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FORM 25-AY
(10-51)

DOUGLAS AIRCRAFT COMPANY, INC.

EL SEGUNDO DIVISION

[illegible] DEPARTMENT

REPORT NUMBER

ES 17622

SUMMARY OF WIND-TUNNEL TESTS ON AN AIR-DROPPABLE LAND MINE

CONTRACT NO. NONR 936(00)

REPORT DATE February 17, 1954

MODEL Project 20

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1.0 SUMMARY

The results of wind-tunnel tests on an air-droppable land mine are presented in this report. It is shown that considerable improvement in stability and damping characteristics can be achieved by the use of a slightly larger fin with a sweepback of thirty degrees. It is recommended that this fin be used on the mine.

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3.0 INTRODUCTION

Free flight drops of the air-droppable land mine resulted in a large amplitude wobbling motion* after release of the paravane. The motion was believed to be caused by low stability and damping, particularly at the lower speeds. Consequently, a wind-tunnel program was initiated for the purpose of improving the stability. A brief summary of the results of the tests are presented in this report. The complete wind-tunnel data are presented in Reference 1.

The tests included tests of four different fins at various angles of sweep, various dive brakes, and dorsal fins. Two nose sections of the body were also tested.

A full scale store was used for the tests and the tests were conducted in the GALCIT 10-Foot Wind Tunnel during October, 1953.

*In general a wobbling motion of a store consists of combined pitching, yawing, and rolling oscillations. The frequencies of the oscillations are identical so that the tail of the store traces out a helix (or a circle neglecting the forward velocity) with one side of store always facing the center.

4.0 DESCRIPTION OF MODEL

A full scale store was used as a model. The store was mounted on the conventional three strut support system by means of a shaft perpendicular to the axis of symmetry and a tail sting. This system was used in the previous tests reported in Reference 2. Diagrams of the store, fins, and dorsal fins are shown in Figure 1. Dimensions used in reduction of the wind-tunnel data are listed below.

4.1 Dimensional Data

Length	Nose B_2	$\ell = 2.73$ ft.
	Nose B_3	$\ell = 2.63$ ft.
Diameter		$d = 0.500$ ft.
Frontal Area		$S_\pi = 0.196$ sq. ft.

Fin, dive brake, and dorsal fin dimensions are shown on Figure 1.

Fins F_h, F_i, and F_j had a wedge airfoil section with a 10 degree included angle. Fin F_g was cut from a flat sheet.

4.2 Symbols

The following symbols are used in describing the model or aerodynamic forces or coefficients.

S_π	Maximum frontal area
ℓ	Store length
d	Store diameter
B	Body Subscript denotes body number
F_X^Y	Fin - Subscript (X) denotes fin configuration Superscript (Y) denotes fin sweepback in degrees
D_X	Dive Brake - Subscript (X) denotes dive brake number
d_x	Dorsal Fin - Subscript (x) denotes dive brake number
C_L	Lift Coefficient $= \frac{L}{qS_\pi}$
C_D	Drag Coefficient $= \frac{D}{qS_\pi}$
C_m	Pitching Moment Coefficient $= \frac{M}{qS_\pi \ell}$

α	Angle-of-Attack
P	Period of Oscillation
$T_{1/2}$	Time to half amplitude

5.0 WIND-TUNNEL TEST RESULTS

Typical data from the wind-tunnel tests are shown in Figures 2 - 8. As can be seen, the tests were run from an angle-of-attack of -30 degrees to +60 degrees. The data were run to large angles because the data at angles near the stall were considered important.

A summary of the more important configurations are shown in Figure 8 and the aerodynamic parameters are compared in Table I. The data shown in Figure 8 are the average of the positive and negative angles-of-attack. The data in Table I were taken from Figure 8 and are strictly applicable only for an angle-of-attack range of ± 10 degrees.

The variation in nose shape results in a negligible change in the stability and a very slight change in drag. However, the increase in fin size results in an appreciable increase in stability. For example, from the original fins (F_g) to the reccommended fins (F_1^{30}) the stability increase is approximately 50 percent and from the original fins to the largest fins (F_j^{30}) the increase is greater than 200 percent. Sweeping the fins from 0 degrees (F_1^{0}) to 30 degrees (F_1^{30}) caused a slight reduction in the stability at small angles-of-attack, but there is an increase in stability at large angles-of-attack ($\alpha = 20$ degrees). However, an increase in sweepback from 30 degrees to 45 degrees caused a reduction in the stability. The addition of dorsal fins materially increases the stability (40 percent for dorsal fin d_1), but interference between the dive brakes and the dorsal fin precludes the use of dorsal fin d_1. The largest dorsal fin that can be used is d_2 which resulted in an increase in stability of 15 percent. The addition of brakes or rotation of the fins resulted in relatively minor changes.

The fin orientation did effect the drag which indicates a possible interference between the wind-tunnel struts and the store. It should be noted that the large decrease in drag coefficient with sweepback of the fins is due to the reduction in projected frontal area of the dive brakes which results when the fin to which it is attached is sweptback, rather than a reduction in the fin drag.

TABLE I

SUMMARY OF THE AERODYNAMIC PARAMETERS

Run No.	Configuration	Variable	C_{L_α}	C_{m_α}	C_D
4	B_2	Nose Shape (Fins Off)	.050	+.0040	.34
1	B_3		.050	+.0040	.33
3a	$B_2F_g{}^{0}D_4$	Nose Shape (Fins On)	.067	-.0205	1.88
2	$B_3F_g{}^{0}D_4$		.067	-.0205	1.80
5	$B_2F_h{}^{30}D_5$	Fin Size	.062	-.0250	1.88
11	$B_2F_i{}^{30}D_5$		.078	-.0280	1.86
7	$B_2F_j{}^{30}D_5$		.104	-.0465	1.92
9	$B_2F_i{}^{0}D_5$	Fin Sweep	.067	-.0310	2.24
11	$B_2F_i{}^{30}D_5$		.078	-.0280	1.86
10	$B_2F_i{}^{45}D_5$		.078	-.0240	1.45
18	$B_2F_i{}^{30}D_5d_1$	Dorsal Fins	.115	-.0390	1.83
19	$B_2F_i{}^{30}D_5d_2$		.102	-.0320	1.83
20	$B_3F_i{}^{30}D_5d_3$		.090	-.0300	1.83
11	$B_2F_i{}^{30}D_5$ $(\phi = 0^\circ)$	Fin Orientation	.078	-.0280	1.86
21	$B_2F_i{}^{30}D_5$ $(\phi = 22.5)$		.070	-.0260	1.81
22	$B_2F_i{}^{30}D_5$ $(\phi = 45^\circ)$		.070	-.0260	1.76
12	$B_2F_i{}^{30}$	Brake Size	1.08	-.0410	0.85
11	$B_2F_i{}^{30}D_5$		.078	-.0390	1.86
13	$B_2F_i{}^{30}D_6$		.078	-.0390	2.26

6.0 DISCUSSION

Of the configurations tested, the following were considered to merit analysis.

Run	Configuration
3a	$B_2F_g{}^{0}D_4$
9	$B_2F_i{}^{0}D_5$
11	$B_2F_1{}^{30}D_5$
10	$B_2F_1{}^{45}D_5$
7	$B_2F_j{}^{30}D_5$
18	$B_2F_1{}^{30}D_5d_1$
19	$B_2F_i{}^{30}D_5d_2$

The large amplitude wobbling motion was encountered after decoupling of the paravane. It was estimated that the speed at this time was about 100-150 ft/sec. Consequently, these speeds were used in two-degree-of-freedom dynamic stability calculations. These calculations were made primarily to investigate the effect of the stability and the damping in pitch with the various configurations. The damping in pitch is a function not only of the stability contribution of the tail, but also the tail length which varies appreciably with sweepback. The results of these calculations are presented in Table II.

TABLE II

TWO-DEGREE-OF-FREEDOM DYNAMIC CHARACTERISTICS

Run	Configuration	Critical Damping (Percent)	V = 100 ft/sec. P (sec.)	T1/2 (sec.)	150 ft/sec. P (sec.)	T1/2 (sec.)	200 ft/sec. P (sec.)	T1/2 (sec.)
3a	$B_2F_g{}^{0}D_4$	4.6	1.47	3.51	0.98	2.33	0.74	1.76
9	$B_2F_1{}^{0}D_5$	5.1	1.20	2.57	0.80	1.72	0.60	1.28
11	$B_2F_1{}^{30}D_5$	5.7	1.26	2.46	0.84	1.64	0.63	1.23
10	$B_2F_1{}^{45}D_5$	5.6	1.36	2.67	0.90	1.78	0.68	1.34
7	$B_2F_J{}^{30}D_5$	7.0	0.98	1.54	0.65	1.03	0.49	0.77
18	$B_2F_1{}^{30}D_5d_1$	6.5	1.07	1.81	0.72	1.21	0.53	0.91
19	$B_2F_1{}^{30}D_5d_2$	6.1	1.18	2.15	0.79	1.43	0.59	1.08

Table II shows that the larger fins (F_1 & F_J) show a considerable improvement over the original fins. In addition, it shows that for the F_1 fins 30 degrees of sweepback of the fins (Run 11) is probably the best compromise from the standpoint of damping and period of oscillation. The dorsal fins (Run 18 and 19) also show a gain, but dorsal fin d_2 which is the largest practical dorsal shows a gain of less than 10 percent. From this analysis it was concluded that analysis of the wobbling amplitude include the following configurations:

Run	Configuration
3a	$B_2F_g{}^{0}D_4$
11	$B_2F_1{}^{30}D_5$
7	$B_2F_J{}^{30}D_5$
19	$B_2F_1{}^{30}D_5d_2$

The amplitude of the wobble motion is shown in Figures 10 and 11. There is a decrease in peak amplitude and an increase in natural frequency as the stability increases. Both of these tend to decrease the amplitude of the wobble motion at any frequency below the critical frequency. Configuration $B_2F_1{}^{30}D_5$ shows a reduction in peak amplitude of about 15 percent and an increase in critical frequency of about 15 percent from the original configuration. Configuration $B_2F_1{}^{30}D_5d_2$ shows a slight improvement over

$B_2F_1^{30}D_5$. Configuration $B_2F_j^{30}D_5$ has a peak amplitude that has a 30 percent lower value and a critical frequency that is 50 percent higher than configuration B_2F_6. These comparisons are strictly true for small amplitude oscillations ($\alpha = \pm 10$ degrees) and for larger amplitudes it is believed that larger improvements will be present because the [illegible]lity increase is larger at angles of about 20-30 degrees than [illegible]ted in Table I.

