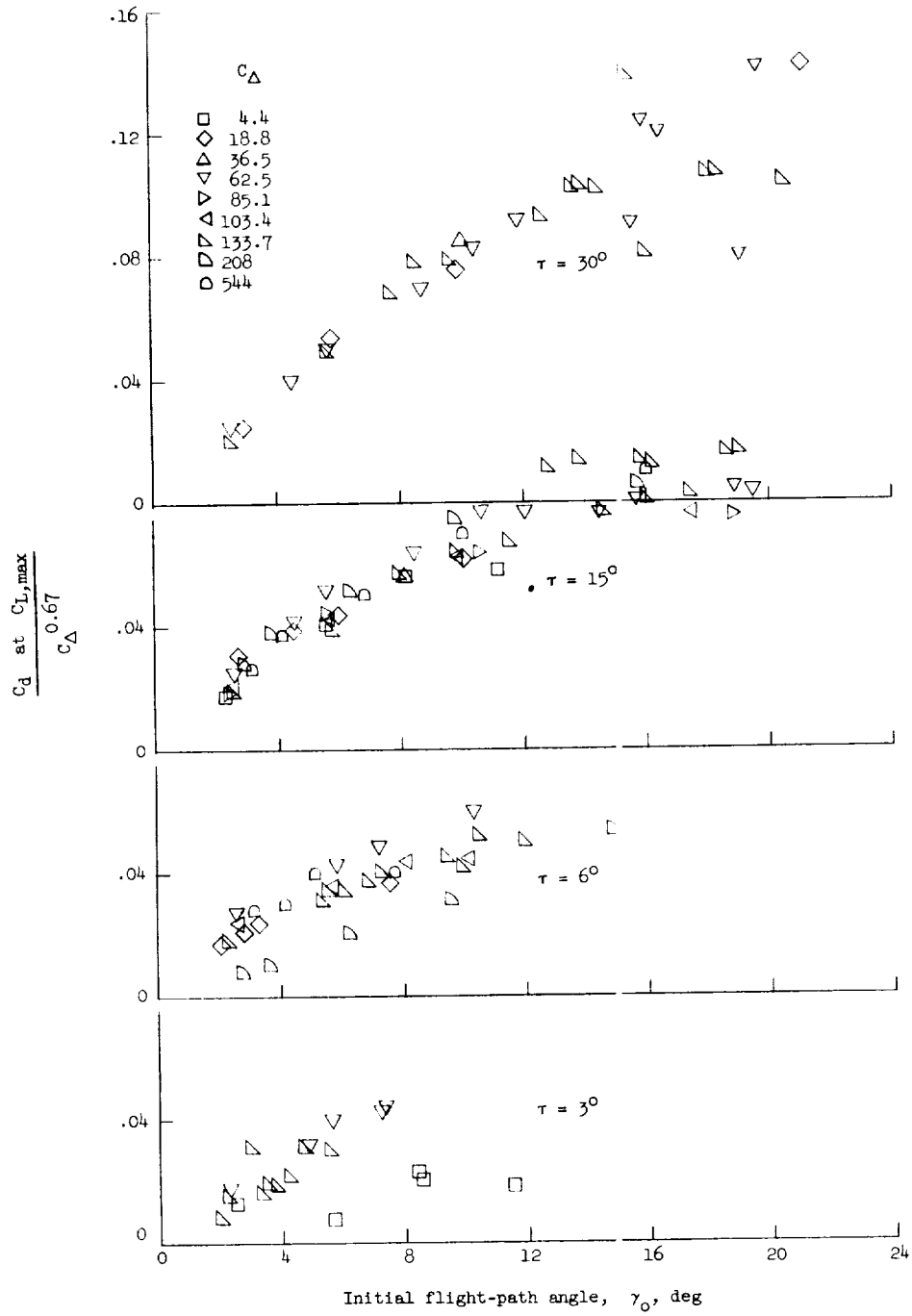
(c) C_d at $C_{L,max}$.

Figure 7.- Continued.

(d) $C_{d,max}$.

Figure 7.- Continued.
