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**AERODYNAMIC STABILITY AND CONTROL, DATA,
MODEL 844-2035**

**Boeing Company
Seattle, Washington**

14 February 1972

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NOTES

The glider configuration represented by the stability and control characteristics presented in this document is not current. Information derived from analysis and wind-tunnel tests as the document was being completed indicated the need for some configuration changes. However, the document is released for distribution to update the information being used by various agencies for stability and control analysis.

The most significant change to the configuration in a stability and control sense is a change in the incidence angle of the folding wing tip extensions. The tip extensions in the document are set at an incidence of -15° degrees relative to a water line. Currently, the tip extensions are considered at an incidence of zero degrees. This change principally affects the zero lift pitching moment with relatively little effect on longitudinal stability. However, it does affect the directional stability at transonic speeds favorably. With this change in tip incidence, the speed for tip extension must also be altered. Currently, tip extensions are considered retracted at speeds higher than Mach 1.2.

Other changes are being considered to correct some stability and control deficiencies evident in the document. The effects of these changes will be distributed in a revision of this document when they are available.

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INTRODUCTION

The aerodynamic stability and control characteristics of the 844-2035 Dyna Soar glider are presented in the following sections of this document. Data are presented for the glider and for the glider plus third stage.

These data are based on wind tunnel tests, where data are available. Where not available, theoretical estimates have been made for the vehicle characteristics.

This is the interim glider configuration. Some vehicle characteristics peculiar to this configuration are not satisfactory and will be modified for the final configuration. The wing tip extension configuration is subject to change. A hood speed brake location is still to be defined. The vertical tail and rudder size may increase. The elevator configuration may change. The possibility of asymmetric deflection of the elevator for roll control to reduce couplings is being considered.

The data presented will be revised as additional wind tunnel data are received and better estimates of the vehicle characteristics are made.

Information presented in the document is estimated for an obsolete configuration, Model 844-2035. The document is being released to up-date data now in the possession of the customer and associates.

REFERENCES

- Reference a BAC D2-6909-1 "Interim System Description of the Dyna Soar Step I", R. L. Campbell, November 29, 1960.
- Reference b C119-ER-10440 "Dyna Soar I Configuration Evaluation Wind Tunnel Test Report Series II", Bell Aircraft Corporation, May 1959.
- Reference c NACA TN 2409 "Summary of Methods for Calculating Dynamic Lateral Stability and Response and for Estimating Lateral Stability Derivatives", Campbell and Mc Kinney, July 1951.
- Reference d NASA TN X - 287 "Theoretical Stability Derivatives for the X-15 Research Airplane at Supersonic and Hypersonic Speeds Including a Comparison with Wind Tunnel Results, Walker and Wolowicz, August 1960.

3.0

CONFIGURATION

3.1

The general arrangement of the 344-2035 configuration is shown on Figure 3.1.1. The configuration is shown in the manufactured shape (referred to as the "cold" shape).

A heat shield is shown covering the pilots wind shield. This is separated from the glider at supersonic speeds. The drag brake, shown on top the body, is actuated at subsonic and low supersonic speeds, only. The wing tip extensions, located on the vertical tails, are extended at supersonic speeds. The rudders are deflected outboard only.

The elevons are split in two panels. This was done to reduce the sensitivity of the elevons for roll control at transonic and supersonic speeds and at high dynamic pressures when the elevons have high effectiveness. In these flight conditions, roll commands are transmitted to the inboard panels only. If a continuous signal is required by the adaptive feature of the flight control system, it will be transmitted to the inboard panel only to conserve A.P.T. fuel.

The inboard elevon panel is shown to have a wedged section to eliminate possible "dead" zones in elevon effectiveness at small deflections at hypersonic speeds. This wedging is probably unnecessary. The elevon section of the inboard panel has been considered modified to the same as that outboard panel for the data in this document.

Elevon actuator housings, not shown on the drawing, are located on the upper wing surface. These are positioned at approximately midspan of the two elevon panels and extend forward of the elevon hinge line. Actuators for the rudders are located in the bottom section of the vertical tail.

A more complete configuration is presented in Reference 2.

TRAIN MARKS

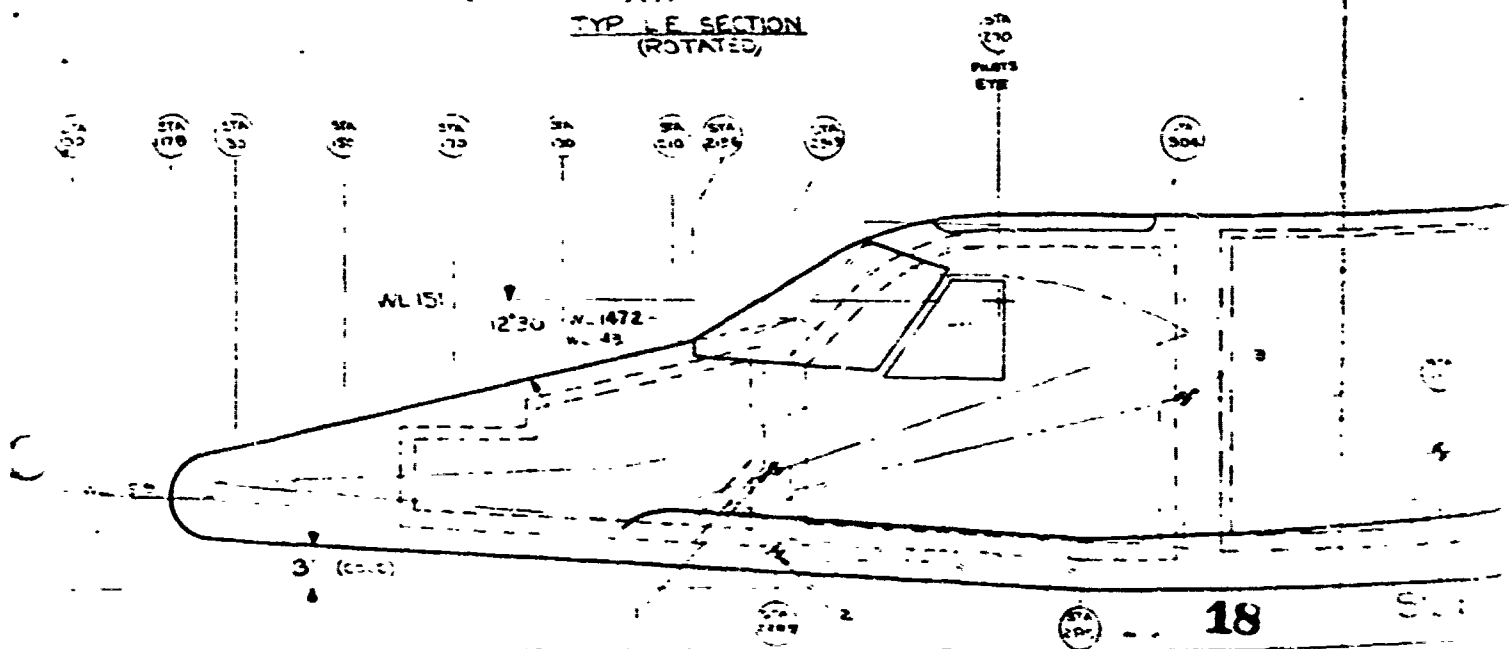
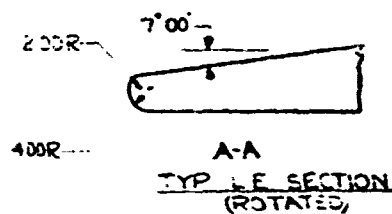
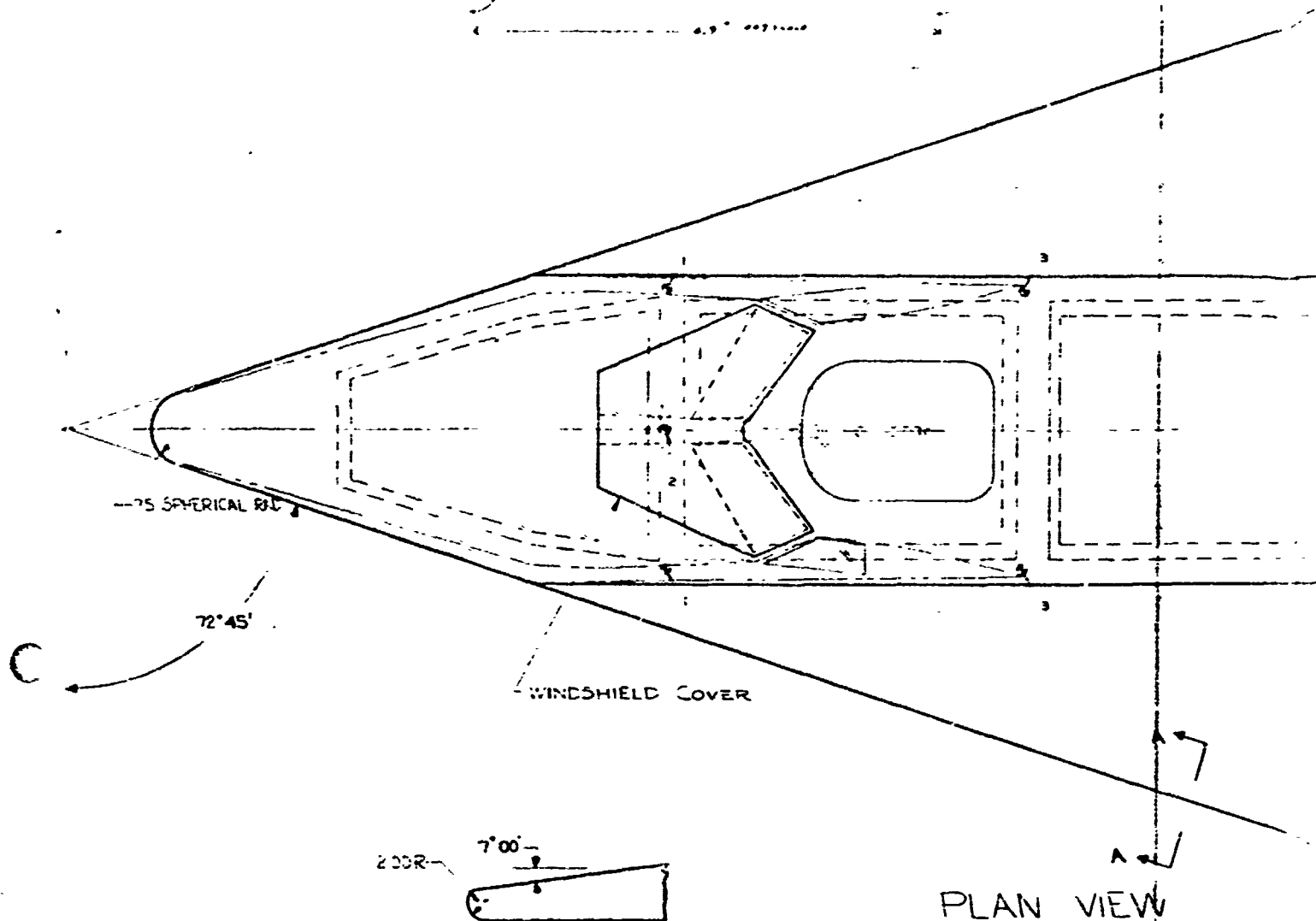
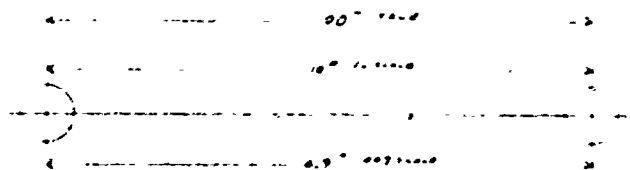


Figure 1



1. - E ADITUM 1.5 NG 24-CN



15.

3.2 WEIGHTS AND MOMENTS OF INERTIA

The design weights and moments of inertia for the glider vehicle are presented below.

For the glider alone (transition section off):

Weight = 9600 lbs.

Principal Moments of Inertia about C.G.:

$$I_y = 12,600 \text{ slugs} - \text{ft}^2 \text{ (pitch)}$$

$$I_x = 4,000 \text{ slugs} - \text{ft}^2 \text{ (roll)}$$

$$I_z = 21,000 \text{ slugs} - \text{ft}^2 \text{ (yaw)}$$

The x principal axis is assumed parallel to glider water lines.

For the 9600 lb. glider plus the third stage, Figure 3.2.1 gives the moments of inertia during third stage burning, and the weights and the center of gravity locations at beginning and end of third stage burning.

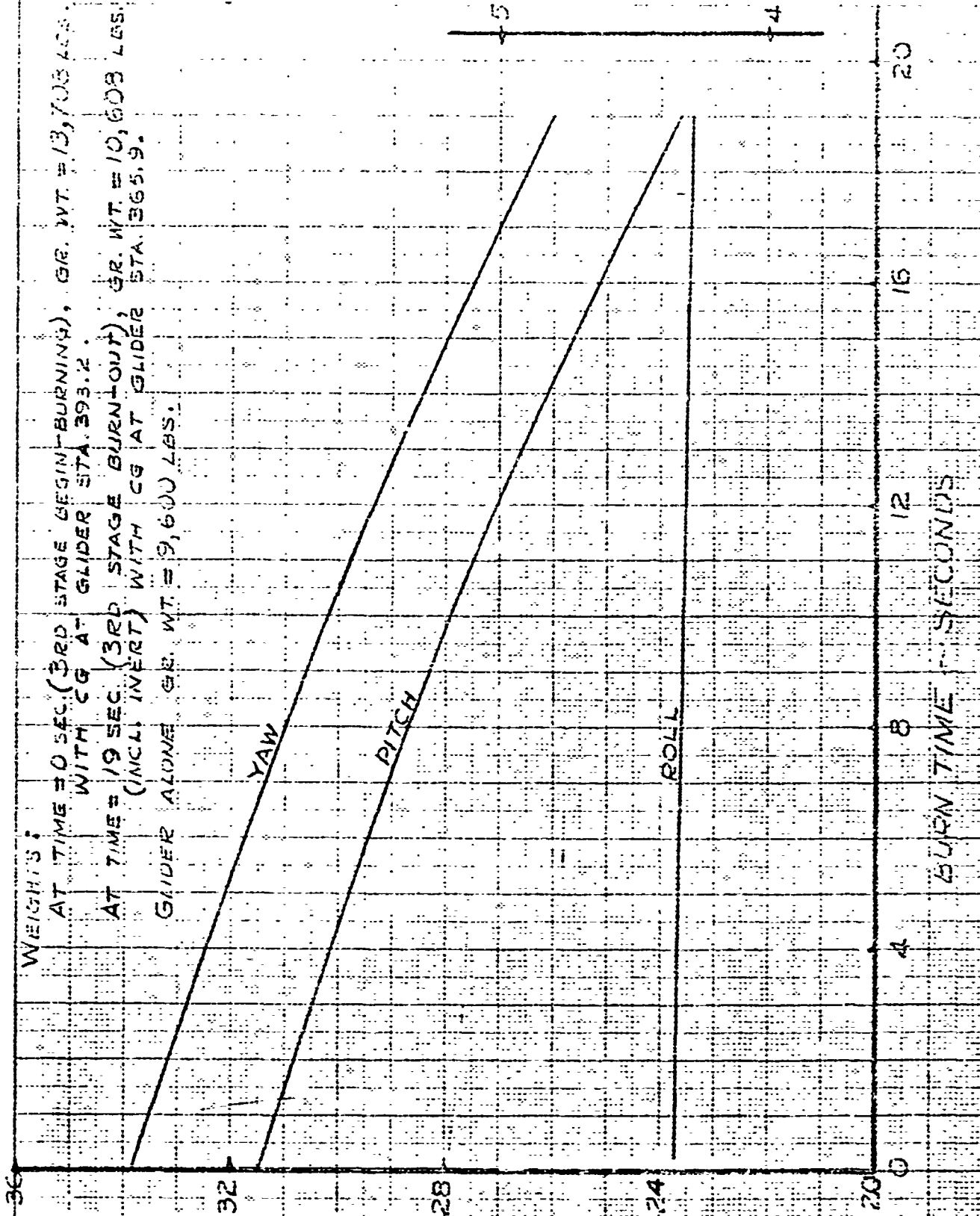
The center of gravity location for the glider alone is shown on Figure 3.3.3.

WEIGHTS:

AT TIME = 0 SEC. (3RD STAGE BEGIN-BURNING), GR. WT. = 13,703 LBS.
WITH CG AT GLIDER STA. 393.2.

AT TIME = 19 SEC. (3RD STAGE BURN-OUT), GR. WT. = 10,608 LBS.
(INCL. INERT) WITH CG AT GLIDER STA. 365.9.