From a handling standpoint configuration $B_2F_1^{30}D_5$ is much more practical than $B_2F_j^{30}D_5$ because the size of the store is less in the stowed position. The fins of $B_2F_1^{30}D_5$ in the stowed position will fit in the minimum box required for the body of the store.

In view of the above discussion it was decided to proceed with configuration $B_2F_1^{30}D_5$. If flight tests indicated the need for a further improvement, dorsal fins or fins F_j^{30} could be added.

7.0 CONCLUSIONS

The following conclusions were reached from these tests:

1. The intermediate size, 30 degree swept fins ($B_2F_4{}^{30}D_5$) should result in considerable improvement over the original fins ($B_2F_g{}^{0}D_4$), and it is recommended that this fin be checked by flight drop.
2. If a further increase in stability is required, a dorsal fin (d_2) be added.
3. The largest fins ($B_2F_g{}^{30}D_5$) increased the stability of the store by approximately 200 percent over the original configuration.
4. Thirty degrees of sweepback appeared to be optimum.

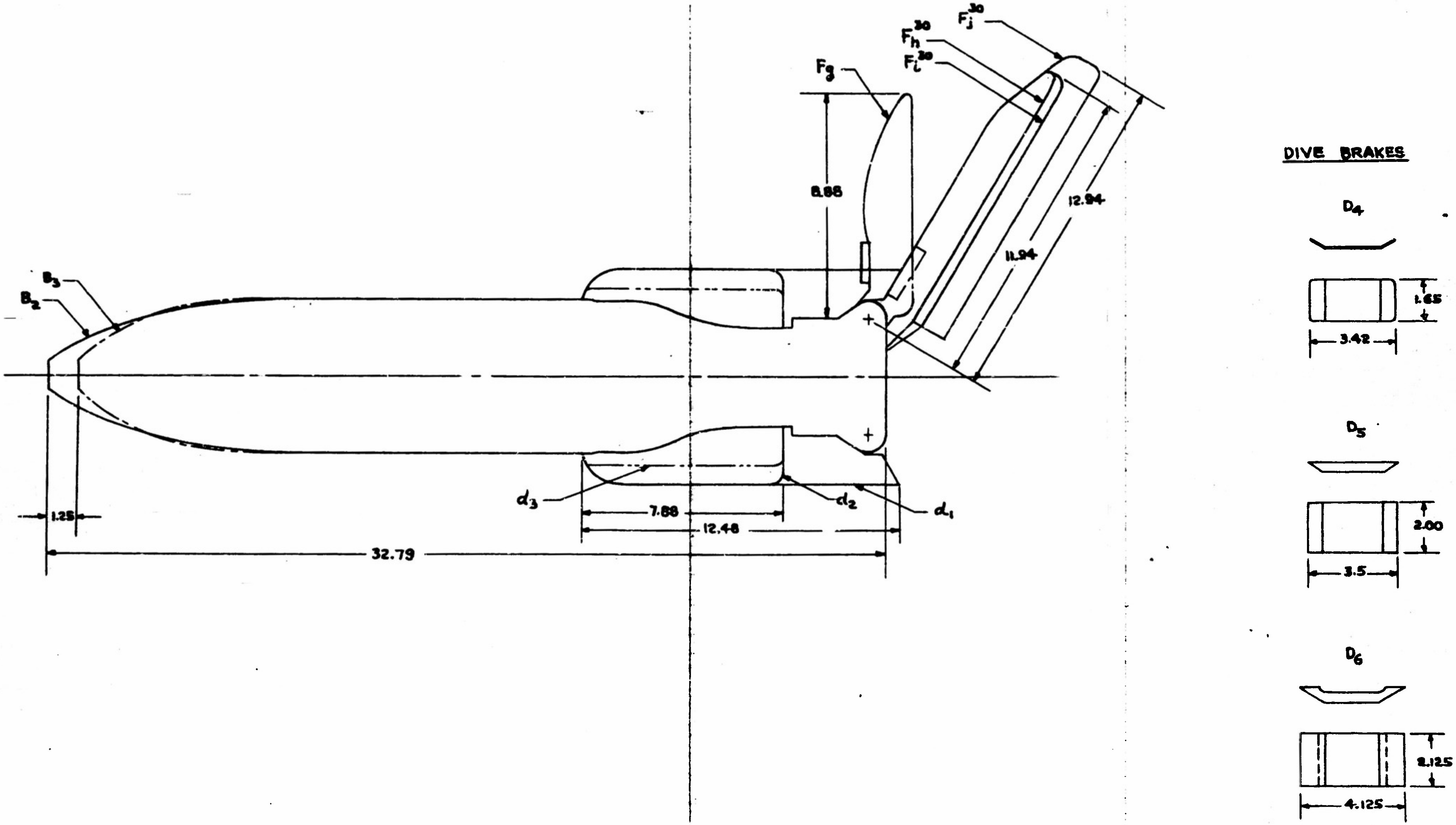
8.0 REFERENCES

1. Harty, Richard B.- Report of Wind-Tunnel Tests on a Full Scale Model of a Douglas (El Segundo) Droppable Store with Fins, Dive Brakes, and Dorsal Fins. GALCIT Report 622 (To be issued)

2. King, A. B. and Sattler, L. E. - Wind-Tunnel Tests of an Air Droppable Land Mine, Douglas Report ES 17235, January 27, 1953.

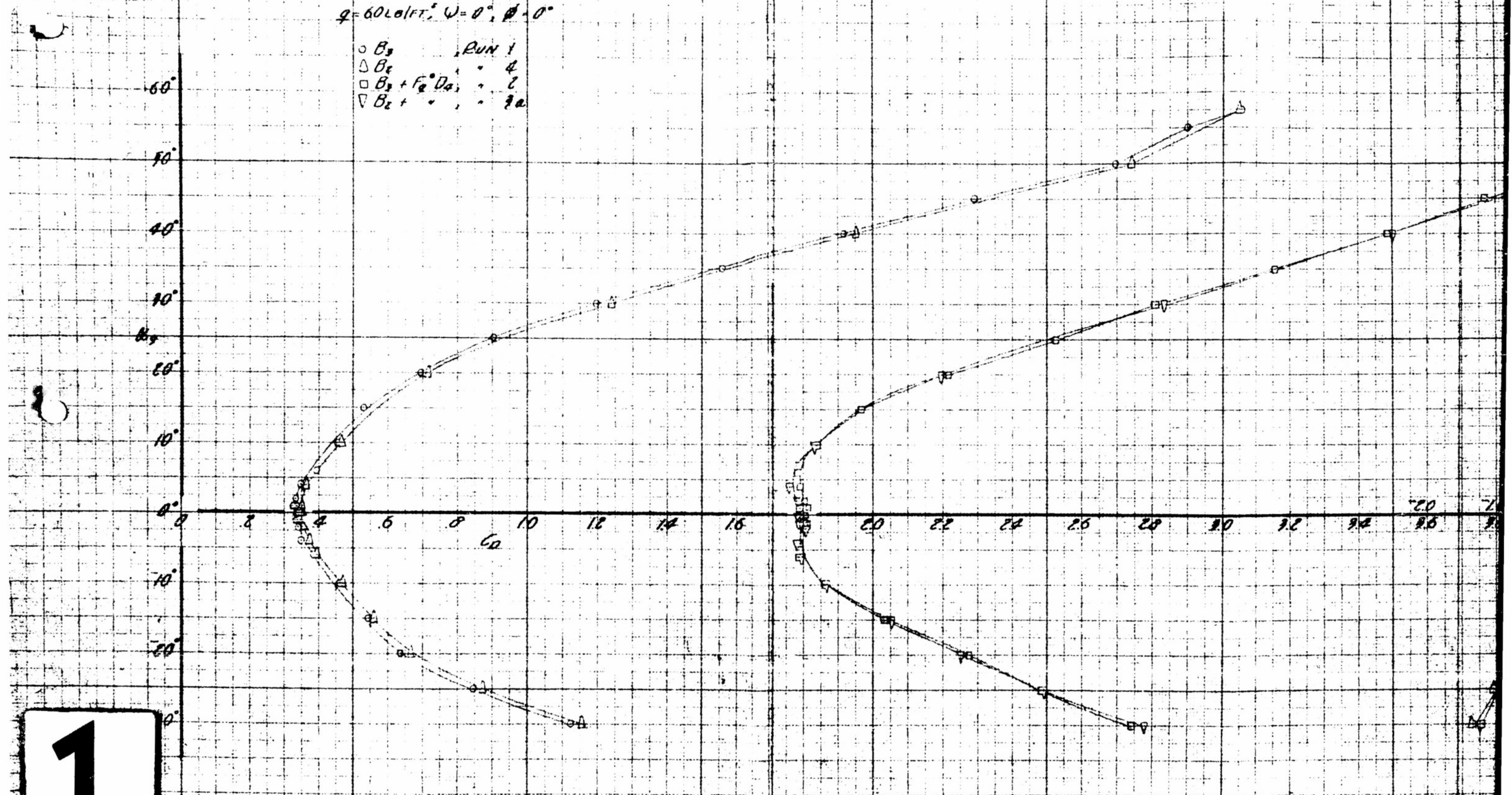
Figure 1

DIAGRAM OF AIR-DROPPABLE LAND MINE



DIMENSIONS IN INCHES FULL SCALE

EFFECTS OF NOSE SHAPE



EFFECTS OF NOSE SHAPE,
($\alpha_g = +57\frac{1}{2}°$ TO $-30°$)