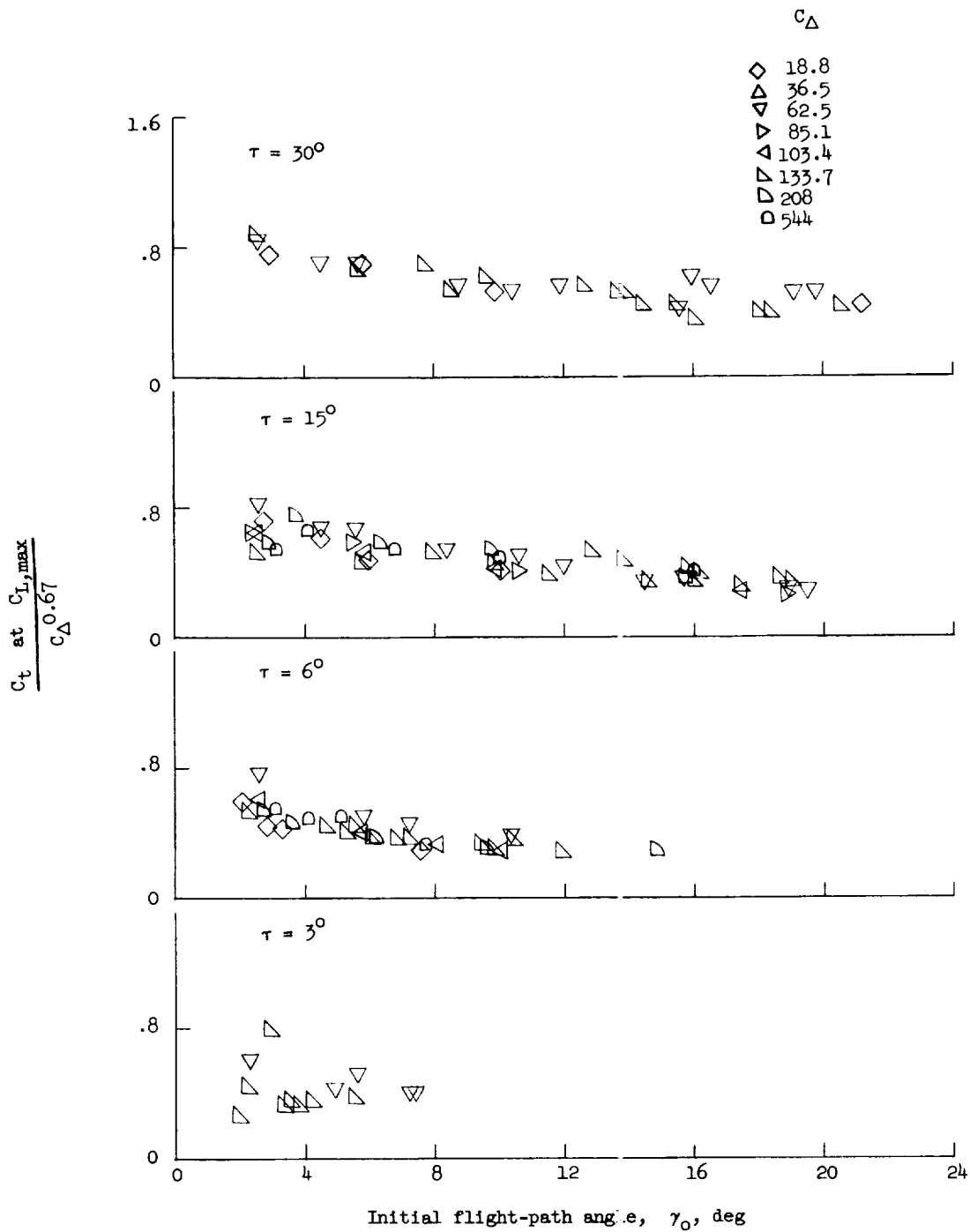
(e) C_t at $C_{L,max}$.

Figure 7.- Continued.
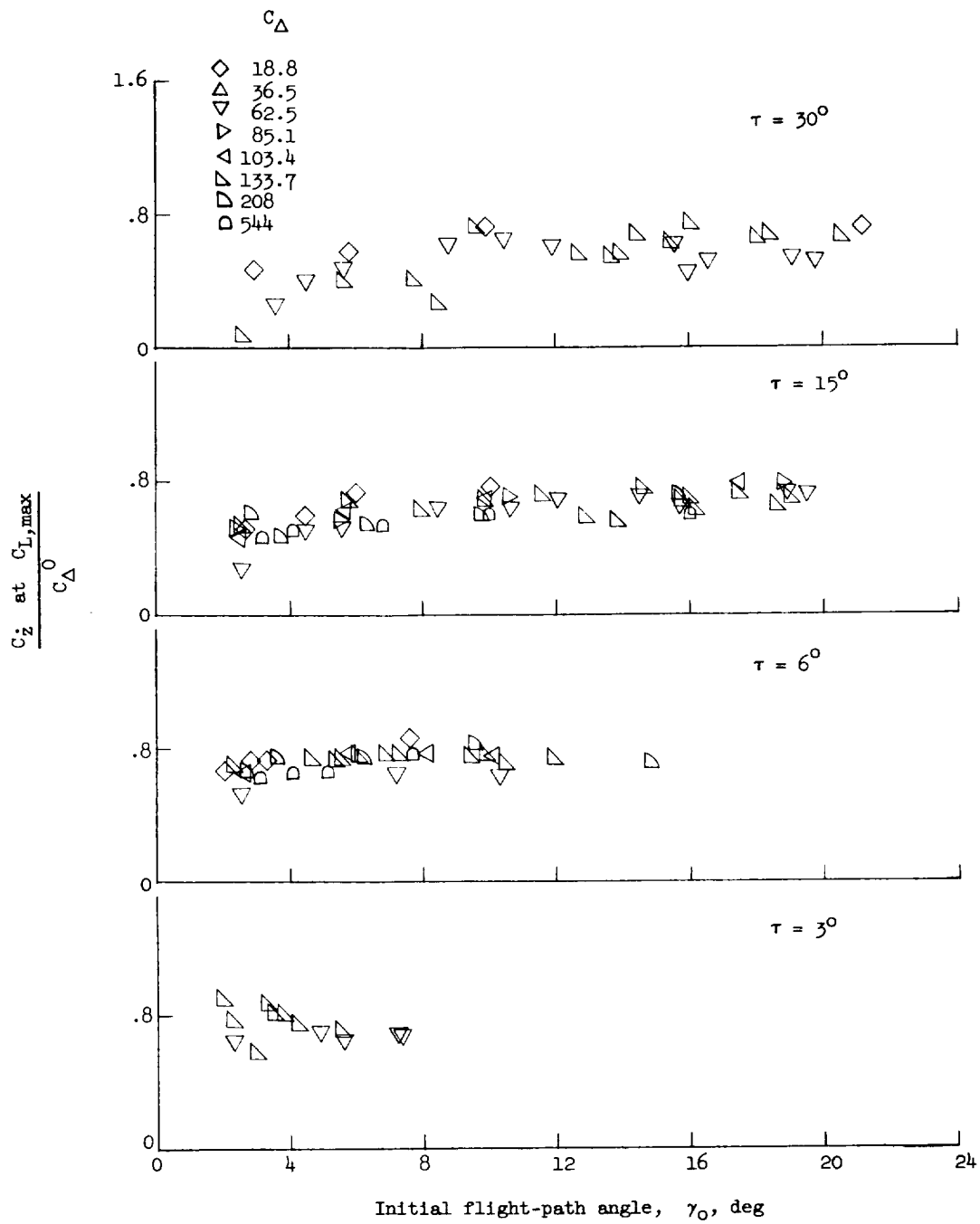