GLIDER ALONE GR. WT. = 9,600 LBS.



PITCH & YAW MOMENTS OF INERTIA - SLUG-FT2

Fig. 5.2.2

REDAWN H.A.C. 12-23-5

12-25

MASS DATA FOR 9600 LB GLIDER AND THIRD STAGE

844-2035

D2-3174

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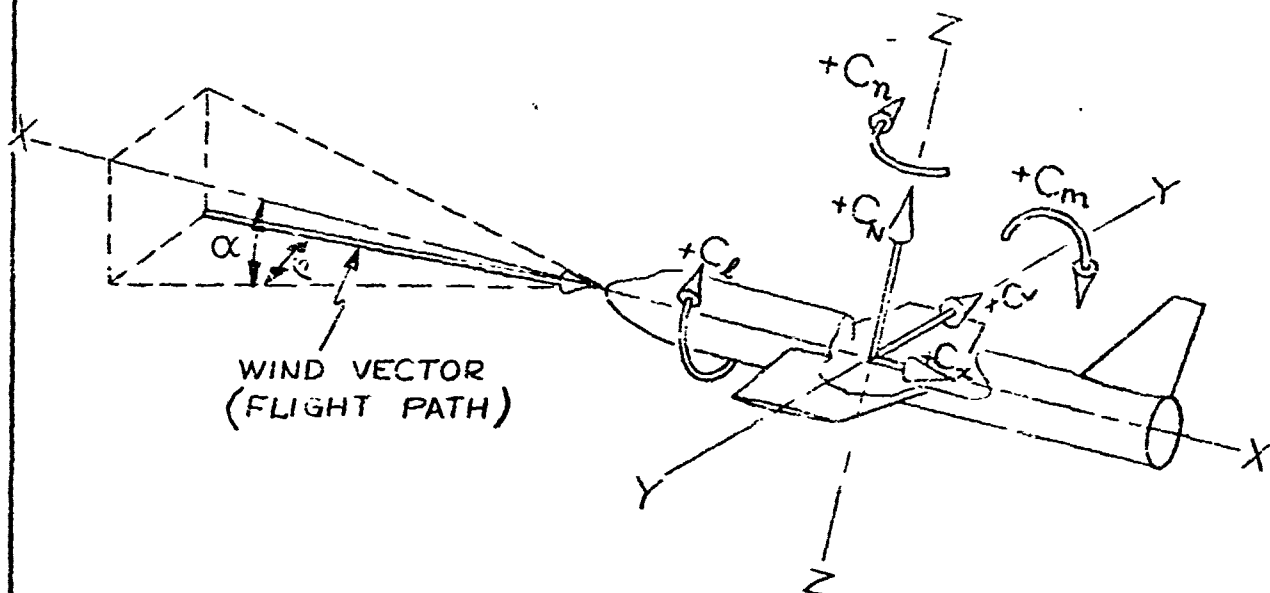
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3.3

AERODYNAMIC DATA AND REFERENCE CONSTANTS

Aerodynamic data in the document are presented on a fixed body axis system. The axis system is shown on Figure 3.3.1. Definition of angle of attack and sideslip and the sign convention for the force and moment coefficients are also shown. The sign conventions for control deflections are shown on Figure 3.3.2.

Reference constants and glider alone center of gravity location are shown on Figure 3.3.3. Some significant aerodynamic configuration constants are also presented.



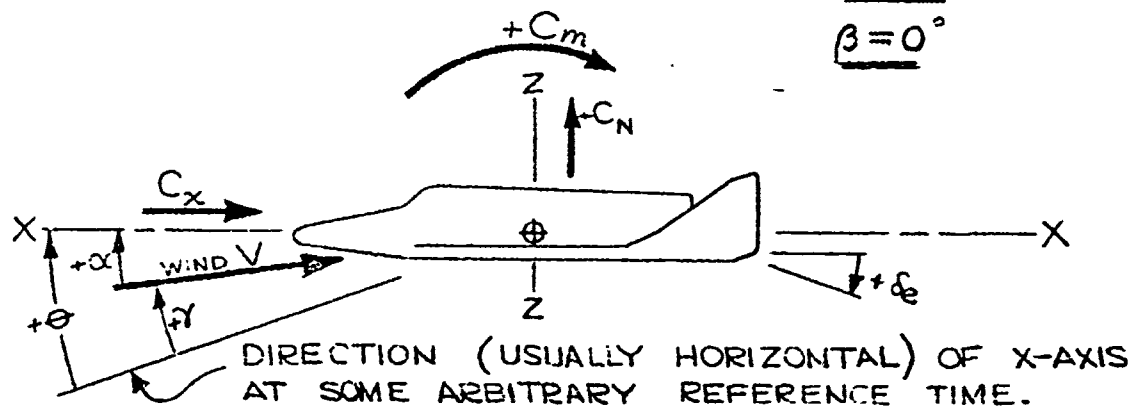
NOTES:

- 1.) THE MUTUALLY PERPENDICULAR X, Y, AND Z AXES ARE FIXED ON THE AIRPLANE, REGARDLESS OF FLIGHT ATTITUDE.
- 2.) ANGLE OF ATTACK IS MEASURED IN THE AIRPLANE PLANE OF SYMMETRY (X-Z PLANE), BETWEEN THE AIRPLANE X-AXIS AND THE PROJECTION OF THE WIND VECTOR INTO THE X-Z PLANE.
- 3.) ANGLE OF SIDESLIP IS MEASURED IN OR PARALLEL TO THE PLANE DEFINED BY THE AIRPLANE Y-AXIS AND THE WIND VECTOR, BETWEEN THE WIND VECTOR AND THE PROJECTION OF THE AIRPLANE X-AXIS INTO THE ABOVE-DEFINED PLANE.
- 4.) FOR THE DYNA SOAR 844-2035 CONFIGURATION, THE X-Y PLANE IS PARALLEL TO THE FLAT, AFT PART OF THE WING UNDERSURFACE.

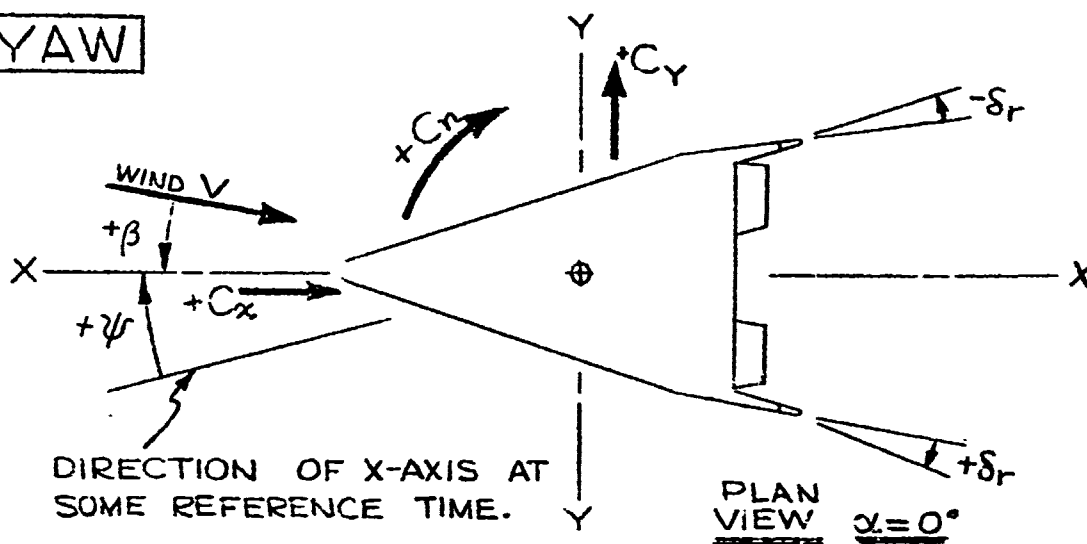
FIG 3.3.1

CMC		REVISED	DATE	BODY AXIS SYSTEM	844-2035
CHECK				NOMENCLATURE - COMBINED	
APR				ANGLE OF ATTACK & SIDESLIP	D2-8174
APR				BOEING AIRPLANE COMPANY	AGE 3.6
NEW M. CARTER 12-23-0					

PITCH



YAW



ROLL

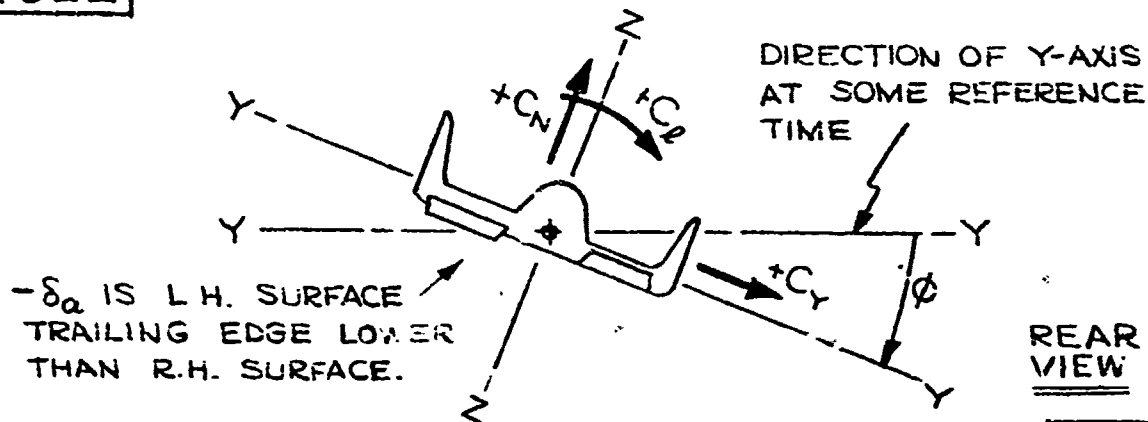


FIG. 33.2

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BODY AXIS SYSTEM ~ NOMENCLATURE

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25

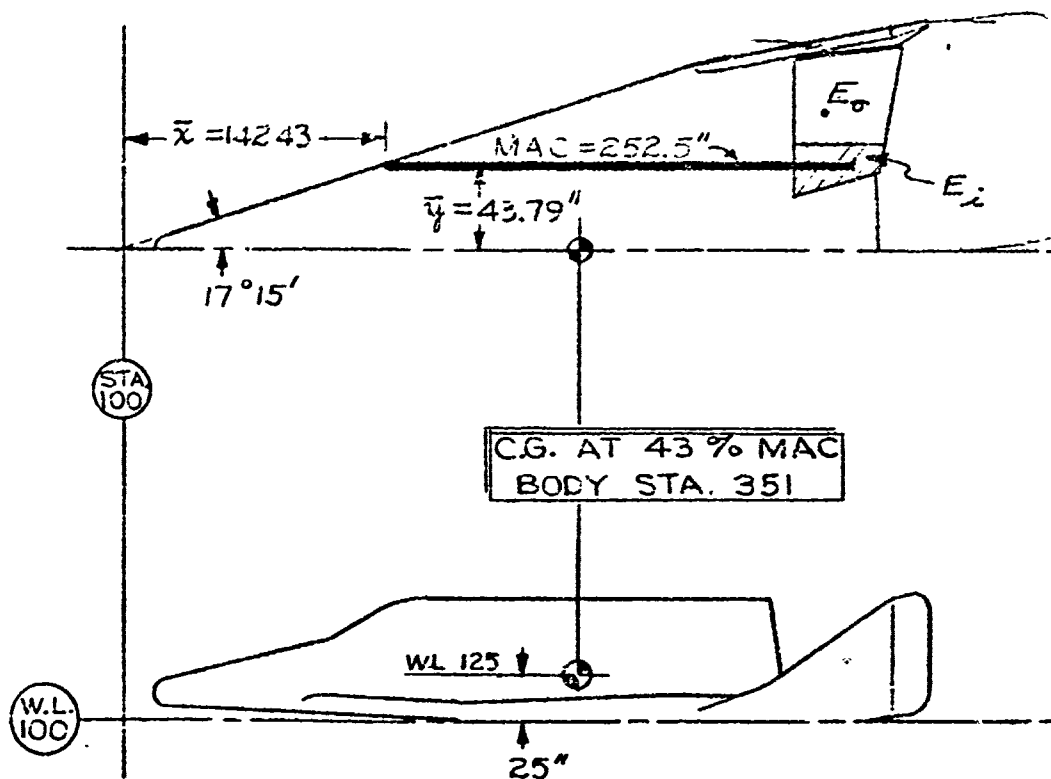
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DWN M. CETER 12-27-60.

14-18820-1 WAF 10-17-65

2-7000

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AERODYNAMIC REFERENCE CONSTANTS :

WING AREA, $S_W = 343.24 \text{ FT.}^2$
 EFFECTIVE SPAN, $b = 236.7 \text{ IN.}$
 ASPECT RATIO, $R = 1.13$
 ROOT CHORD, $C_R = 406.1 \text{ IN.}$
 TIP CHORD, $C_T = 107.8 \text{ IN.}$
 $\lambda = C_T / C_R = .265$

ELEVONS :

FULL ELEVON AREA, $S_E = .14 S_W$
 INBOARD PORTION AREA, $E_i = .047 S_W$
 OUTBOARD PORTION AREA, $E_o = .093 S_W$

FIG. 3.33

CHECK		REVISED	DATE	AERODYNAMIC REFERENCE CONSTANTS & PERTINENT DIMENSIONS	844-2035
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APL					
DAN M. CARTER 20350					
				BOEING AIRPLANE COMPANY	26
					PAGE 3.8

4.0

DEFINITION OF SYMBOLSSymbolDefinition

a.c.	aerodynamic center
AR	aspect ratio
b	wing span
B.S.	body station
$\bar{c}$, m.a.c. or M.A.C.	mean aerodynamic chord
c_e	eleven chord
c.g. or C.G.	center of gravity
c_r	wing root chord
c_t	wing tip chord
HM	hinge moment
i_t	incidence angle of wing tip extensions
I_x	moment of inertia in roll
I_y	moment of inertia in pitch
I_z	moment of inertia in yaw
l	rolling moment
L	lift force
m	pitching moment
M	Mach number or pitching moment
n	yawing moment
N	normal force
P	roll rate
q	pitch rate or dynamic pressure in PSF
r	yaw rate

S_e or S_E	elevon area
S_r or S_R	rudder area
S_t	wing tip extension area
S_w	wing area
V	velocity
X	force along X (roll) axis
Y	force along Y (pitch) axis
α	angle of attack
α_{OL}	angle of attack at zero lift
β	angle of sideslip
δ_a	aileron deflection angle
δ_{eL}	left elevon deflection angle
δ_{eR}	right elevon deflection angle
δ_e or δ_E	elevon deflection angle, elevons deflecting together
δ_R	rudder deflection angle
θ	pitch angle
ϕ	roll angle
ψ	yaw angle
λ	wing taper ratio $\frac{c_t}{c_r}$
C_l	rolling moment coefficient, $\frac{L}{q S_w c}$
C_{lp}	$= \partial C_l / \partial (pb/2V)$
C_{lr}	$= \partial C_l / \partial (rb/2V)$
$C_{l\beta}$	$= \partial C_l / \partial \beta$
$C_{l\dot{\beta}}$	$= \partial C_l / \partial (\dot{\beta} b/2V)$
$C_{l\delta_a}$	$= \partial C_l / \partial \delta_a$
$C_{l\delta_R}$	$= \partial C_l / \partial \delta_R$