C_D, C_L, C_m VS. α_g

IAI

HAPE

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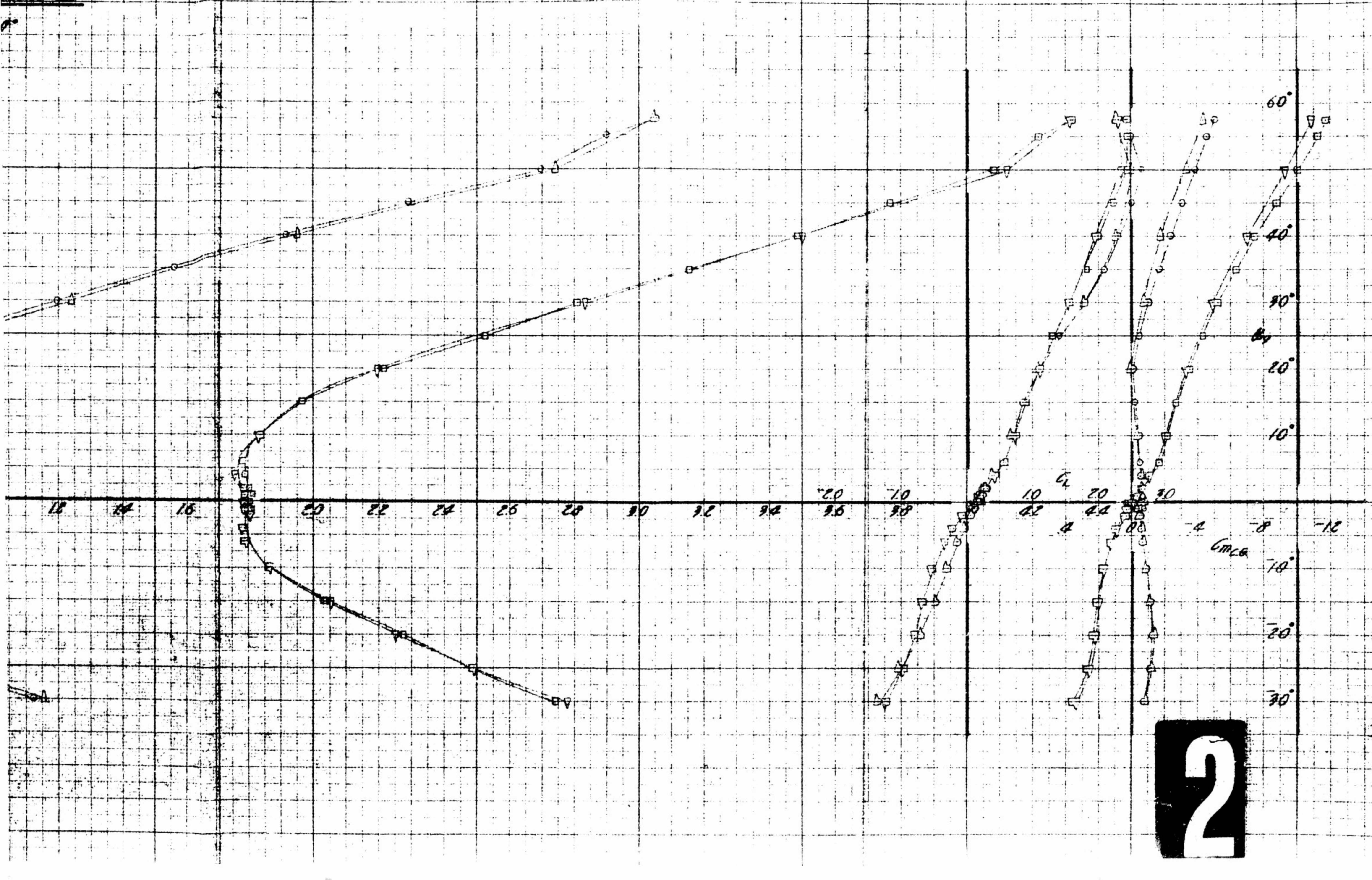
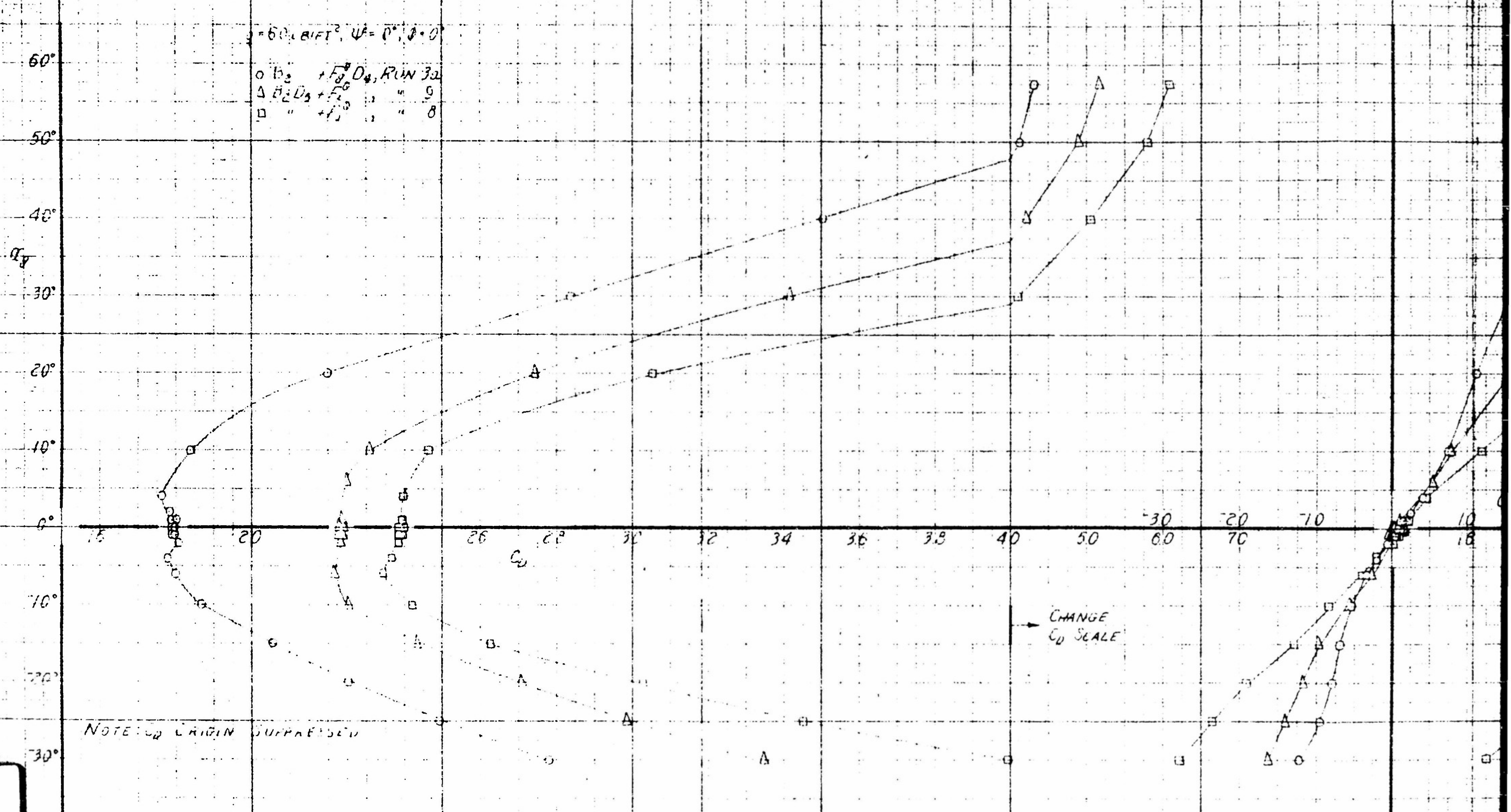
FIG. 2
17622