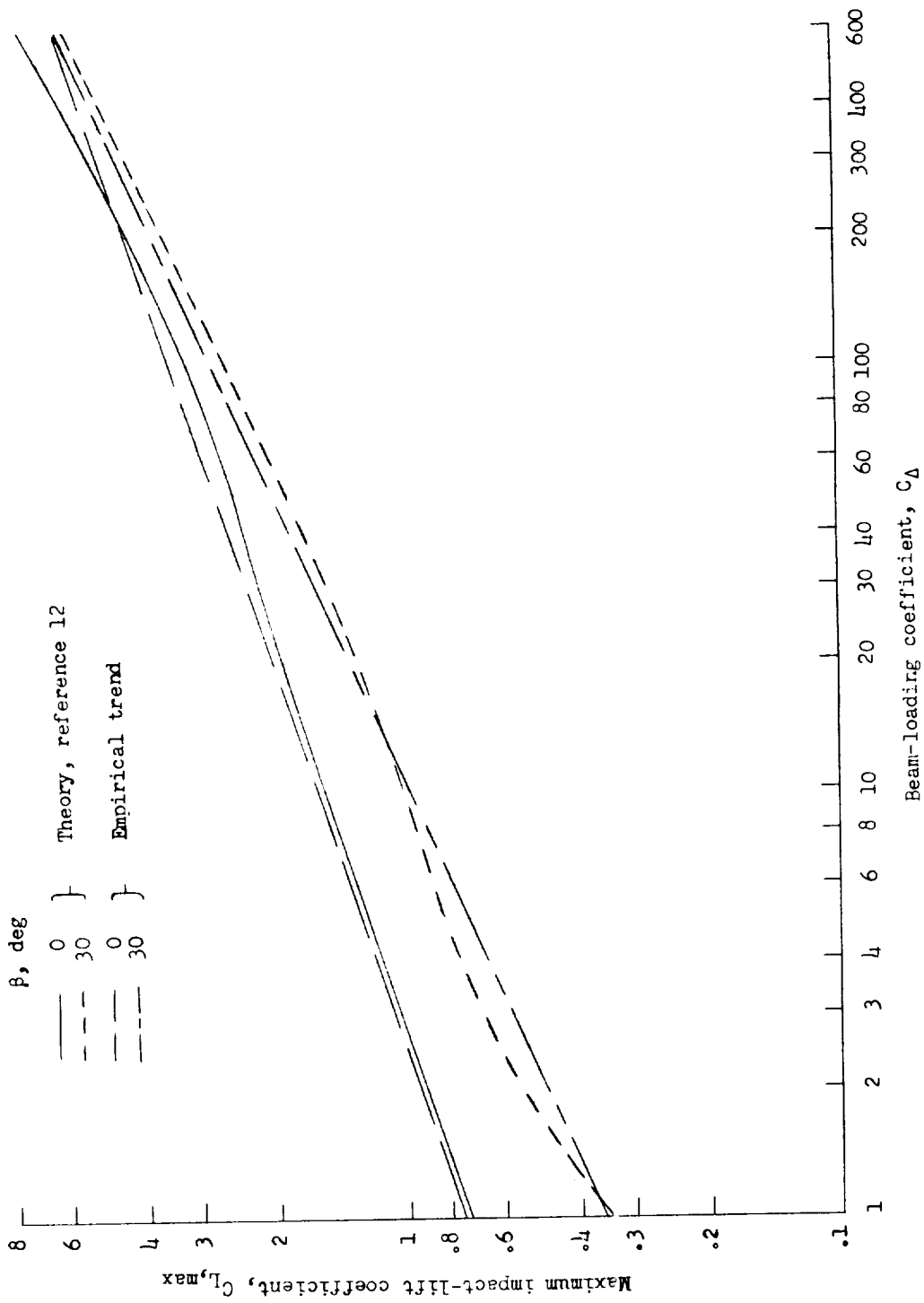(f) $C_{\dot{z}}$ at $C_{L,max}$.

Figure 7.- Concluded.