C_L lift coefficient, $\frac{L}{q S_w}$ C_m pitching moment coefficient, $\frac{M}{q S_w \bar{c}}$ C_{m_0}

pitching moment coefficient at zero lift

 $C_{m\dot{\alpha}}$

$$= \partial C_m / \partial (\dot{\alpha} \bar{c} / 2V)$$

 $C_{m\alpha}$

$$= \partial C_m / \partial \alpha$$

 $C_{m\dot{\alpha}}$

$$= \partial C_m / \partial (\dot{\alpha} \bar{c} / 2V)$$

 $C_{m\delta_a}$

$$= \partial C_m / \partial \delta_a$$

 $C_{m\delta_e}$

$$= \partial C_m / \partial \delta_e$$

 C_n yawing moment coefficient, $\frac{N}{q S_w b}$ C_{np}

$$= \partial C_n / \partial (p b / 2V)$$

 C_{nr}

$$= \partial C_n / \partial (r b / 2V)$$

 $C_{n\delta_a}$

$$= \partial C_n / \partial \delta_a$$

 $C_{n\delta_r}$

$$= \partial C_n / \partial \delta_r$$

 $C_{n\beta}$

$$= \partial C_n / \partial \beta$$

 $C_{n\dot{\beta}}$

$$= \partial C_n / \partial (\dot{\beta} b / 2V)$$

 C_N normal force coefficient, $\frac{N}{q S_w}$ $C_{N\alpha}$

$$= \partial C_N / \partial \alpha$$

 $C_{N\dot{\alpha}}$

$$= \partial C_N / \partial (\dot{\alpha} \bar{c} / 2V)$$

 $C_{N\delta_a}$

$$= \partial C_N / \partial \delta_a$$

 $C_{N\delta_e}$

$$= \partial C_N / \partial \delta_e$$

 C_{Nq}

$$= \partial C_N / \partial (q \bar{c} / 2V)$$

 C_x axial force coefficient, $\frac{X}{q S_w}$ C_y side force coefficient, $Y / q S_w$ $C_{y\beta}$

$$= \partial C_y / \partial \beta$$

 $C_{y\dot{\beta}}$

$$= \partial C_y / \partial (\dot{\beta} b / 2V)$$

$C_{y_{\delta a}}$

$$= \partial C_Y / \partial \delta a$$

$C_{y_{\delta r}}$

$$= \partial C_Y / \partial \delta r$$

C_{y_p}

$$= \partial C_Y / \partial (p b / 2V)$$

C_{y_r}

$$= \partial C_Y / \partial (r b / 2V)$$

C_h

$$\text{hinge moment coefficient, } \frac{HM}{q S_e C_e}$$

C_{h_α}

$$= \partial C_h / \partial \alpha$$

$C_{h_{\delta e}}$

$$= \partial C_h / \partial \delta e$$

5.0 LONGITUDINAL STABILITY AND CONTROL (GLIDER)

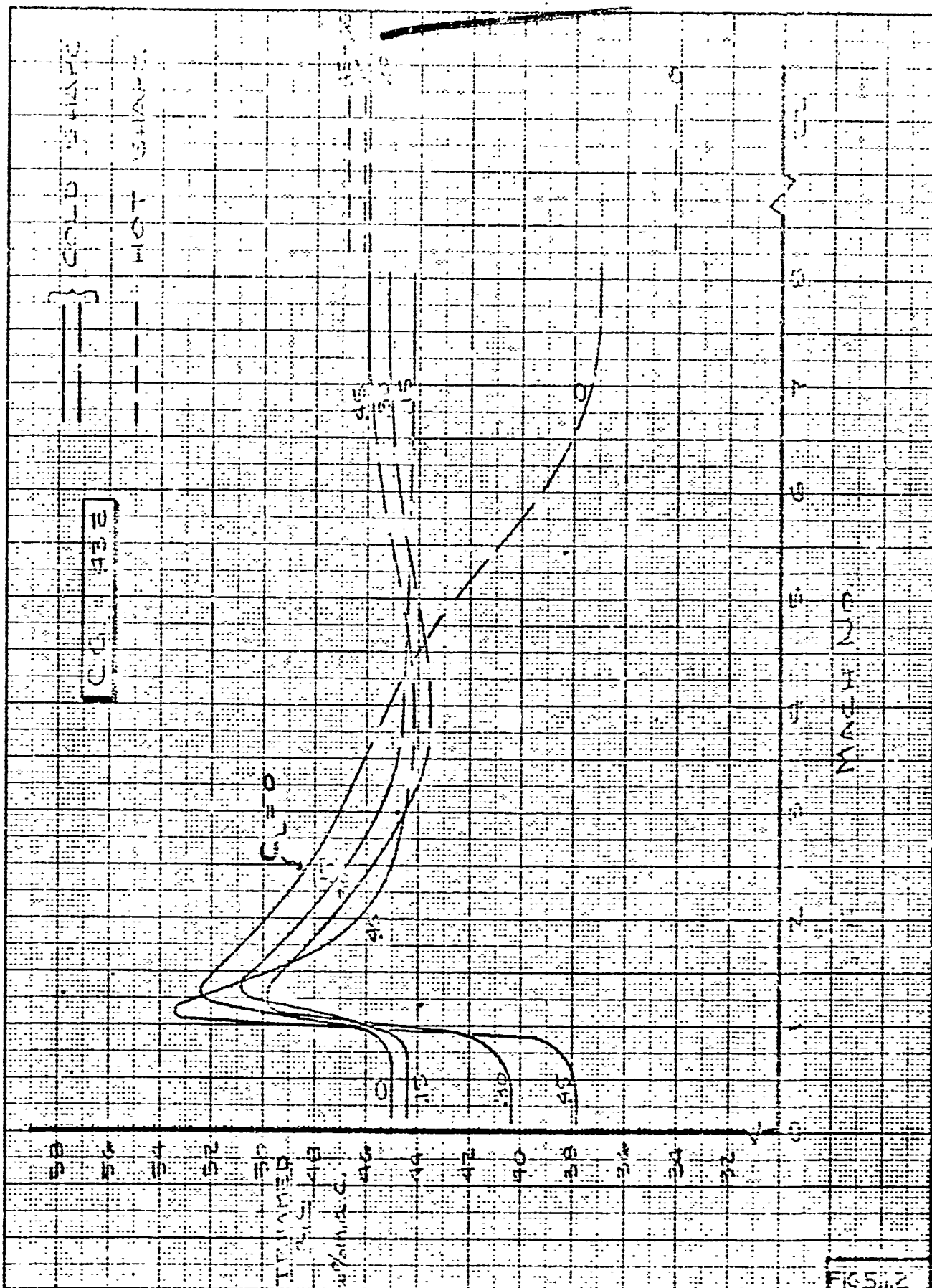
5.1 SUMMARY

Longitudinal stability and control data are presented in the following sections for the 344-2035 glider configuration. Data are presented through the speed range of the glider. The elevator configuration of the glider has been modified from the 344-2035 such that the inboard panel has no wedging (same section as the outboard panel) for the data to be presented.

The glider aerodynamic configuration varies as a function of speed. At subsonic and supersonic speeds, wing tip extensions, located on the outboard surface of the vertical tails, are extended for increased stability. At hypersonic speeds, the glider is subjected to high temperatures resulting in structural deformation. Data are presented for these changes of configuration.

Normal force, axial force and pitching moment coefficients comprise the data presented in the following sections. The data are presented at the nominal center of gravity position of 43% of the M.A.C. and a vertical c.g. location at water line 125.

Summary curves of these coefficient data are presented on Figures 5.1.1 through 5.1.7. Trimmed aerodynamic center as a function of Mach number and trimmed lift coefficient is presented on Figures 5.1.1 and 5.1.2. Normal force curve slope, at trimmed elevator deflection for a given C_L , is presented on Figures 5.1.6 and 5.1.7. A minor amount of fairing was required to produce these curves from the basic data to be presented, except at $M=0.7$. The data at $M=0.7$ produce appreciable discontinuities in the curves and have been faired out of the summary data.



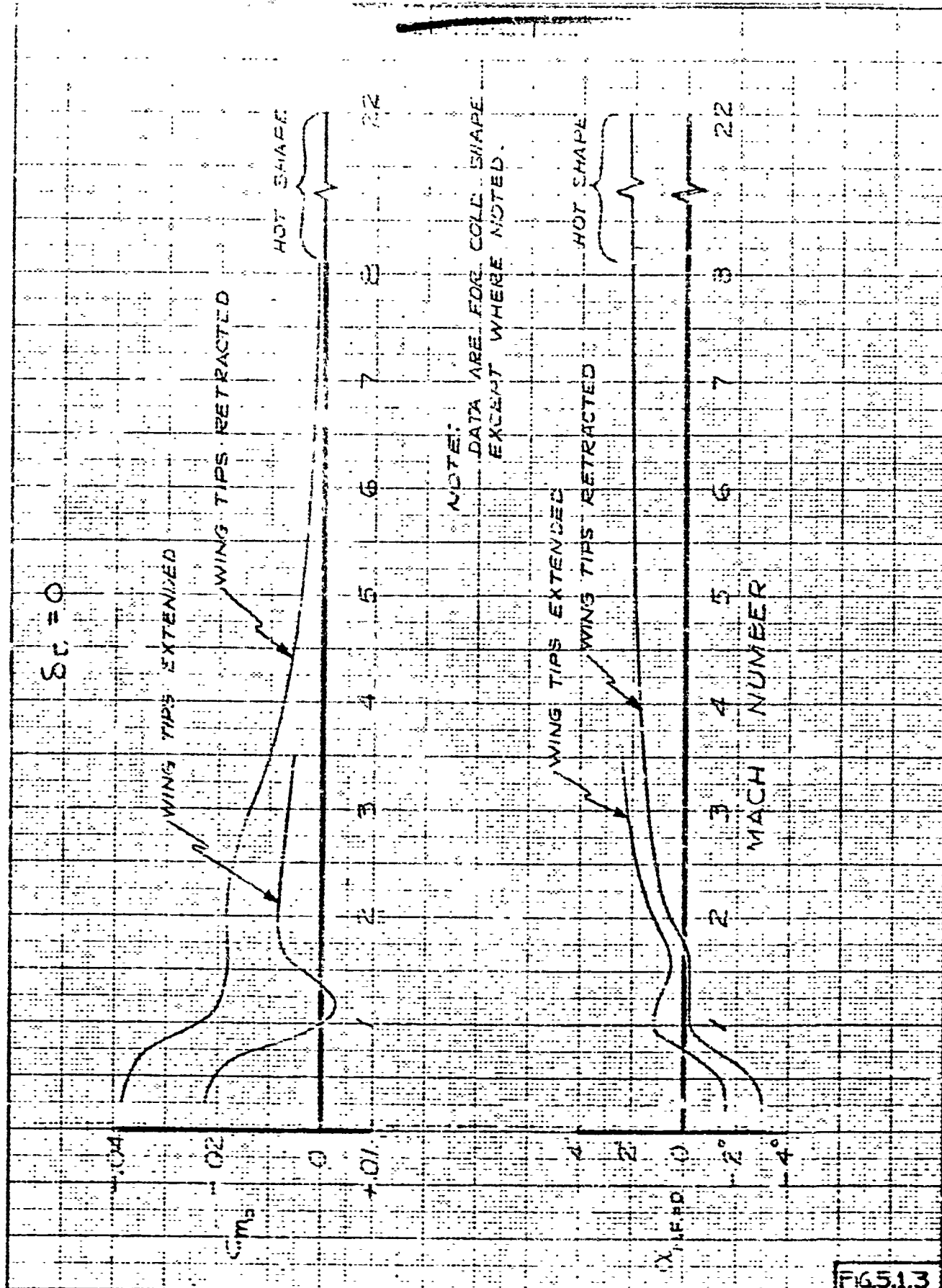
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AERODYNAMIC CENTER
WING TIPS RETRACTED

BOEING AIRPLANE COMPANY

33

FIG 5.2
844-2035
D2-8174
PAGE
5.3



M. CARTER 12-16-60 REVISED DATE

ANGLE OF ATTACK
AND PITCHING MOMENT
AT ZERO NORMAL FORCE

BOEING AIRPLANE COMPANY

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FIG. 5.13

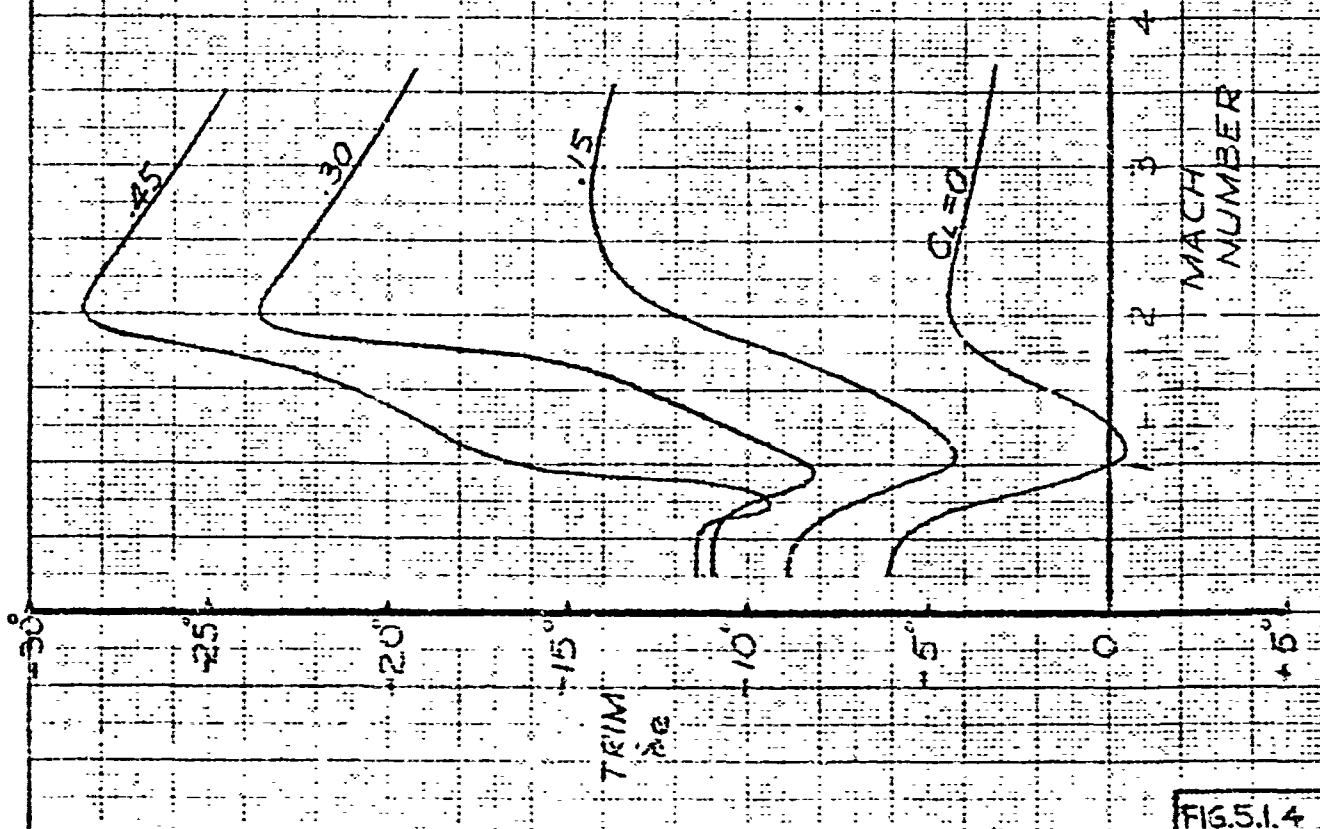
544-2035

D2-8174

PAGE 4

C.G. AT 43% M.A.C.