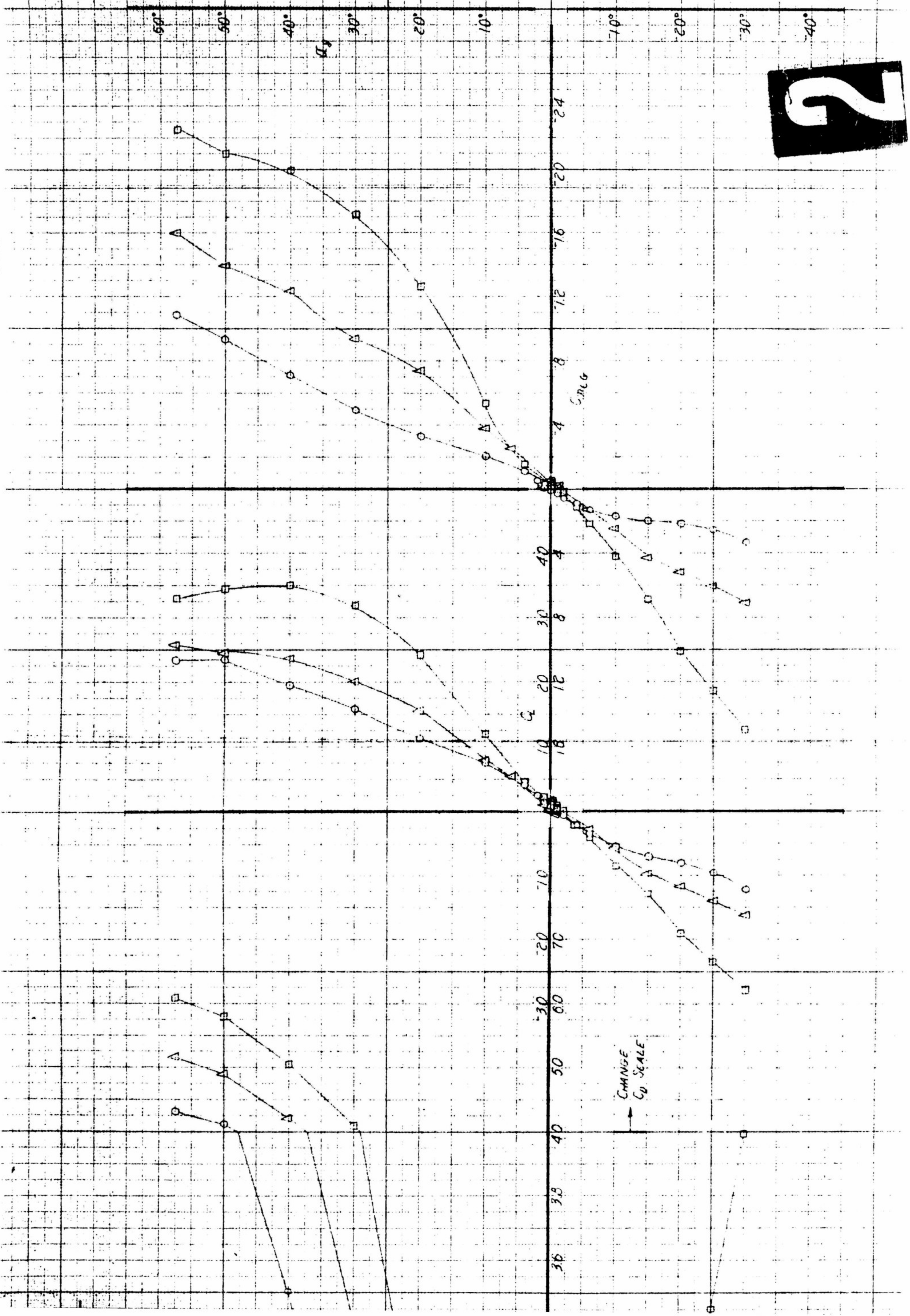
2

EFFECTS OF FIN SIZE WITH VARIED DIVE BRAKES



EFFECTS OF FIN SIZE WITH VARIED DIVE BRAKES,
SWEEP = 0°,
(α_g = +5.7° TO -30°)

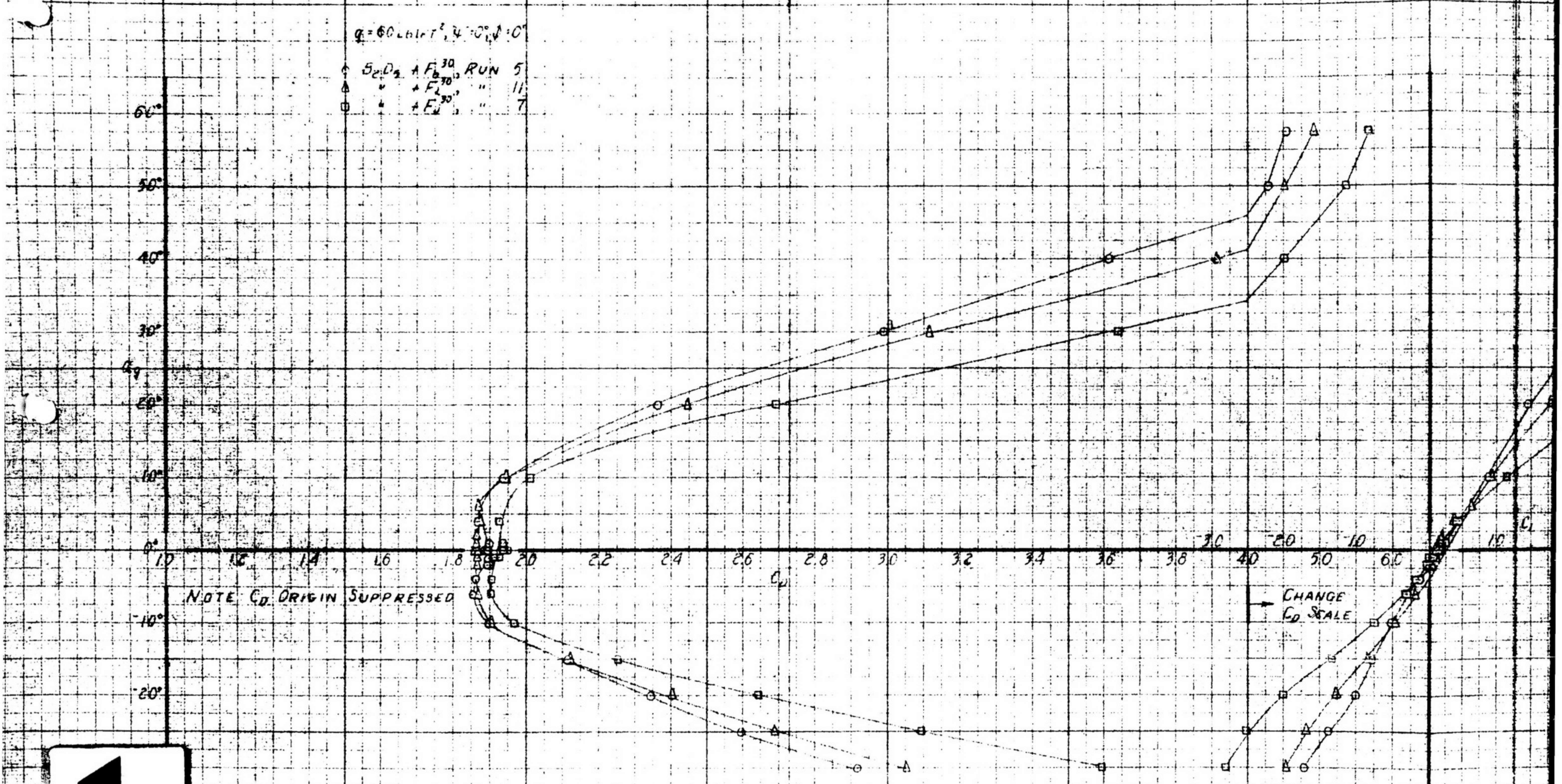
C_D, C_L, C_m vs. α_g



α_g
60°
50°
40°
30°
20°
10°
-10°
-20°
-30°
-40°
C_{mCG}
-24
-20
-16
-12
8
4
C_L
40
30
20
10
4
8
12
16
-10
-20
-30
70
60
50
40
38
36
CHANGE C_D SCALE

2

EFFECTS OF FIN SIZE WITH SMALL DIVE BRAKES



EFFECTS OF FIN SIZE WITH SMALL DIVE BRAKES,
SWEEP = 30°,
(a_g = +57½° TO -30°)