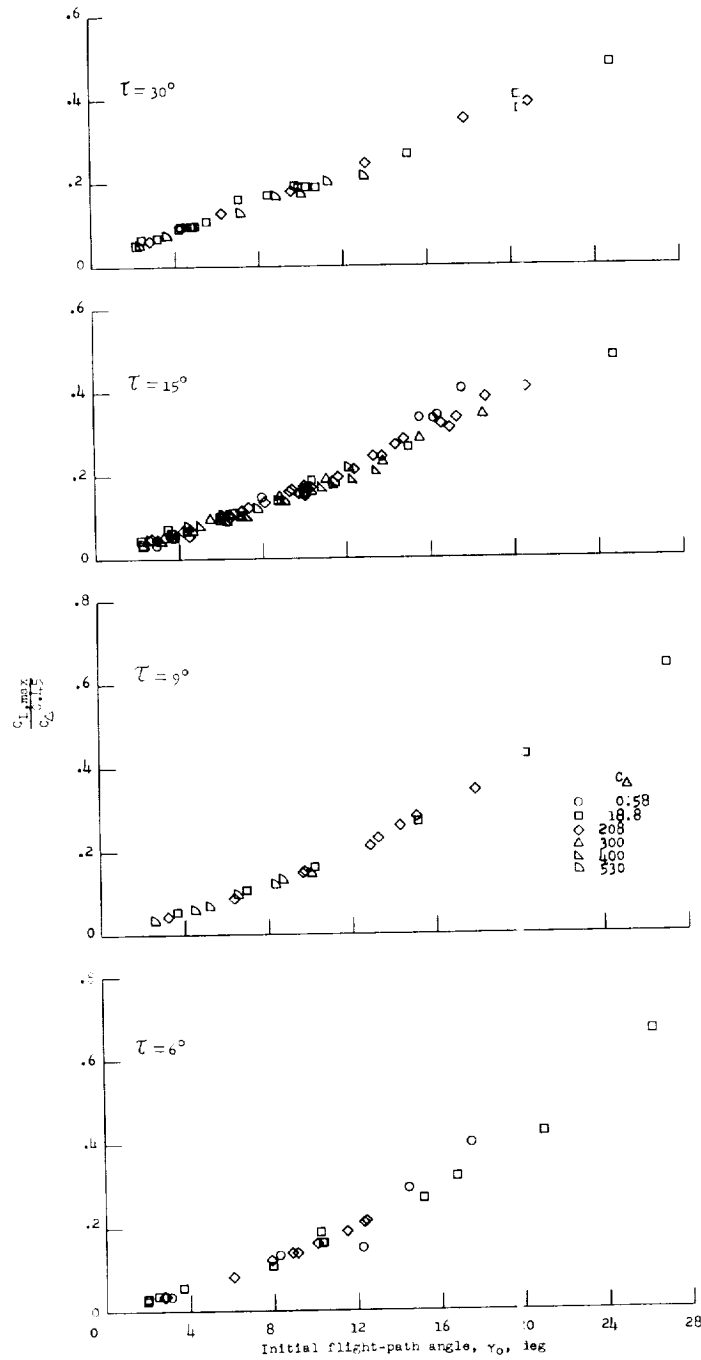
(a) $C_{L,max}$.

Figure 8.- Variation of coefficients reduced by beam-loading factors with initial flight-path angle. $\beta = 30°$.
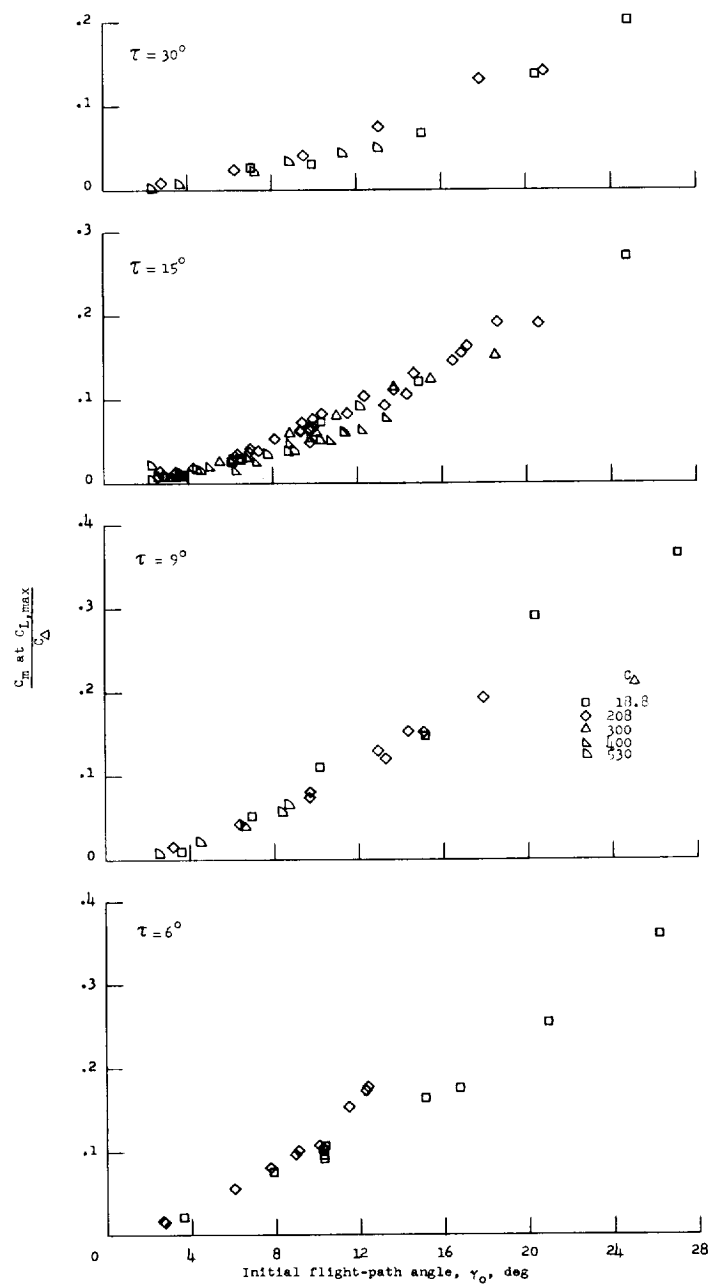
(b) C_m at $C_{L,max}$.