$S_{\text{ref}} = 14$



M. CARTER 12-16-60

ELEVATOR REQUIRED TO
TRIM - WING TIPS
EXTENDED

BOEING AIRPLANE COMPANY

35

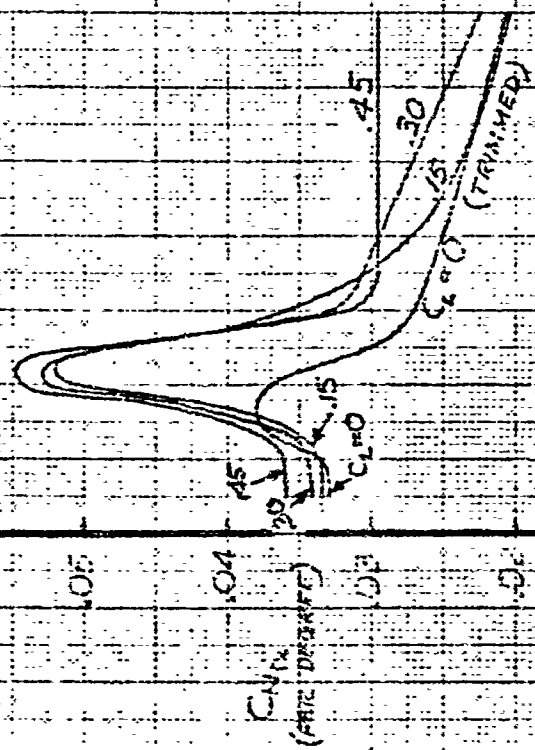
FIG. 5.1.4

844-2035

D2-8174

PAGE 55

C.G. = 43% MAC



MAC 4011 C 81

M. CARTER 1221-0 NORMAL FORCE CURVE SLOPE WING TIPS EXTENDED

FIG. 516

844-2035

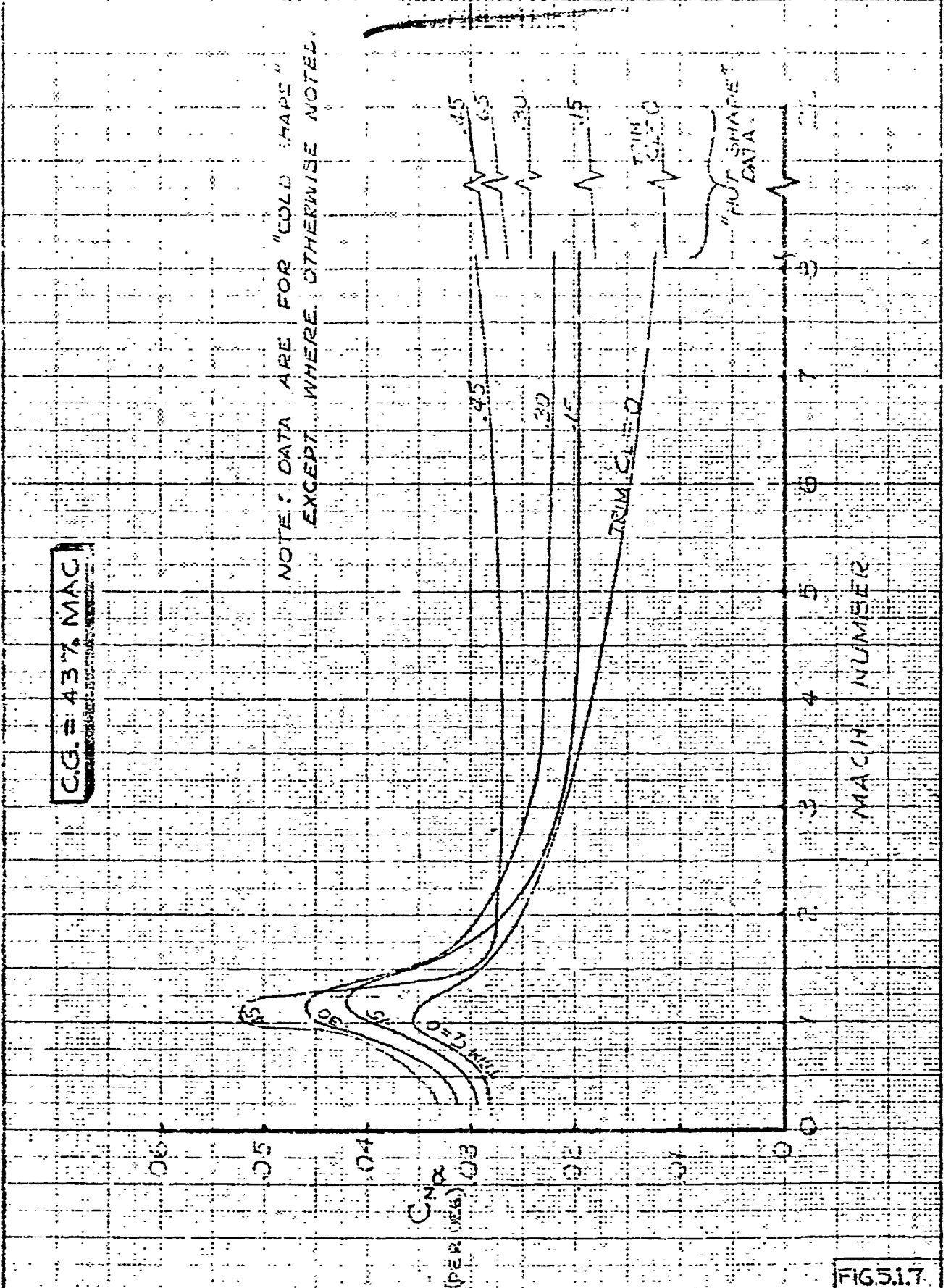
D2-8174

BOEING AIRPLANE COMPANY

37 PAGE 5.7

C.G. = 43% MAC

NOTE: DATA ARE FOR "COLD SHAPE" EXCEPT WHERE OTHERWISE NOTED.



M. CARVER 12-20-0

NORMAL FORCE CURVE SLOPE
WING TIPS RETRACTED

FIG. 51.7
844-2035
D2-8174

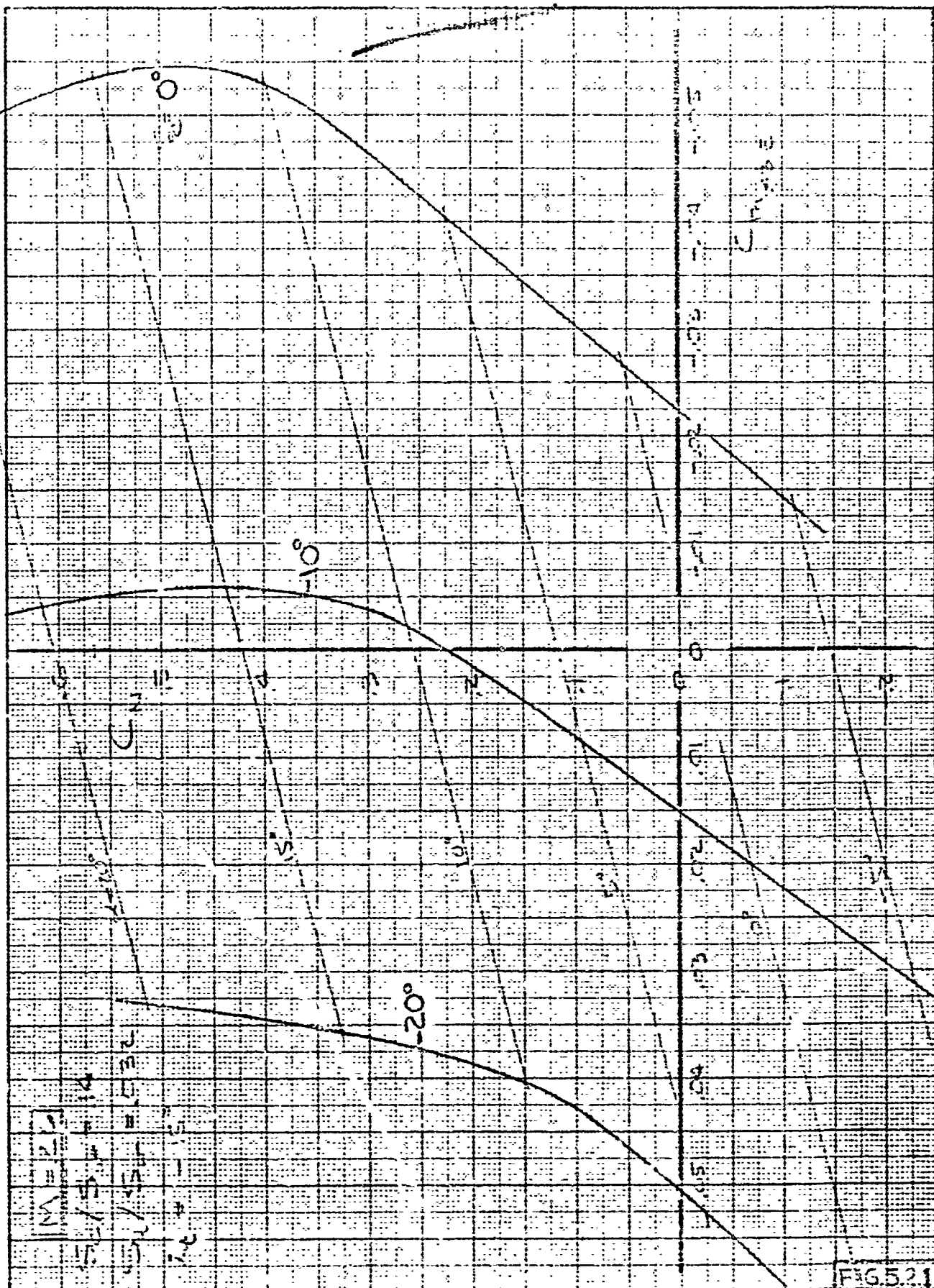
5.2

LANDING SPEED

Basic stability and elevon effectiveness plots are presented on Figures 5.2.1 and 5.2.2 for the glider at a Mach number typical of landing speed. These data were determined from wind tunnel tests performed in the A.R.C. 12-Foot Pressure Wind Tunnel and the Boeing Transonic Wind Tunnel on a .15 scale model of the 844-205 configuration. These data have been modified to the 844-2035 configuration as required.

The change in stability and control effectiveness with landing gear extended and in close proximity to the ground is shown on Figure 5.2.3. These data were determined from wind tunnel tests in the Boeing Transonic Wind Tunnel on a similar configuration and modified for the present configuration. The incremental effect of extending the landing gear is shown on Figure 5.2.4. It was assumed that proximity to the ground would have little effect on these increments.

Axial force coefficients as a function of angle of attack are shown on Figures 5.3.1 and 5.3.2 at $M = .26$ which is typical of landing. The axial force increment due to landing gear extension is shown on Figure 5.2.5. Axial force is assumed to be unaffected by the presence of the ground.



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LONGITUDINAL STABILITY
WING TIPS EXTENDED
M = 2.6

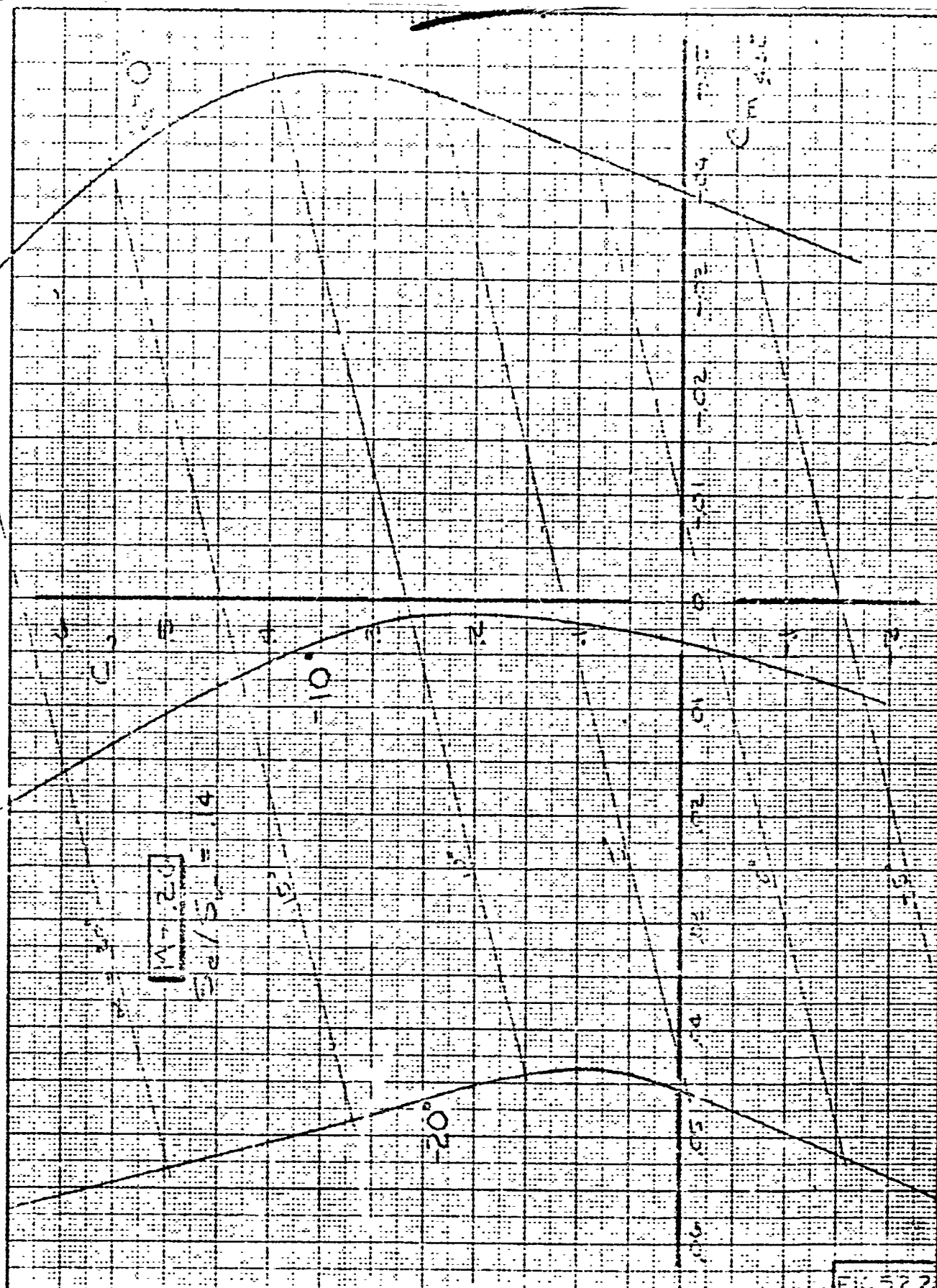
BOEING AIRPLANE COMPANY **40**

FIG. 5.2.1

844-2035

DZ-8174

PAGE 5.10

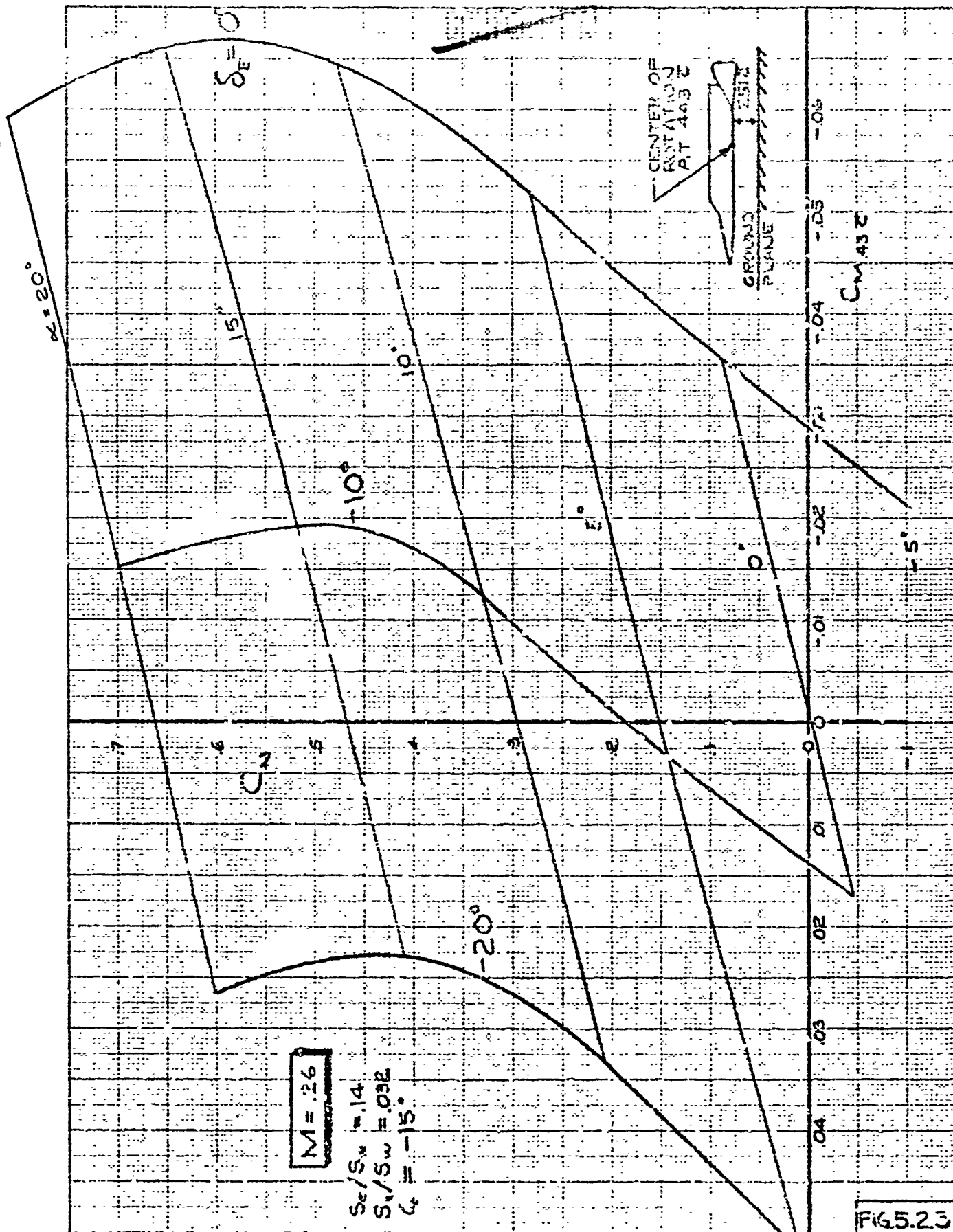


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LONGITUDINAL STABILITY
WING TIP RETRACTED
M = .26

BOEING AIRPLANE COMPANY **41**

FIG 5.2.2
644-2035
D2-8174
PAGE
5.11



$M = .26$

$S_e/S_w = .14$
 $S_e/S_w = .032$
 $\zeta = -15^\circ$

J.L. Francis 12/14/46

LONGITUDINAL STABILITY,
 WING TIPS & LANDING GEAR DOWN.
 IN PRESENCE OF GROUND PLANE

FIG 5.23

1844-2035

D2-8174

42

5.12

DATA BASED ON TWT 6.5

$M = 26$

$CG = 43\% MAC$

ΔC_N

-5

0

5

10

15

20

$\alpha - DEG$

ΔC_{MASS}

-5

0

5

10

15

20

$\alpha - DEG$

F65.2.4

844-2035

D2-8174

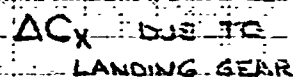
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EFFECT OF LANDING GEAR

BOEING AIRPLANE COMPANY

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PAGE 5.13



EFFECT OF LANDING GEAR ON CHORD FORCE

5.14

5.3

SUBSONIC - TRANSONIC SPEEDS

Basic stability and control effectiveness data are presented on Figures 53.1 through 53.10. Data are shown at Mach numbers of 0.5, 0.7, 0.9, 0.95, and 1.05 for both the wing tip extensions retracted and extended. The data are presented in this fashion and for the various Mach numbers due to the appreciable non-linearities of the aerodynamics. The data are based on results of wind tunnel tests in the Boeing Transonic Wind Tunnel and preliminary results of tests in the L.P.C. 16-Foot Transonic Wind Tunnel. Due to the preliminary nature of some of these data, some modification to the characteristics shown can be anticipated. The tunnel data were modified to the current configuration by empirical and theoretical analysis.