C_D, C_L, C_m VS. a_g

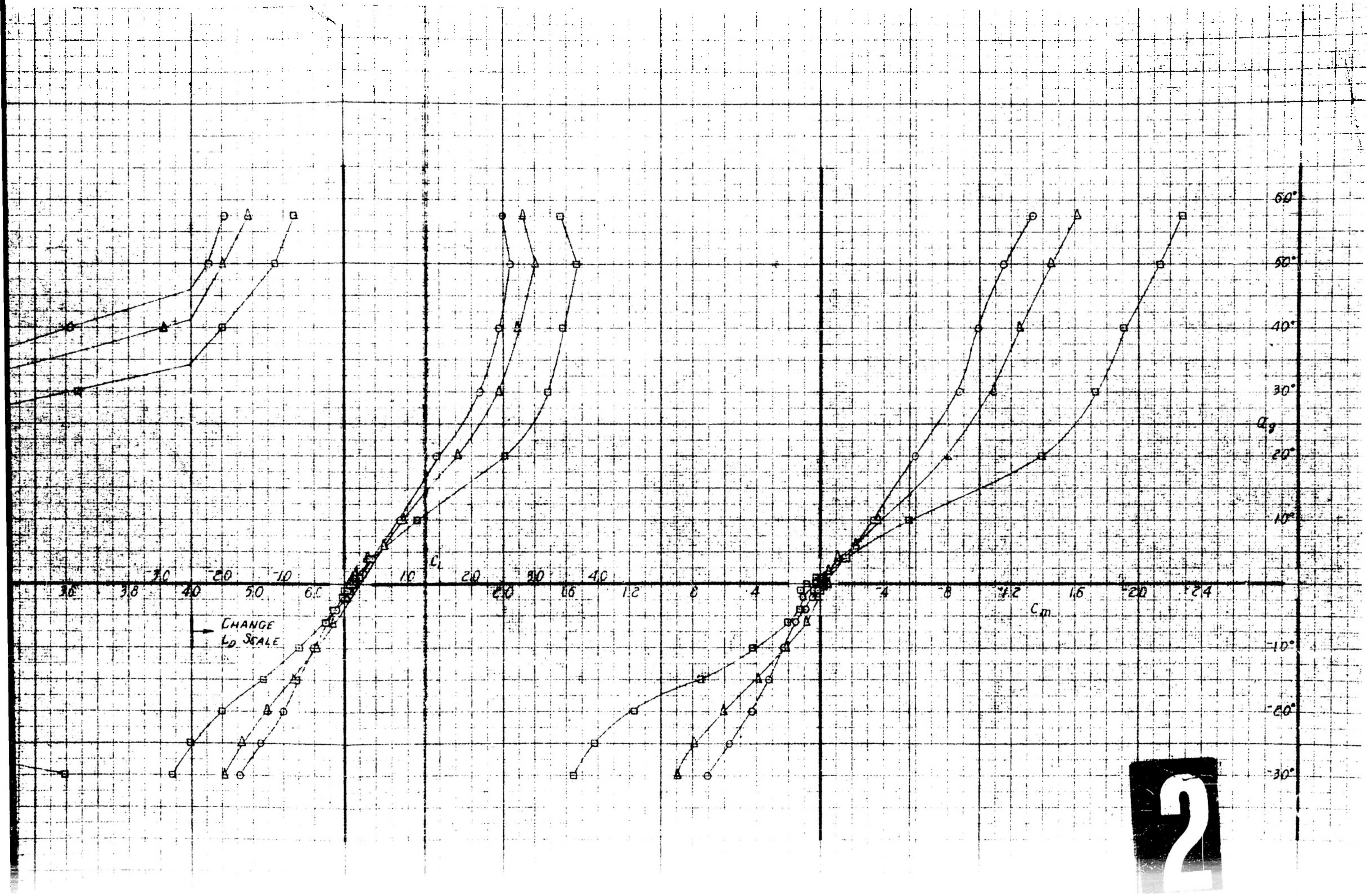

CHANGE L_D SCALE
C_L
C_m
α_g
60°
50°
40°
30°
20°
10°
-10°
-20°
-30°
3.6
3.8
4.0
5.0
6.0
-3.0
-2.0
-1.0
1.0
2.0
3.0
4.0
.6
1.2
.8
.4
.4
.8
1.2
1.6
2.0
2.4
2

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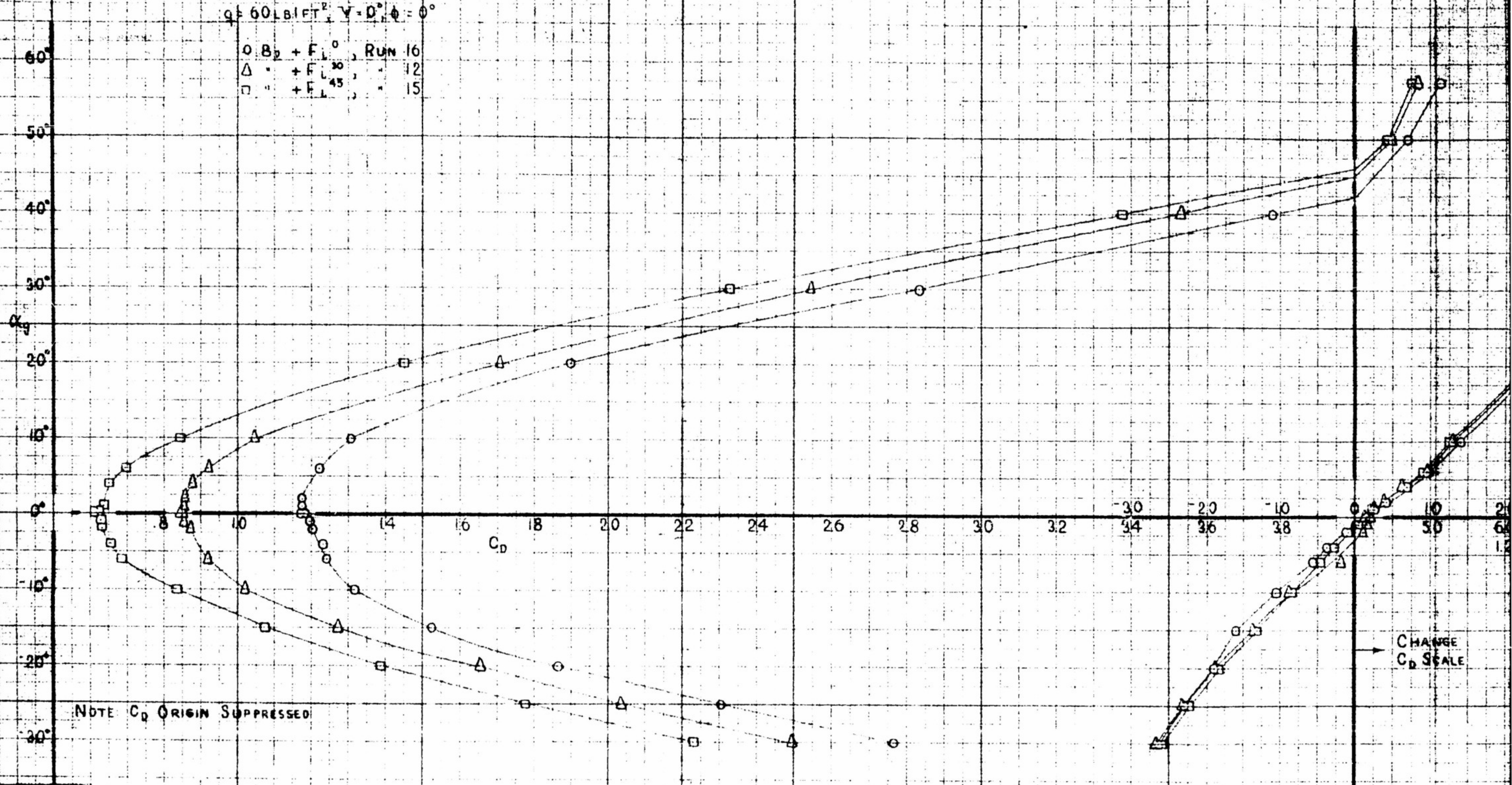
Fig 5

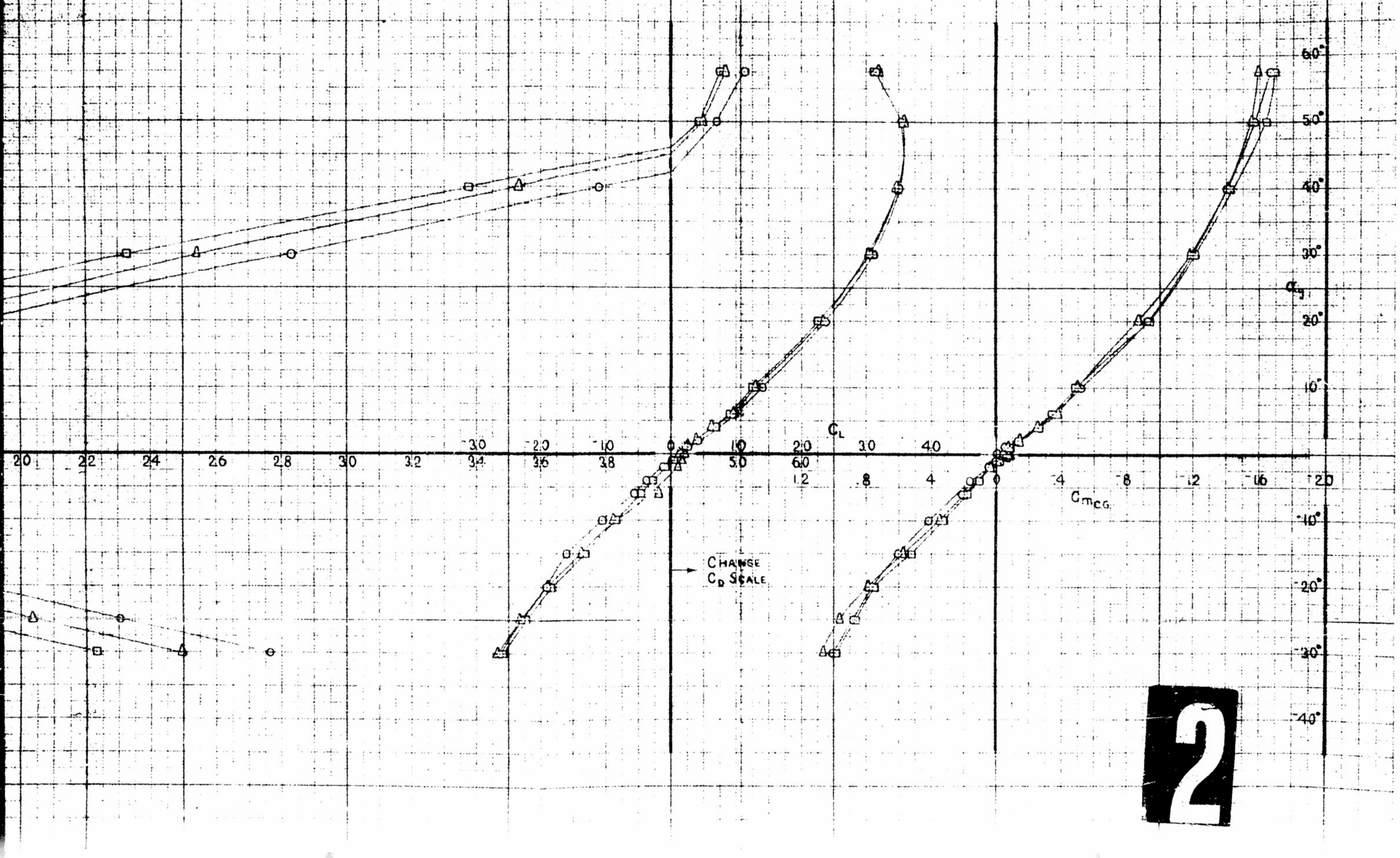
EFFECTS OF SWEEP ON FINS F_i WITH NO DIVE BRAKES