Figure 8.- Continued.
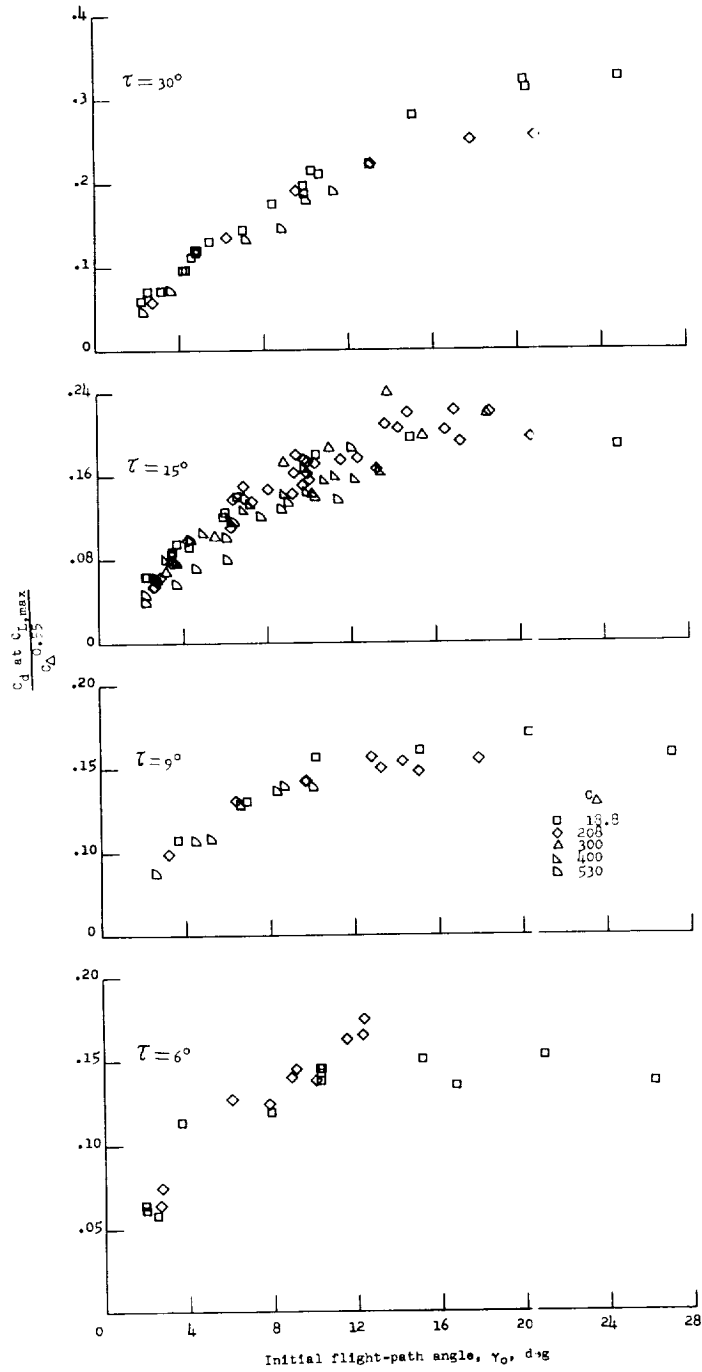
(c) C_d at $C_{L,max}$.

Figure 8.- Continued.