Data shown at $M=0.7$ show discontinuity with the other data as a function of Mach number as discussed in the summary. These trends of the $M=0.7$ data were corroborated to some degree by the two tunnel tests mentioned. Further testing will be done to define these data better.

Axial force data as function of angle of attack are shown on Figure 53.11 for the glider with wing tips extended and on Figure 53.12 for wing tips retracted. These data are for the glider in trimmed flight.

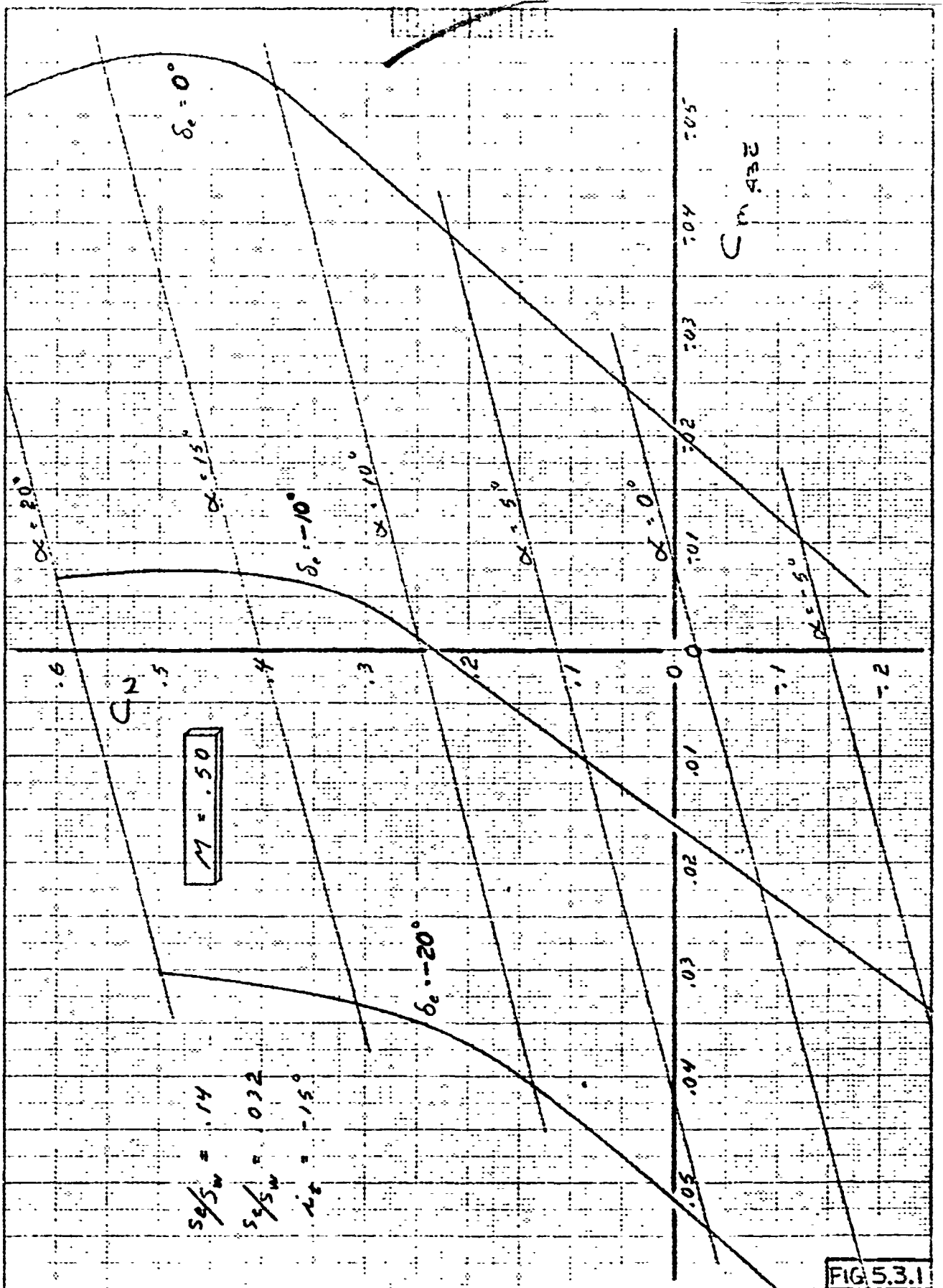


FIG 5.3.1

844-2035

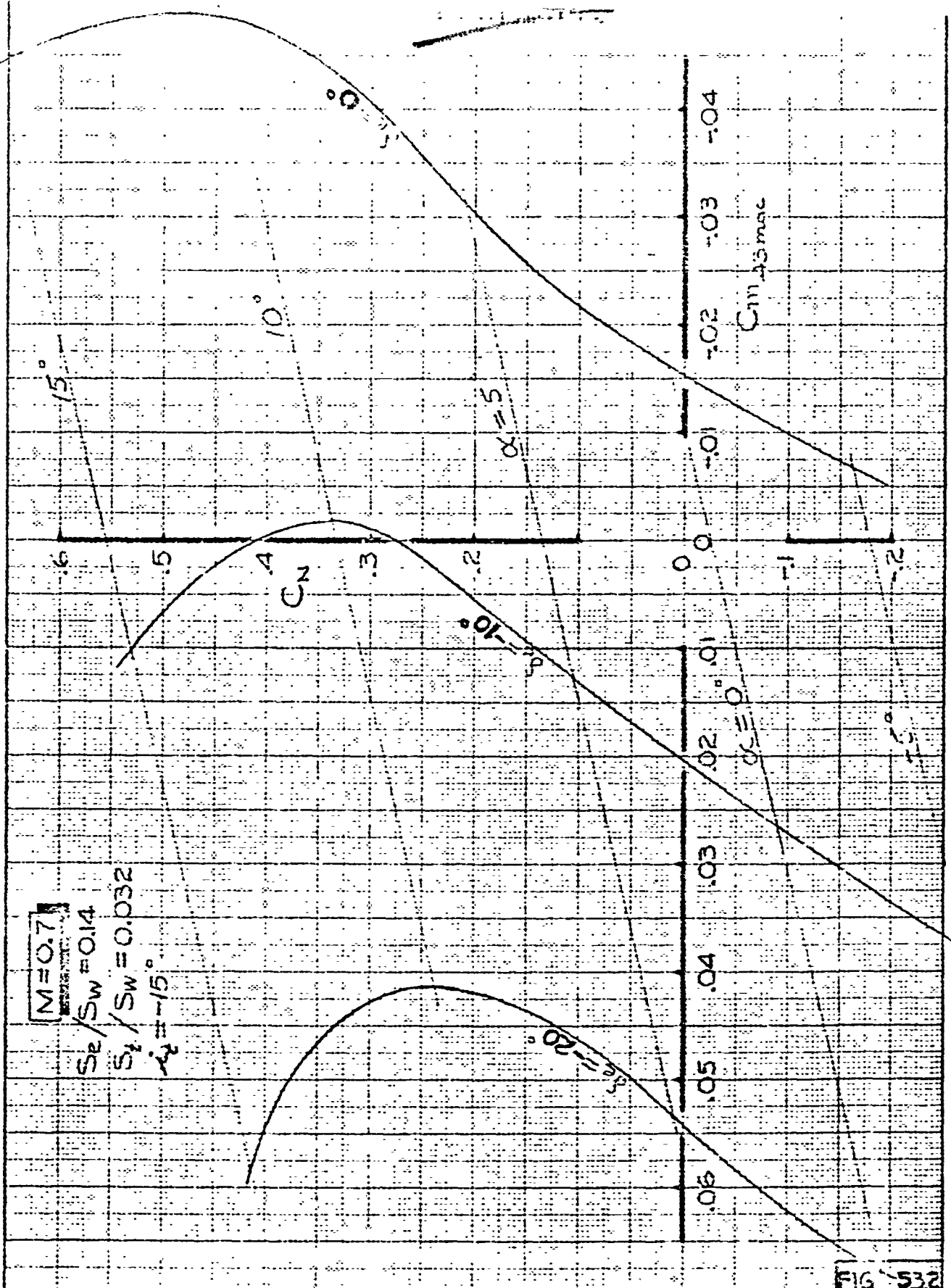
D2-8174

FIG 5.6

DCL 12-9-60
B/C
DWV. PW

LONGITUDINAL STABILITY
WING TIPS EXTENDED
 $M = .50$

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18-114-100

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CHECK				WING TIPS EXTENDED
APP				M = 0.7
ACW				

FIG 532
844-2035
D2-8174
PAGE 517

$$M=0.9$$

$$S_c/S_{c0}=0.14$$

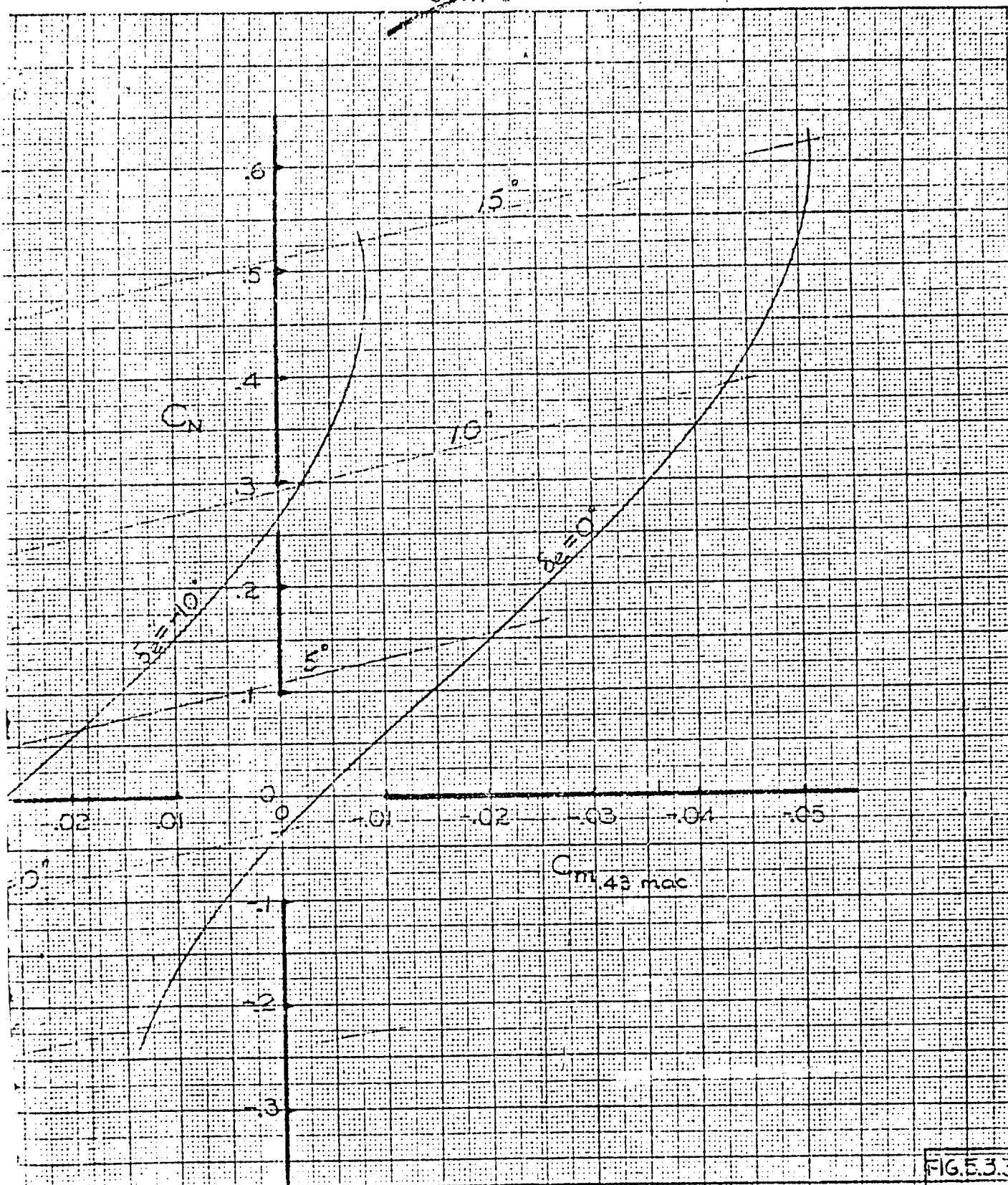
$$S_r/S_w=0.032$$

$$\alpha = -15^\circ$$

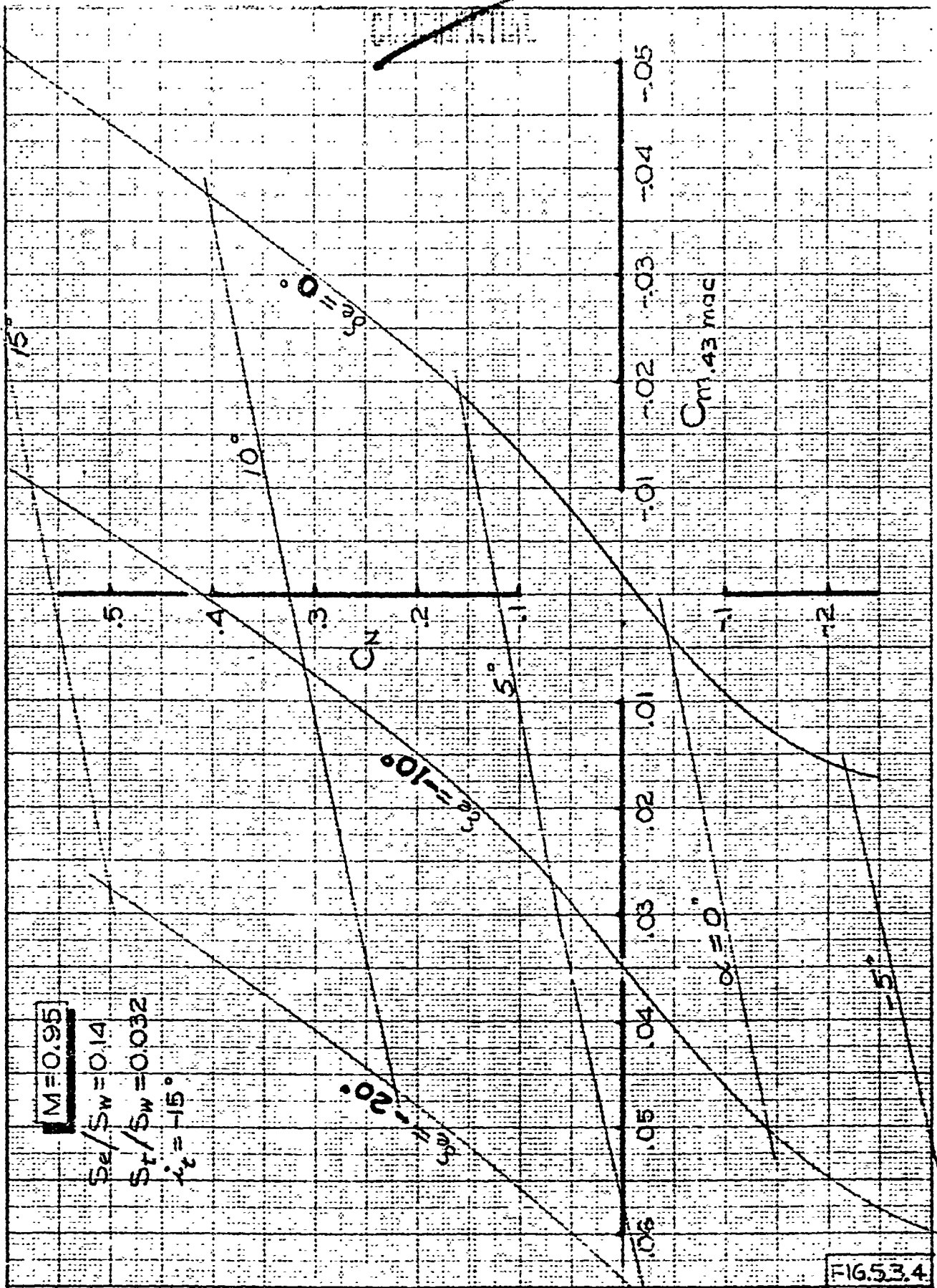
.09 .08 .07 .06 .05 .04

$C_{m, \text{mac}}$

$\alpha =$



DESIGNED BY	ANALYST	REVISION	DATE	LONGITUDINAL STABILITY	FIG. E.3.3
APPROVED BY	APPROVED BY			WING TIPS EXTENDED	844-2035
				M=0.9	D2-8174
					PAGE
					5.18