Effects of Sweep on Fins F_L with No Dive Brakes, (α_g = +57½° to 30°)

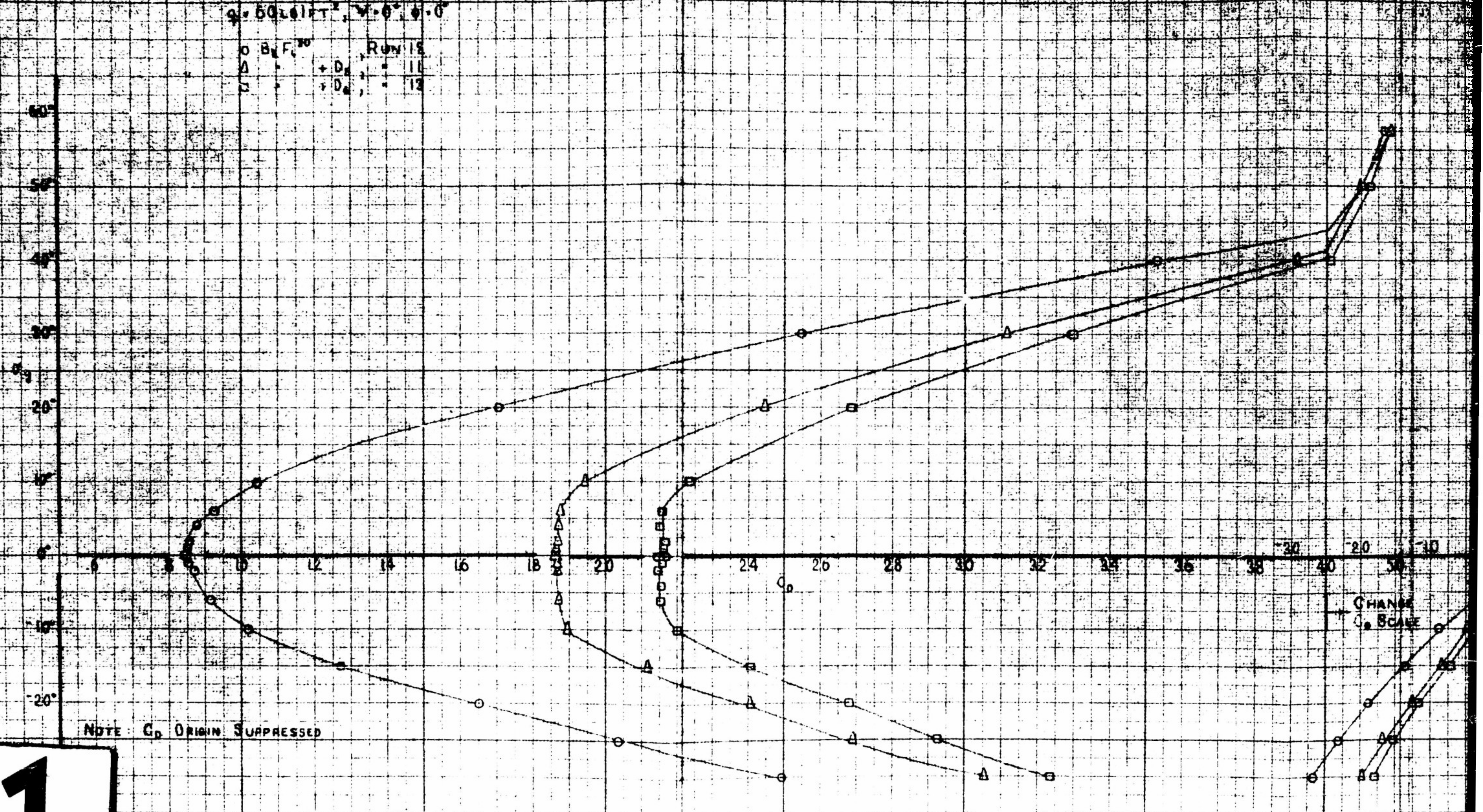
C_D, C_L, C_m vs α_g

DIVE BRAKES



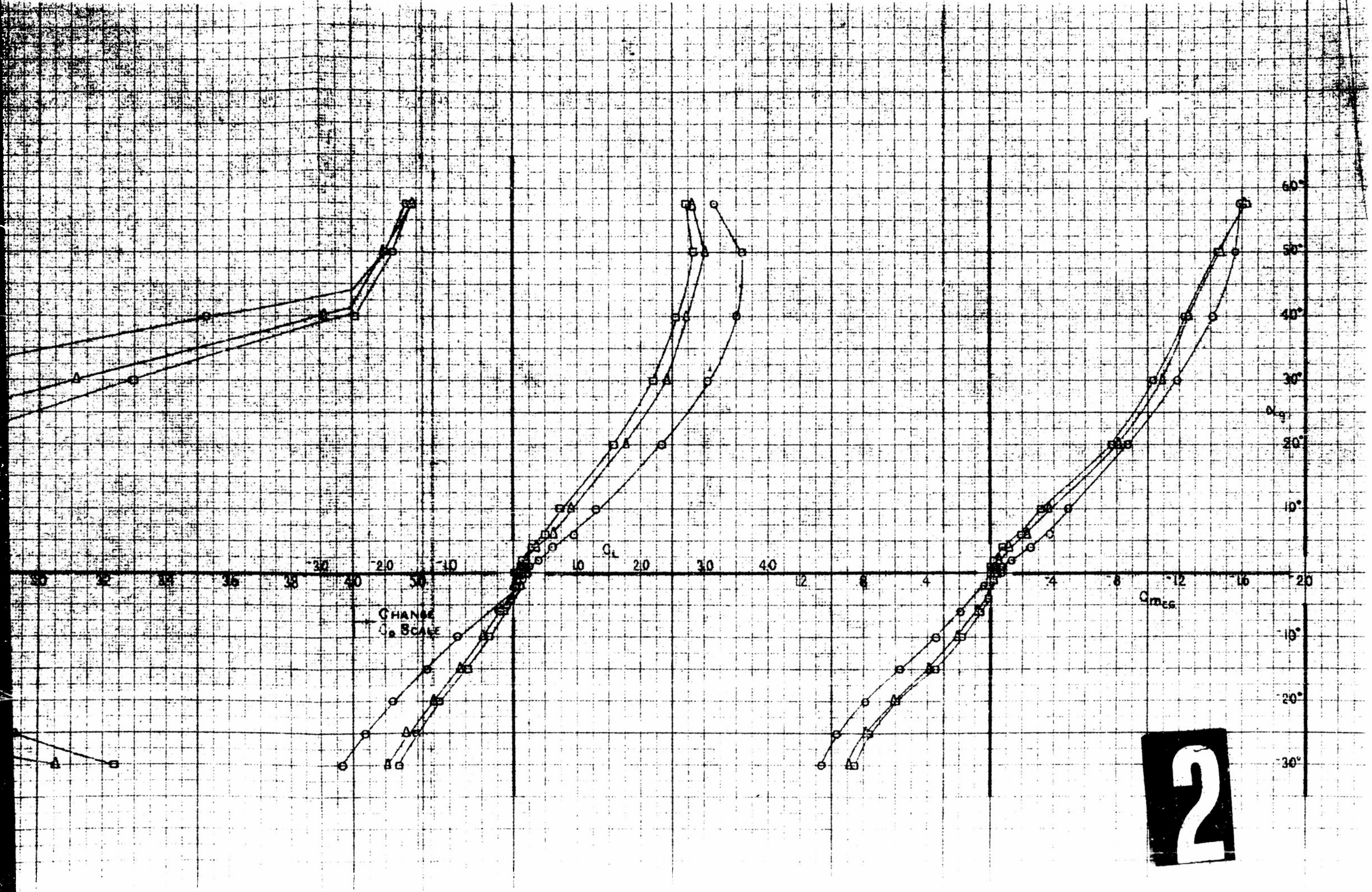
2

EFFECTS OF DIVE BRAKES ON FINS F_i^{30}



Effects of Dive Brakes on Fins F_i^{30}
(α_g = +57½° to -30°)