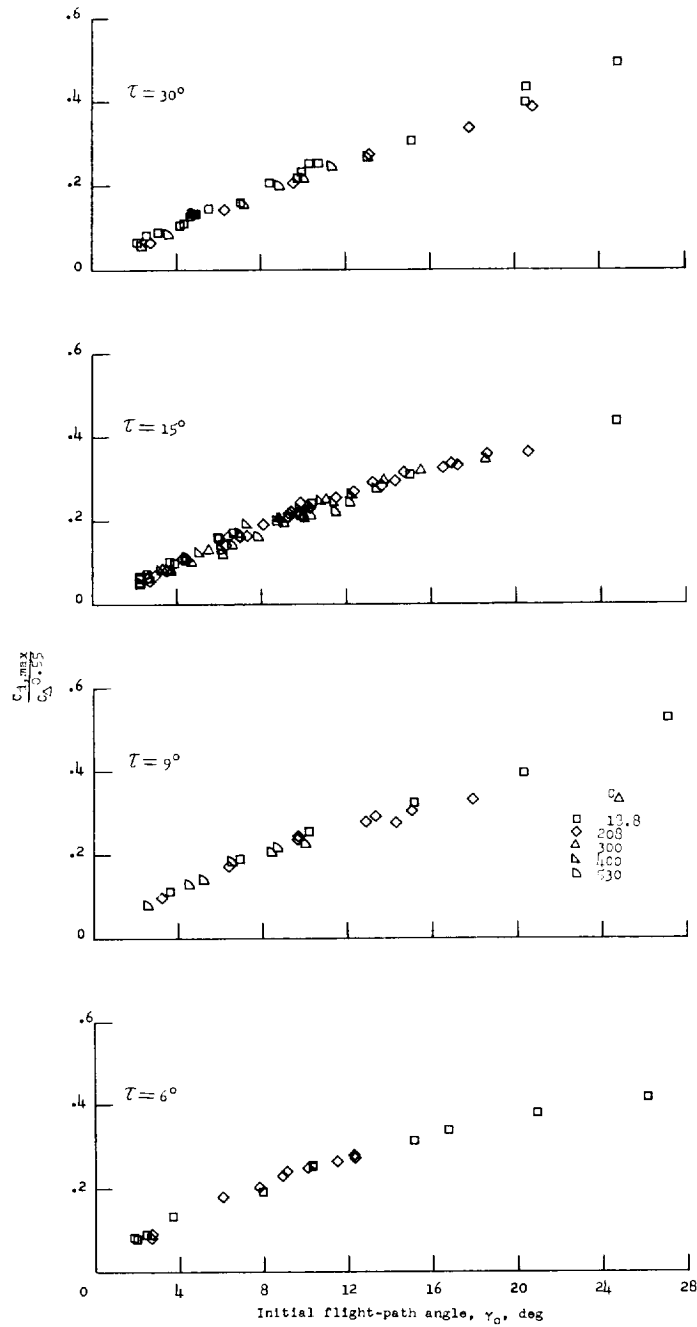
(d) $C_{d,max}$.

Figure 8.- Continued.
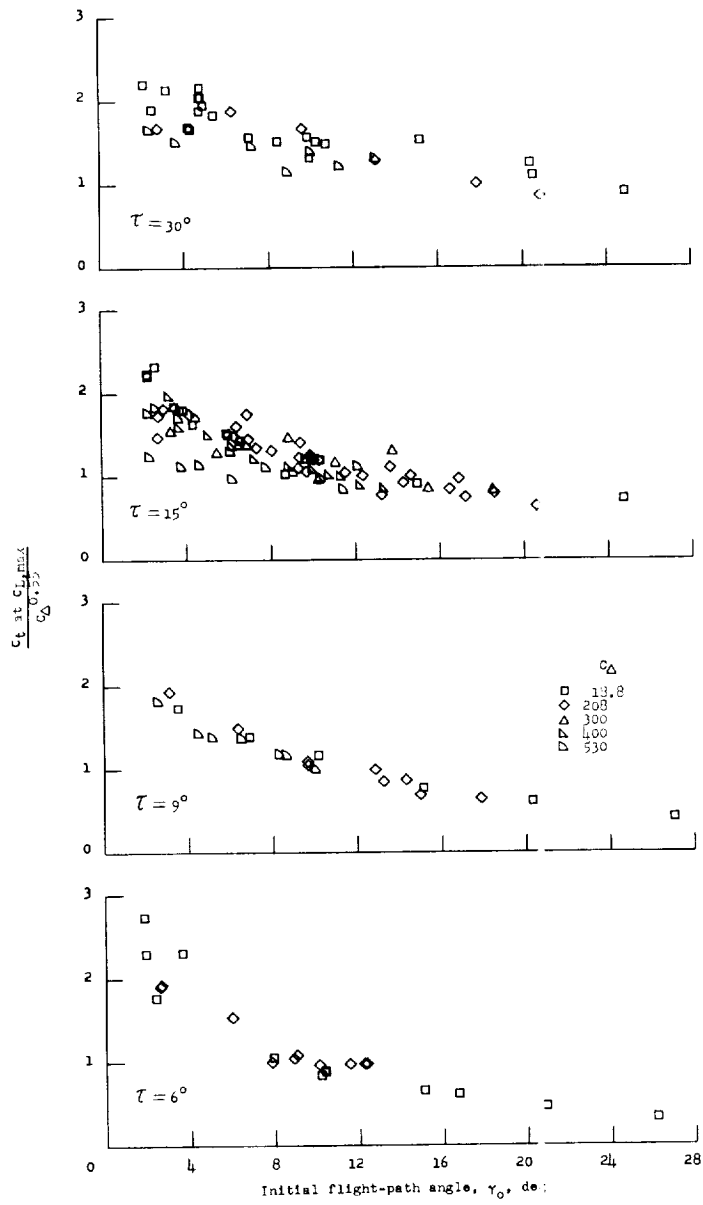
(e) C_t at $C_{L,max}$.

Figure 8.- Continued.