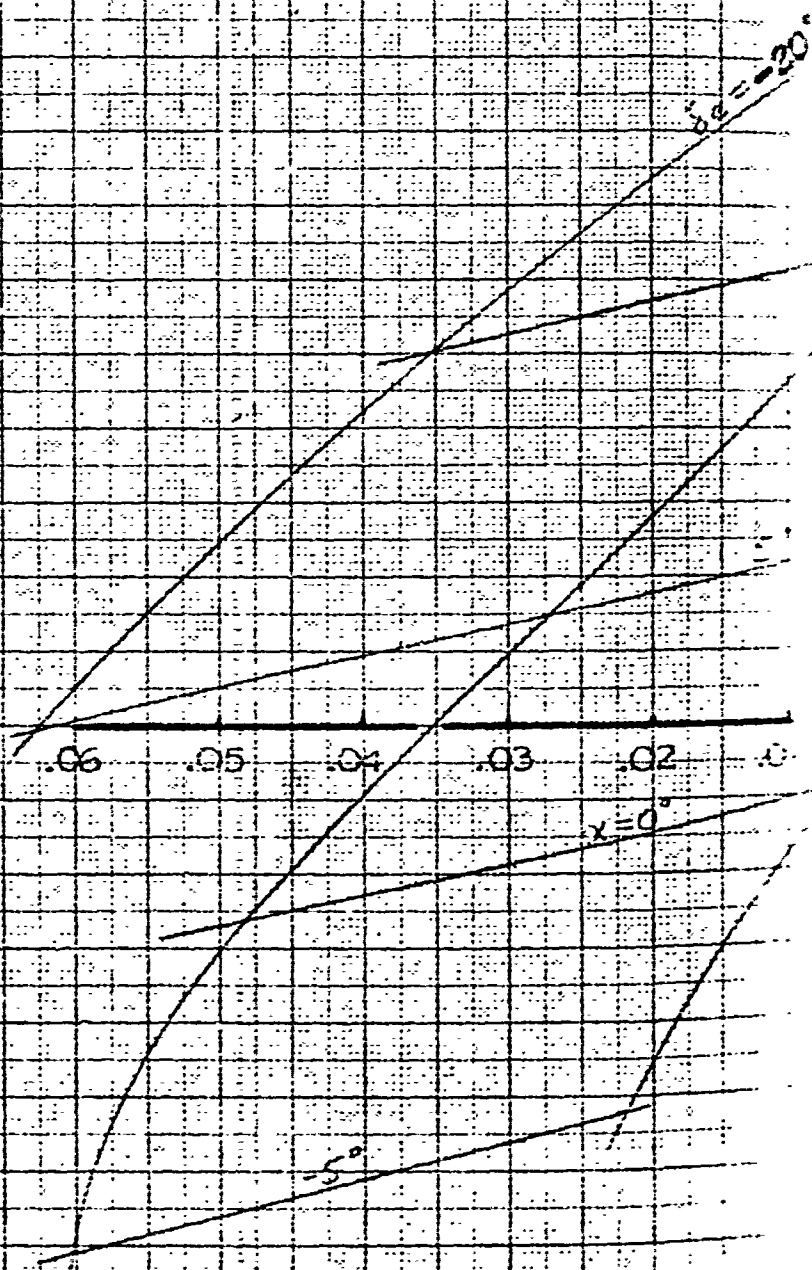
CAL. M. CARTER 12-12-60 CHECK APR APR	REVISED DATE LONGITUDINAL STABILITY WING TIPS EXTENDED M = .95 BOEING AIRPLANE COMPANY 50	FIG. 53.4 844-2035 D2-8174 PAGE 5.19
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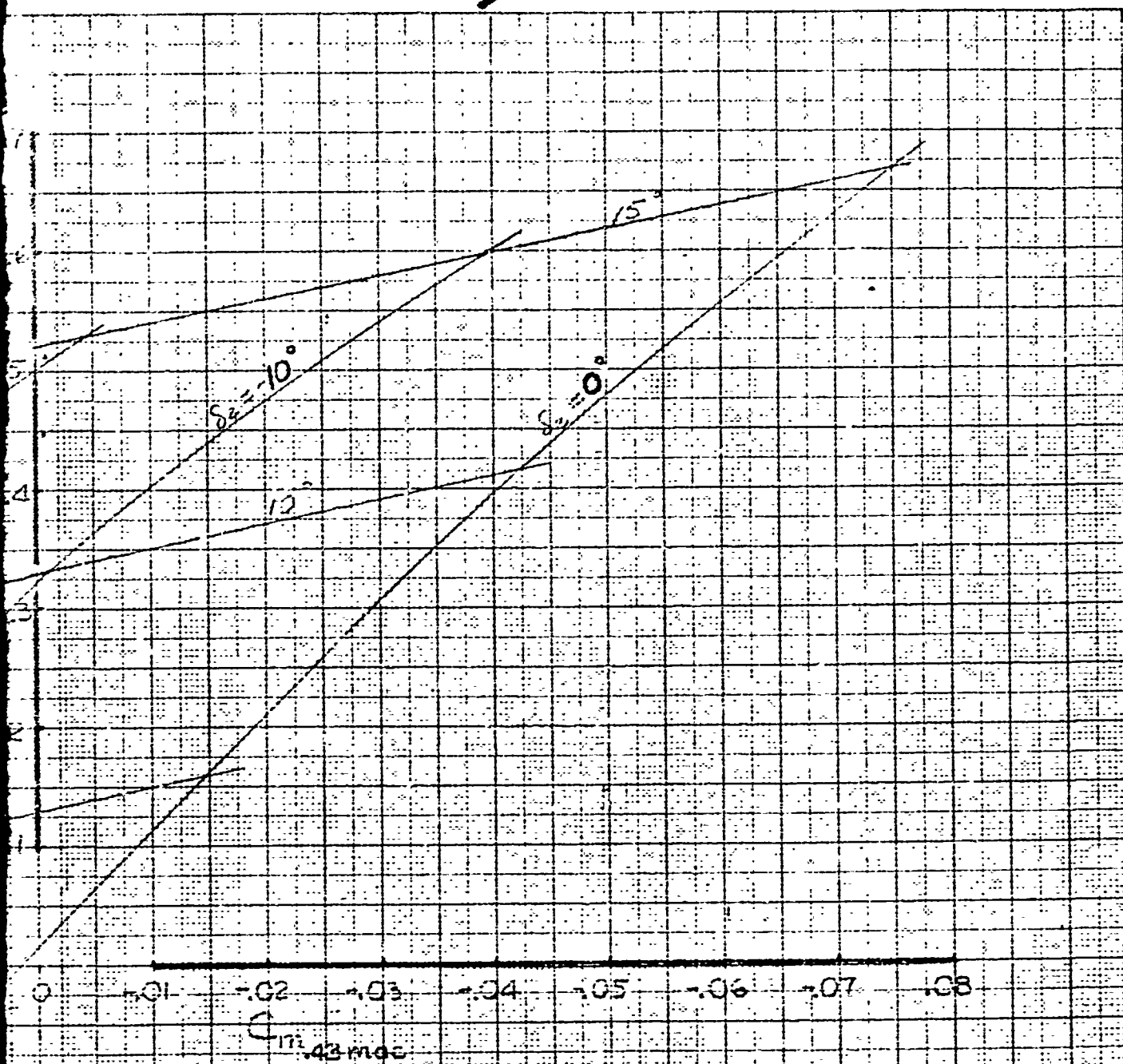
$$M = 1.05$$

$$S_b/S_{b_0} = 0.14$$

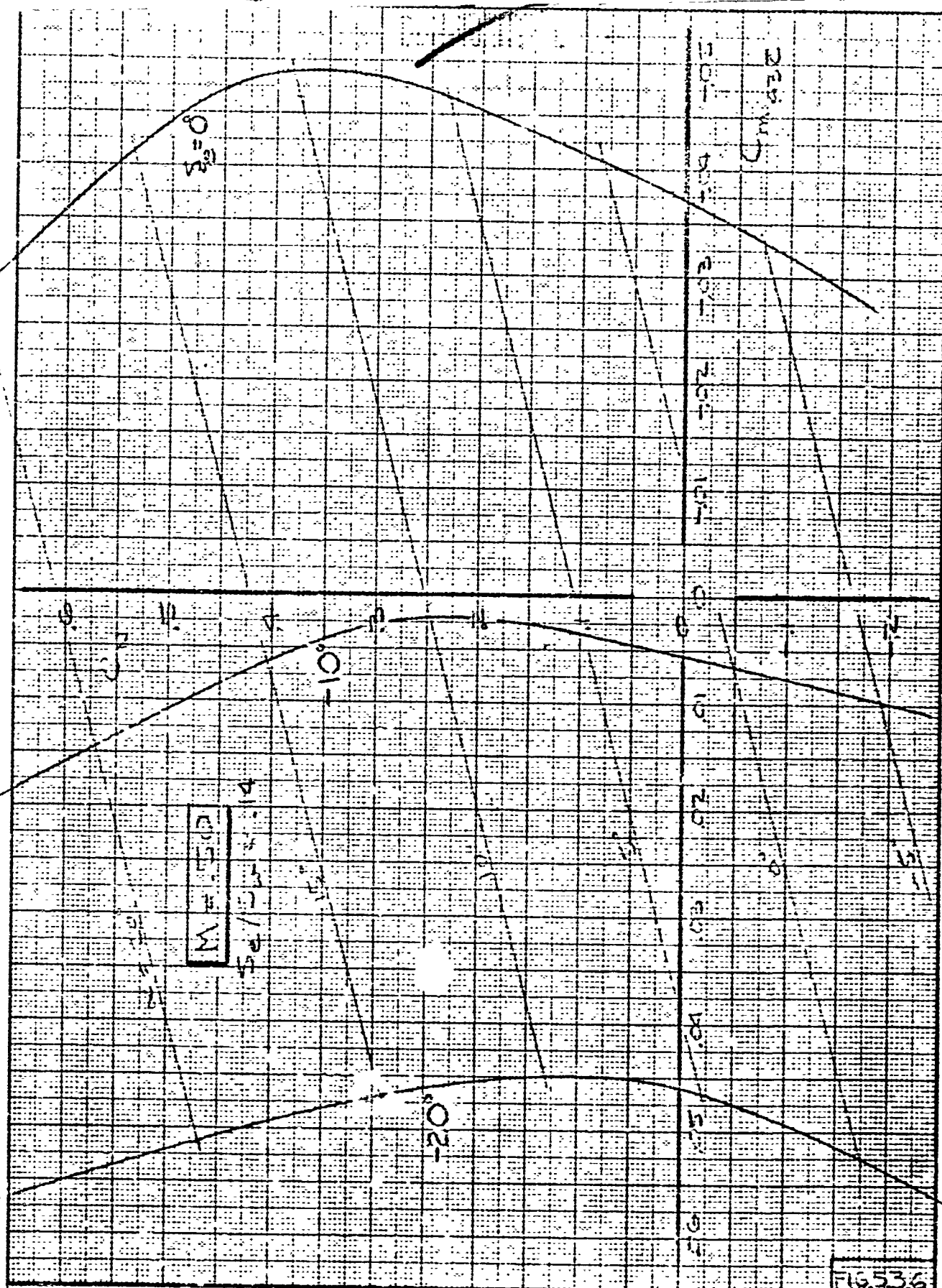
$$S_t/S_{t_0} = 0.032$$

$$\alpha_t = -15^\circ$$





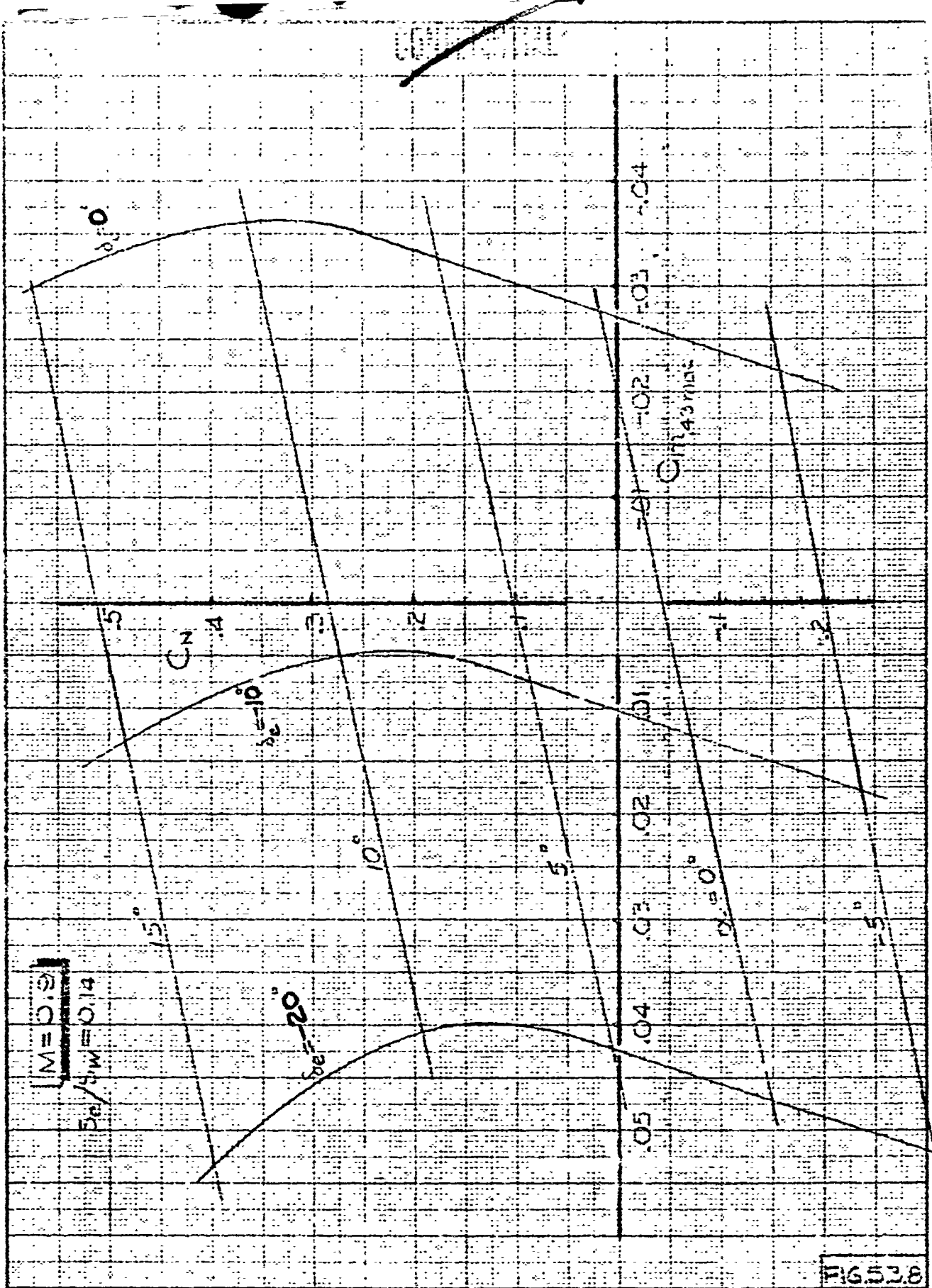
CALC	M. Cant.	12.9.60	REVISED	DATE	LONGITUDINAL STABILITY	FIG 535
CHECK					WING TIPS EXTENDED	244-2035
APPRO					ME=1.05	D2-8174
APPRO						PAGE 520