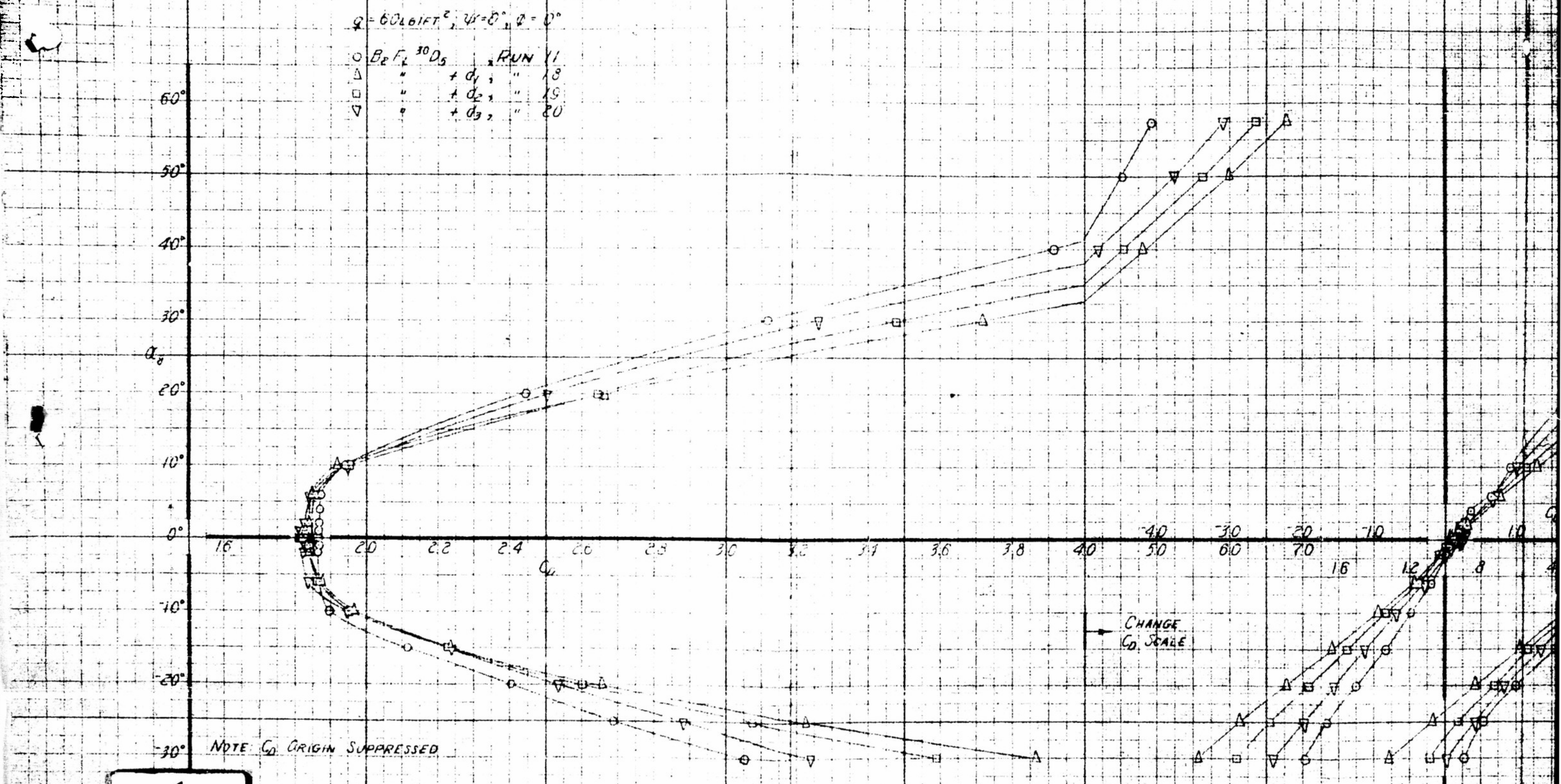
C_D, C_L, C_m vs α_g



60°
50°
40°
30°
20°
10°
-10°
-20°
-30°
α_g
30
32
34
36
38
40
50
-30
-20
-10
10
20
30
40
C_L
12
8
4
4
8
12
16
20
$C_{m_{CG}}$
CHANGE C_D SCALE

2

EFFECTS OF DORSAL FINS

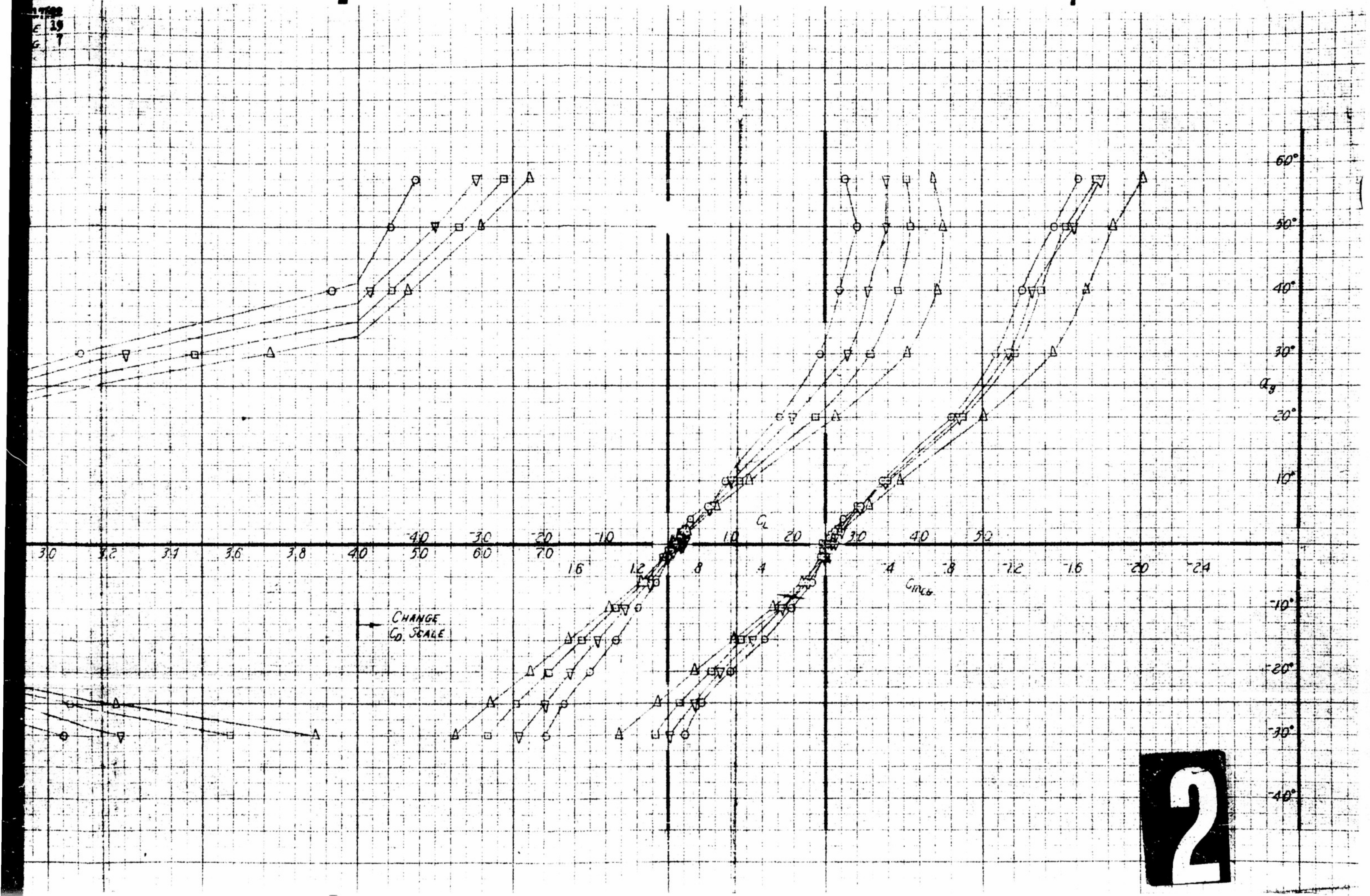


Note: C_D Origin Suppressed

Effects of Dorsal Fins.
($\alpha_g = +57\frac{1}{2}°$ to $-30°$)

C_D, C_L, C_m vs. α_g

E 39
G 7


60°
50°
40°
30°
α_g
20°
10°
-10°
-20°
-30°
-40°
C_L
-4.0
-3.0
-2.0
-1.0
1.0
2.0
3.0
4.0
5.0
3.0
3.2
3.4
3.6
3.8
4.0
5.0
6.0
7.0
1.6
1.2
.8
.4
.4
.8
1.2
1.6
2.0
2.4
$C_{m_{c.g.}}$
CHANGE
C_D SCALE

2

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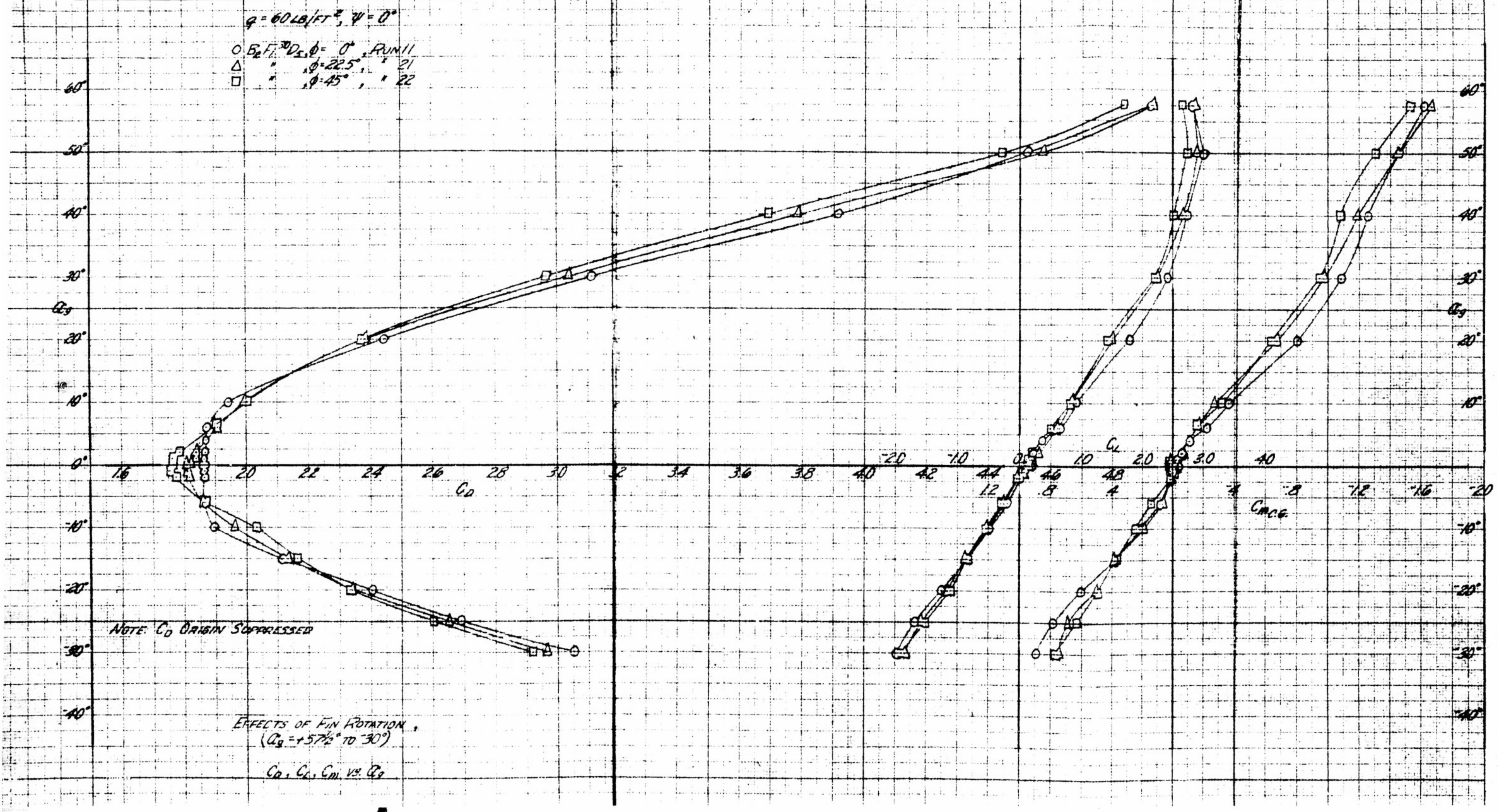
FIG. 8