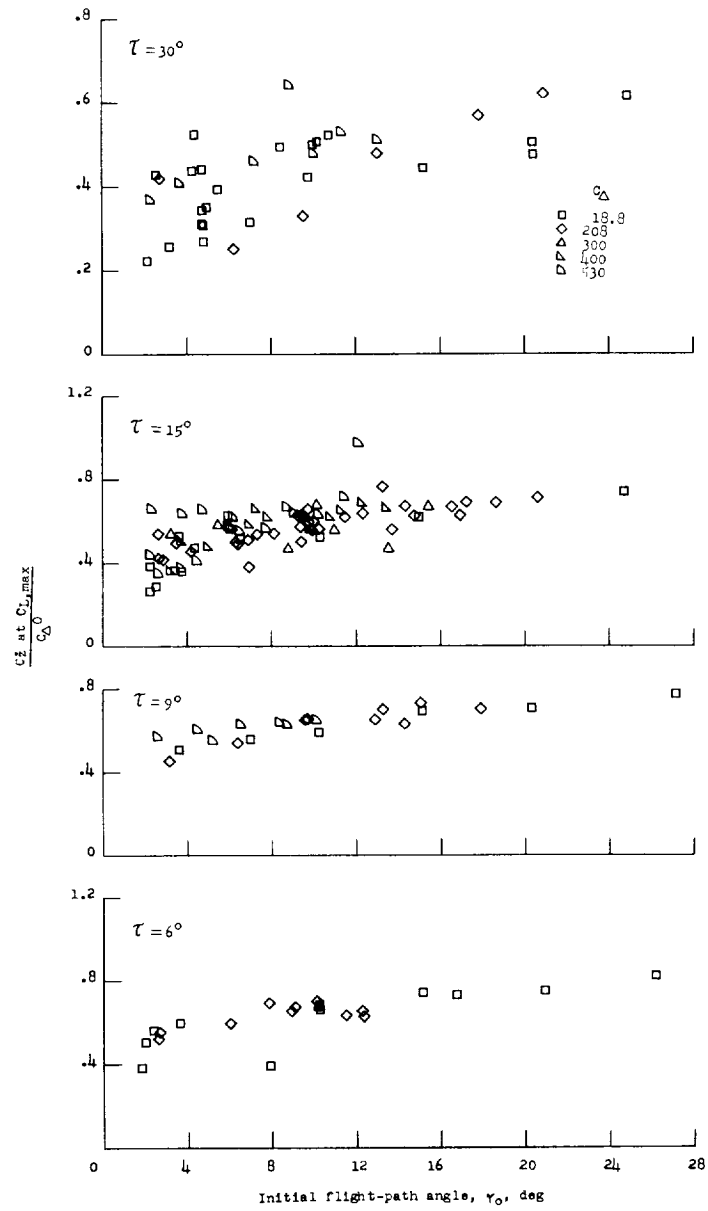
(f) $C_{\dot{Z}}$ at $C_{L,max}$.

Figure 8.- Concluded.

Figure 9.- Theoretical variation of maximum impact lift coefficient $C_{L,max}$ with beam-loading coefficient C_Δ. $\tau = 15^o$; $\gamma_o = 20^o$.
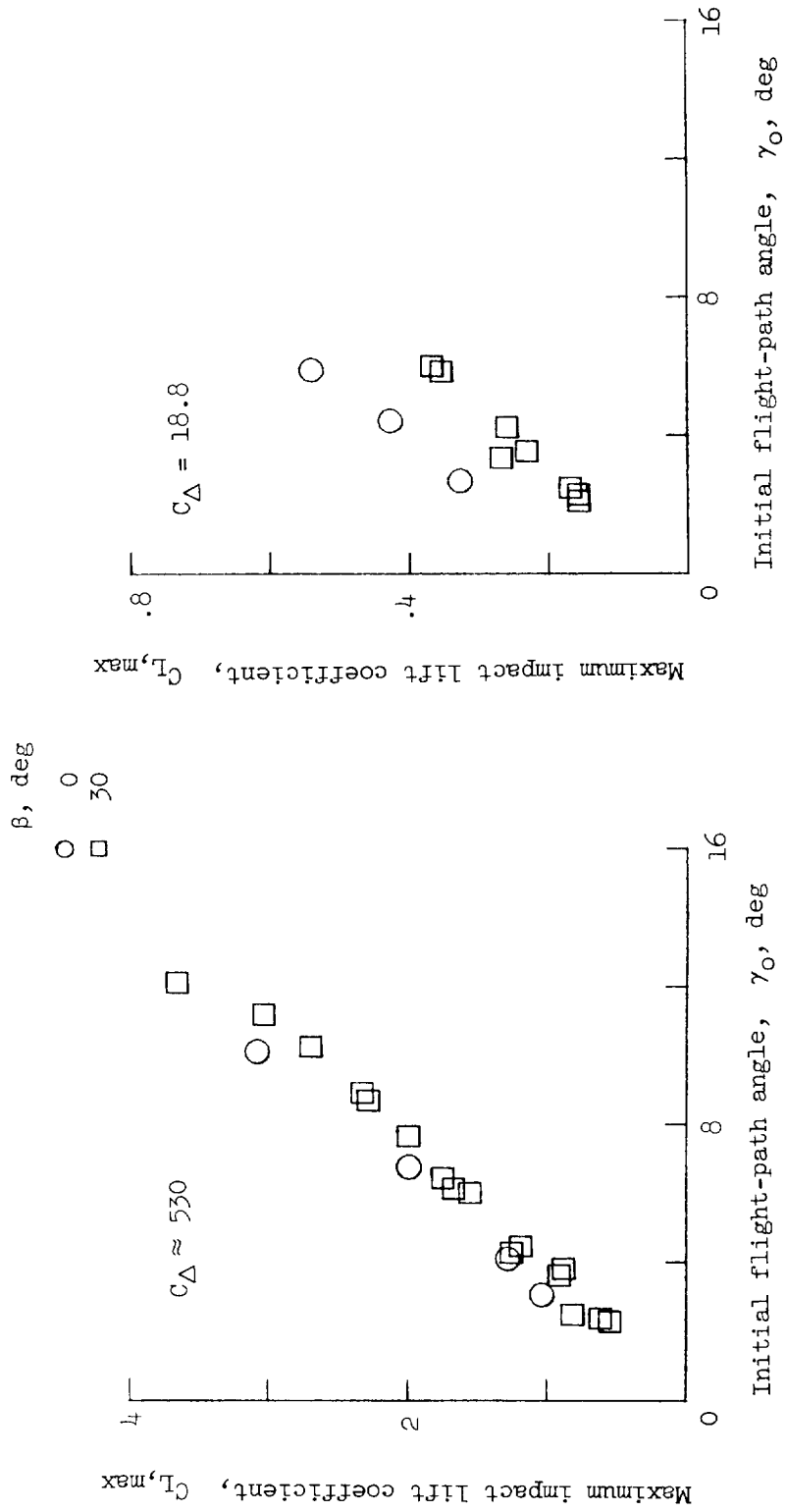
Figure 10.- Lift reduction due to dead rise at two beam loadings. $\tau = 15^{\circ}$.