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LONGITUDINAL STABILITY
WING TIPS RETRACTED
 $M = .5$
BOEING AIRPLANE COMPANY

FIG. 53.6
844-2035
D2-8174
PAGE 521



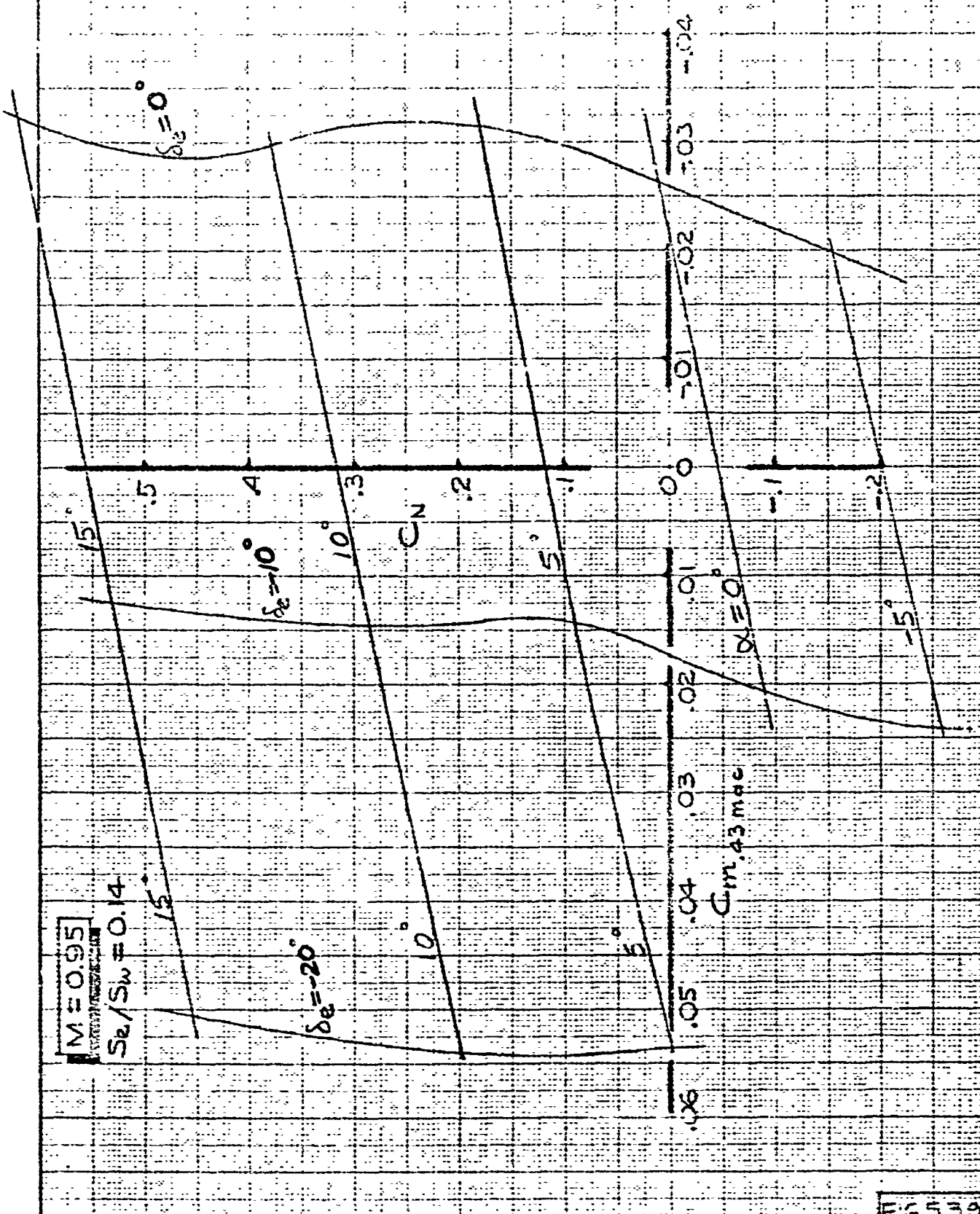
$M = 0.9$
 $S_{ref}/S_w = 0.14$

FIG 538
 844-2035
 02-8174
 PAGE 5.23

BY M. CARTER 12-7-60
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 APPROVED
 APPROVED

LONGITUDINAL STABILITY
 WING TIPS RETRACTED, $M = 0.9$

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$M = 0.95$

$S_e/S_w = 0.14$

REVISED

BY	M. CARTER	12-9-60	REVISED	DATE
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APP				