EFFECTS OF FIN ROTATION



EFFECTS OF FIN ROTATION, ($\alpha_g = +57\frac{1}{2}°$ TO $-30°$)

C_D, C_L, C_m VS. α_g

Figure 9

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FORM 30-250 A-1 (4-49)

SUMMARY OF LIFT AND PITCHING MOMENT DATA

(AVERAGE OF POSITIVE AND NEGATIVE ANGLES OF ATTACK)

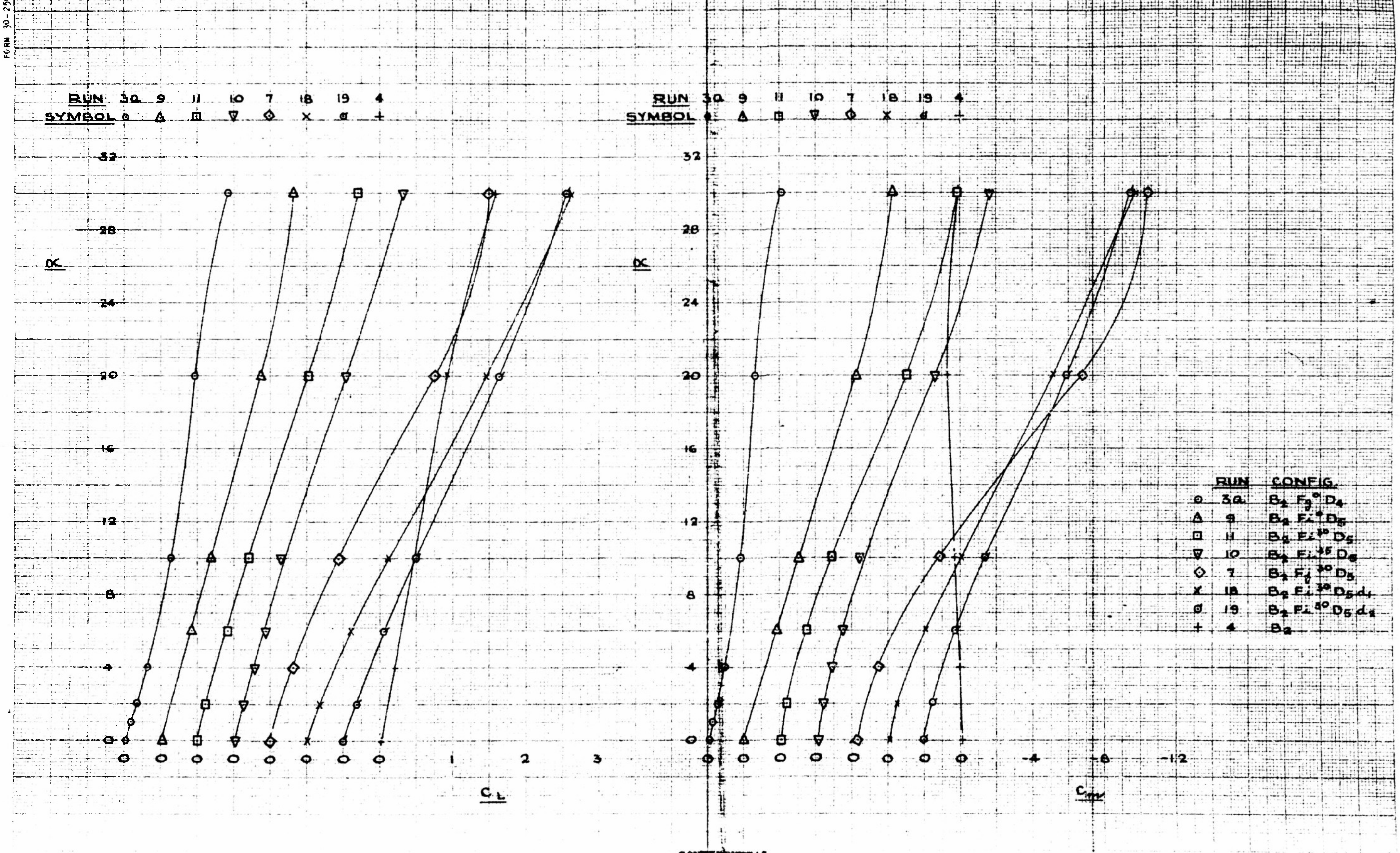

Figure 10

FORM 30-250-1 (9-51)

AMPLITUDE OF WOBBLE MOTION

V = 100 FT/SEC.

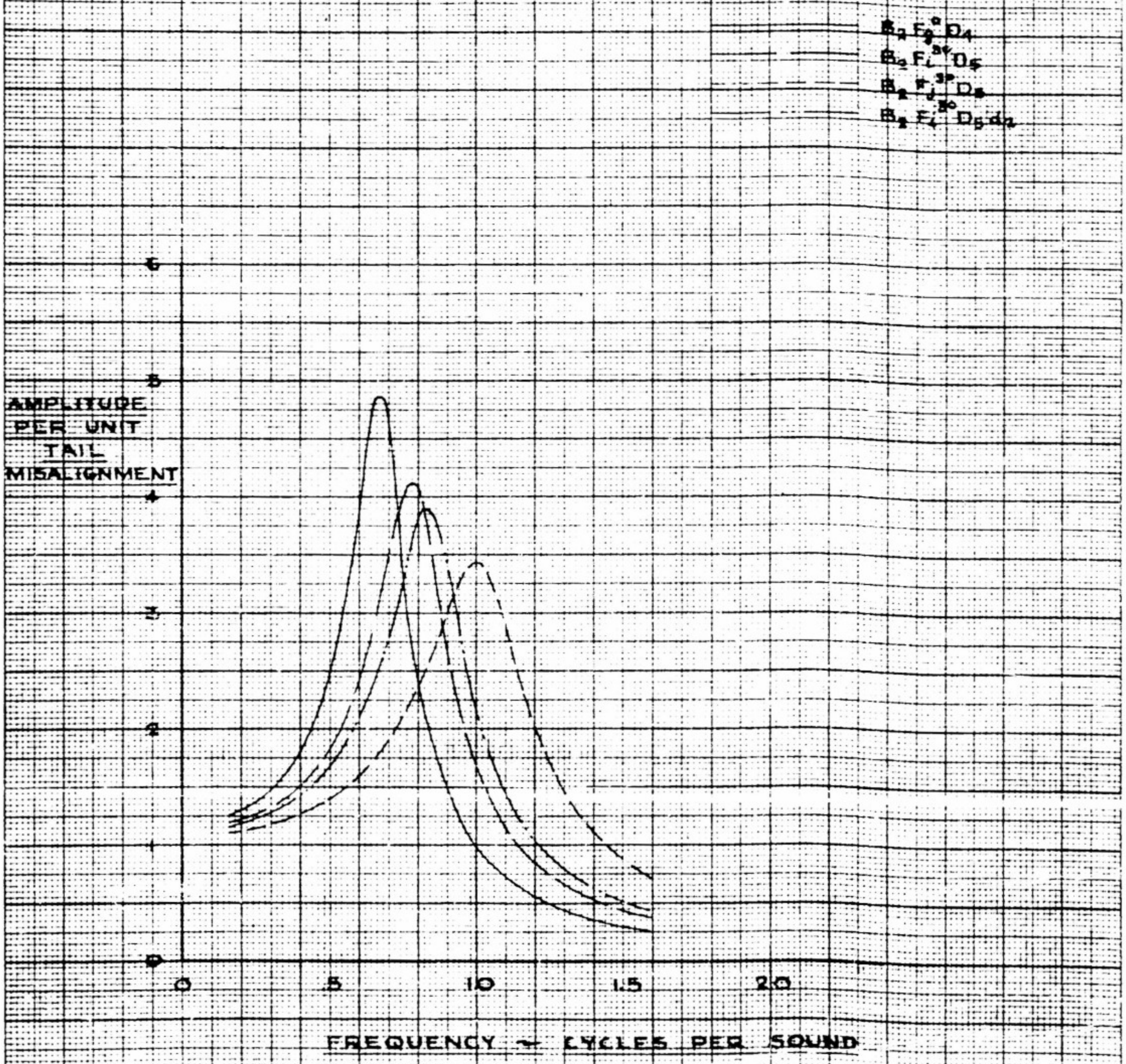

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Figure 11