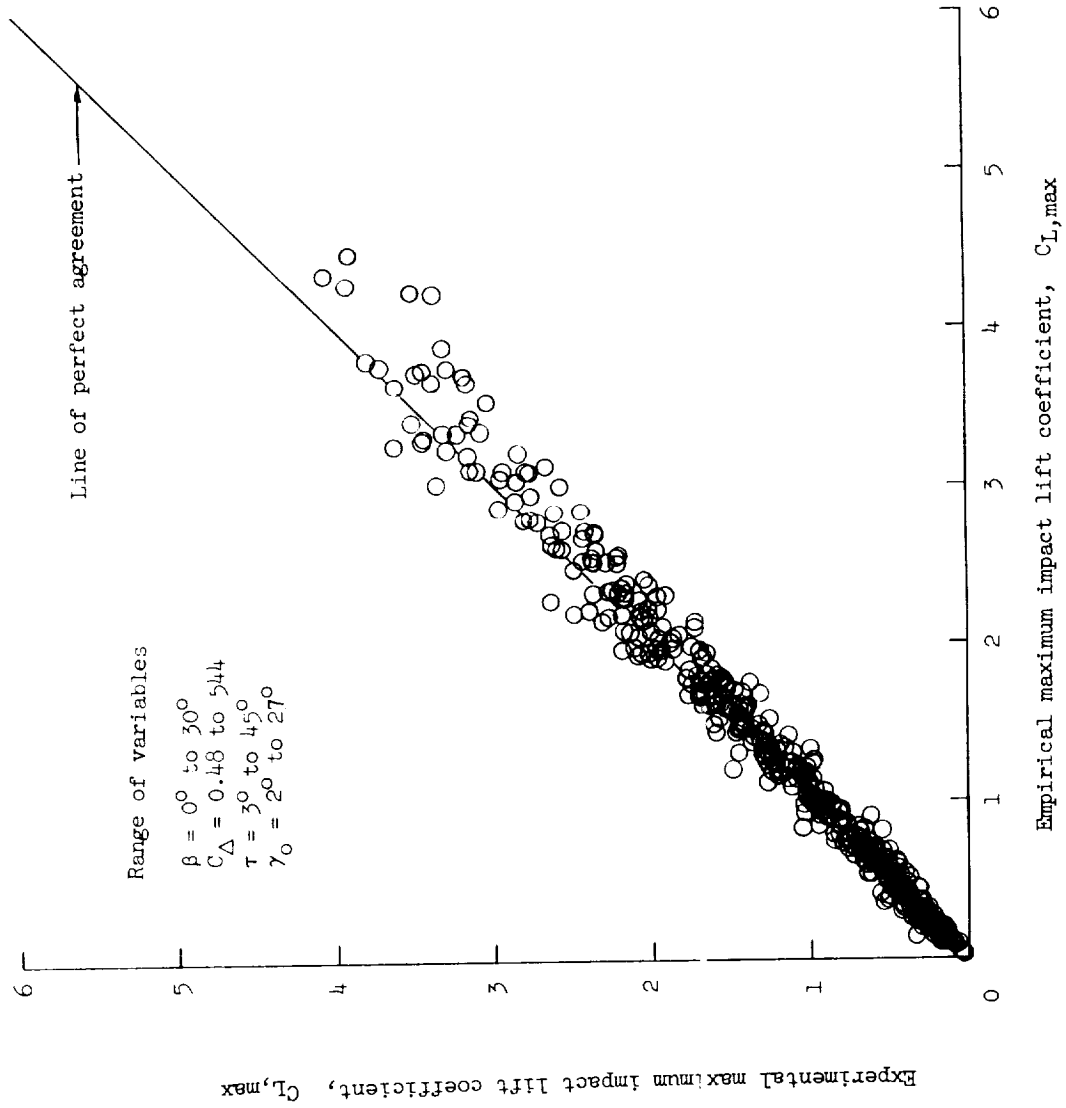
Figure 11.- Comparison of empirical and experimental maximum impact lift coefficient.