LONGITUDINAL STABILITY WING TIPS RETRACTED, $M = .95$

BOEING AIRPLANE COMPANY 56

FIG 5.39
244-2035
02-6174
PAGE 5.24

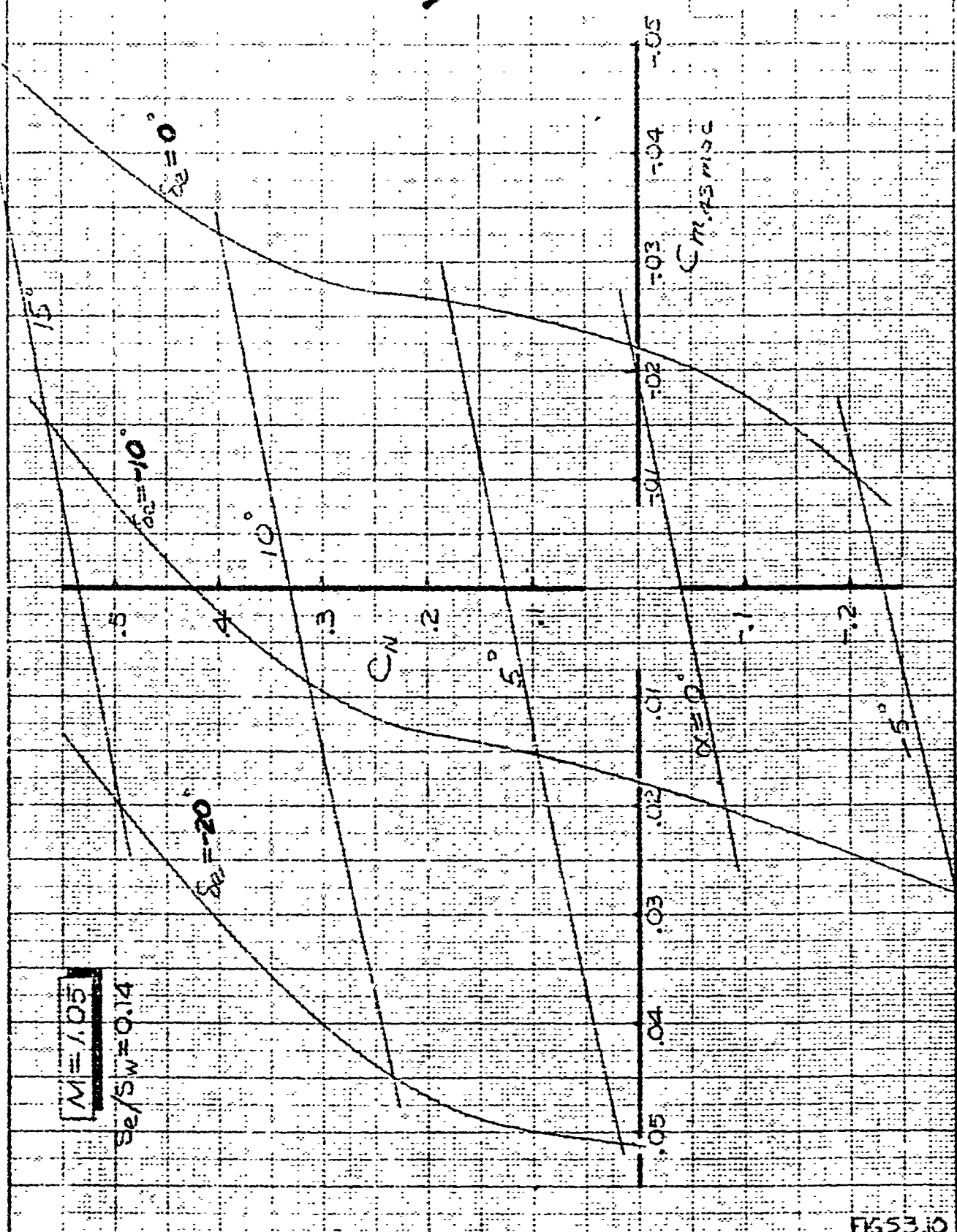


FIG 53.10

GLIDER AIRCRAFT
C.G. 43% MAC

MODEL 2035

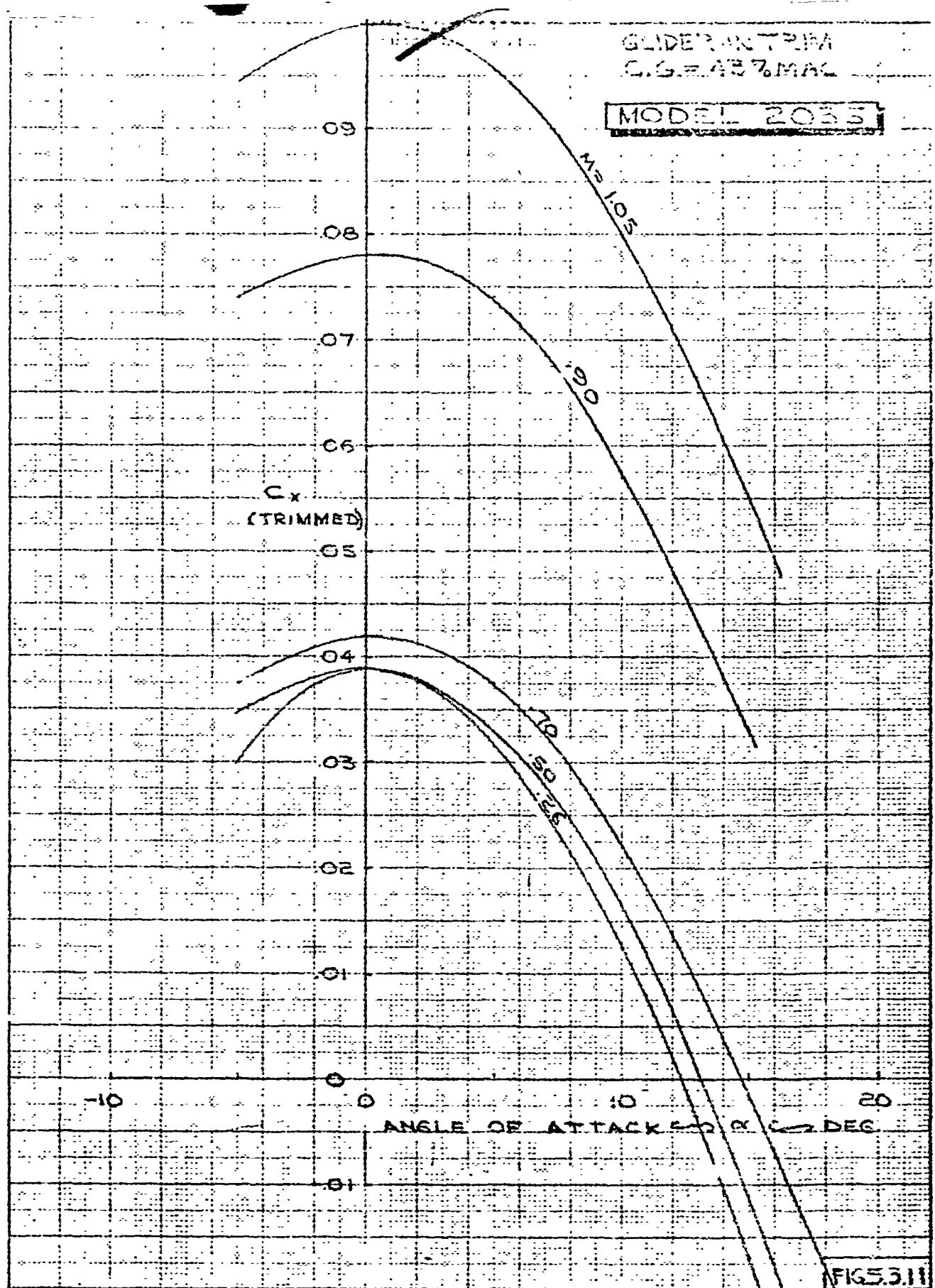


FIG 5.3.11

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CHORD FORCE COEFFICIENT
WING TIPS EXTENDED

844-2035
D2-8174

BOEING AIRPLANE COMPANY **58**

PAGE 526

CHORD IN TRIM
C.G. = 43% MAC

MODEL 2035

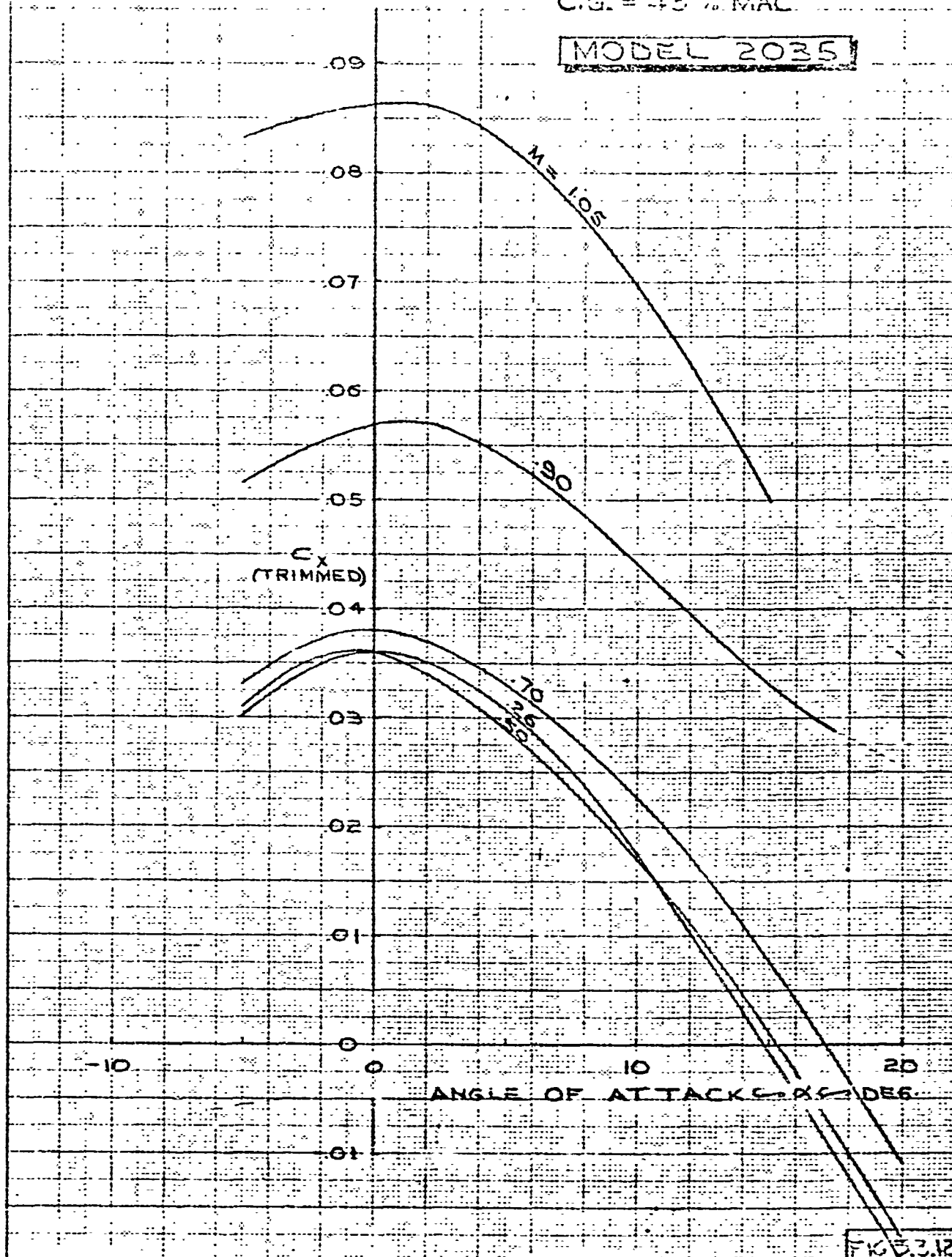


FIG. 3.12

DEZ

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CHORD FORCE COEFFICIENT
WING TIPS RETRACTED

44-2035

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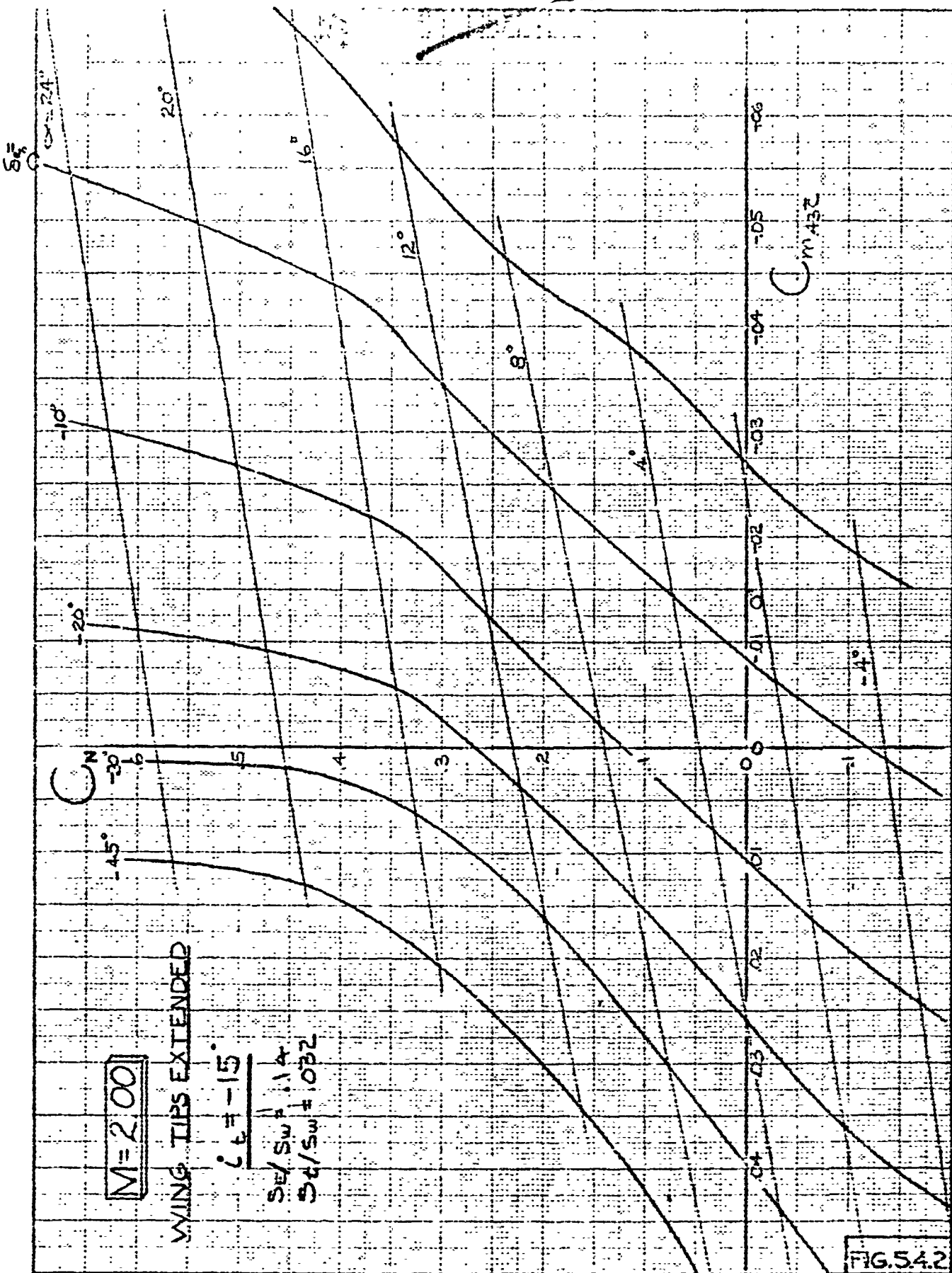
BOEING AIRPLANE COMPANY

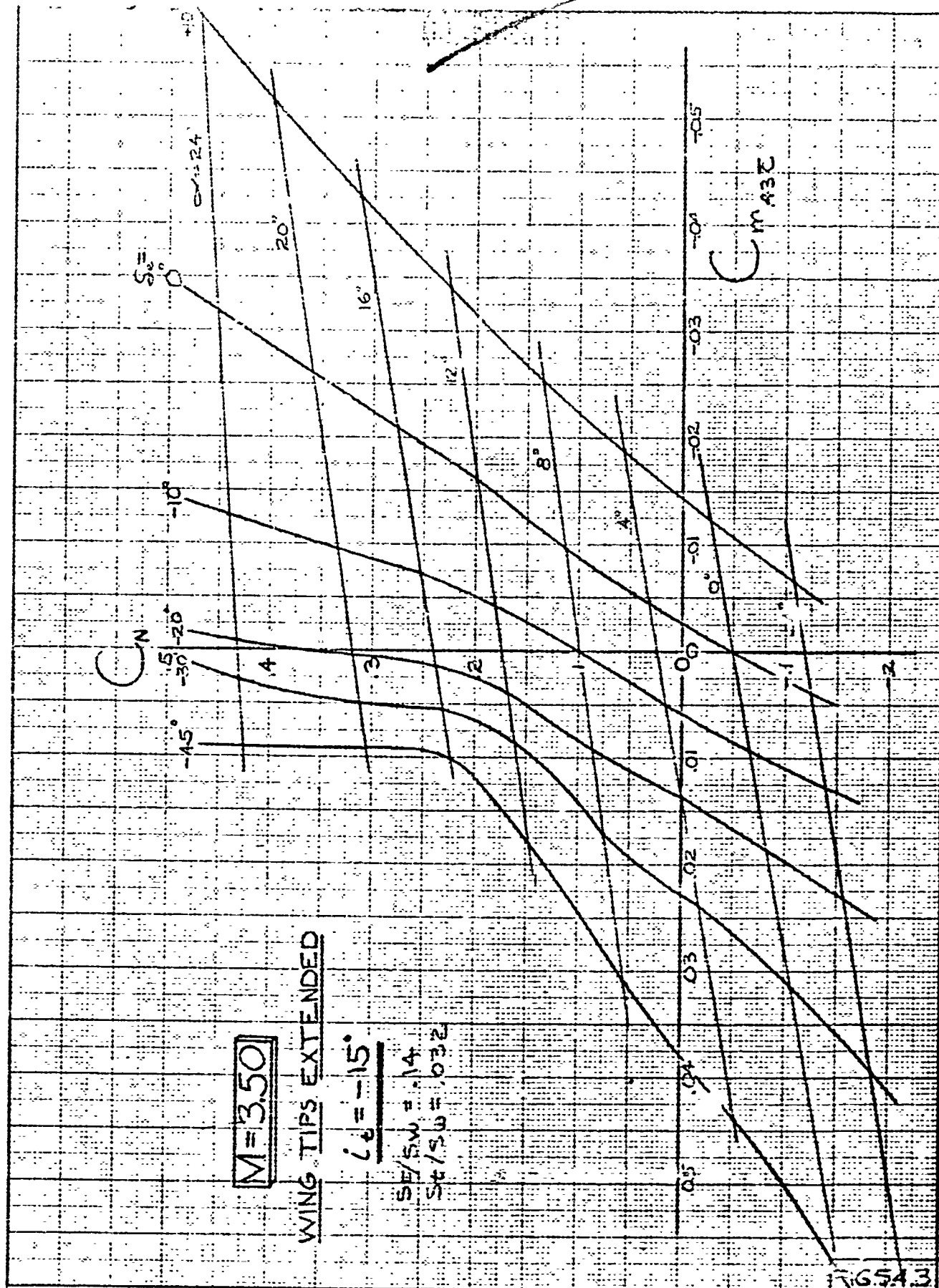
59

PAGE 527

Longitudinal stability and control characteristics at supersonic speeds for Mach numbers of 1.6, 2.0 and 3.5 are shown for wing tip extensions retracted, Figures 5.4.4 through 5.4.6 and for wing tip extensions extended, Figures 5.4.1 through 5.4.3. These curves were derived from wind tunnel tests performed in the Boeing Supersonic Wind Tunnel. The 814-1058 glider configuration was tested with variations in model components to give parametric data. The parametric data were corrected by theoretical methods to obtain predictions of pitch characteristics on the 844-2035 configuration.

Chord force coefficient data for the glider in trim and with wing tips extended are shown on Figure 5.4.7. Data with the tip extensions retracted are shown on Figure 5.4.8.





M=3.50

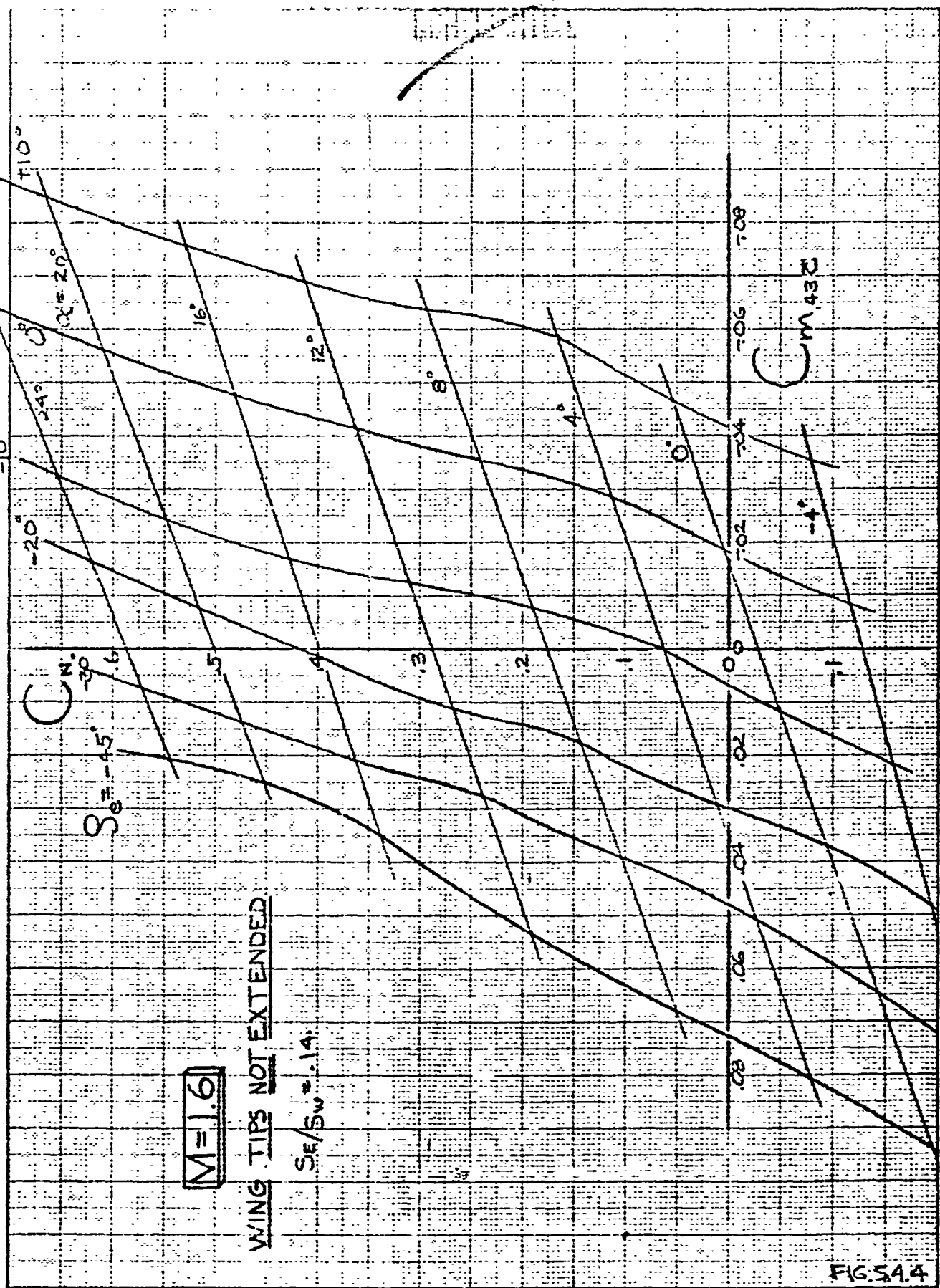
WING TIPS EXTENDED

$i_b = -15^\circ$

$S_F/S_W = .14$
 $S_t/S_W = .032$

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M=1.6

WING TIPS NOT EXTENDED

$S_E/S_W = .14$

FIG. 5.4.4

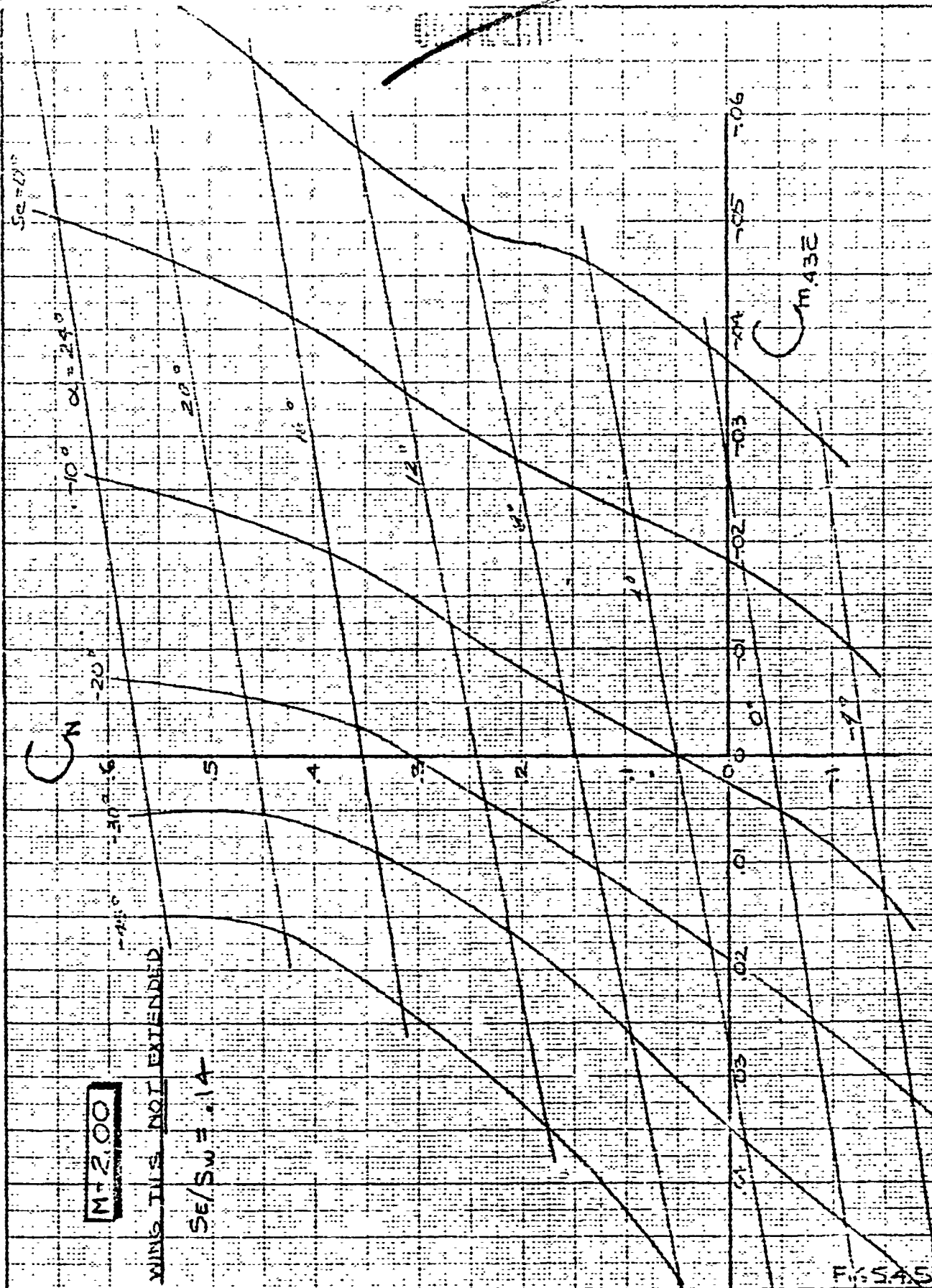
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LONGITUDINAL STABILITY
WING TIPS RETRACTED M=1.6

844-2035
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BOEING AIRPLANE COMPANY

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APR					

LONGITUDINAL STABILITY
WING TIPS RETRACTED M=2.0

BOEING AIRPLANE COMPANY

844-2035
D2-2174
65 PAGE 5.33

CONFIDENTIAL

MODEL 2035
WING TIPS EXTENDED

GLIDER IN TRIM

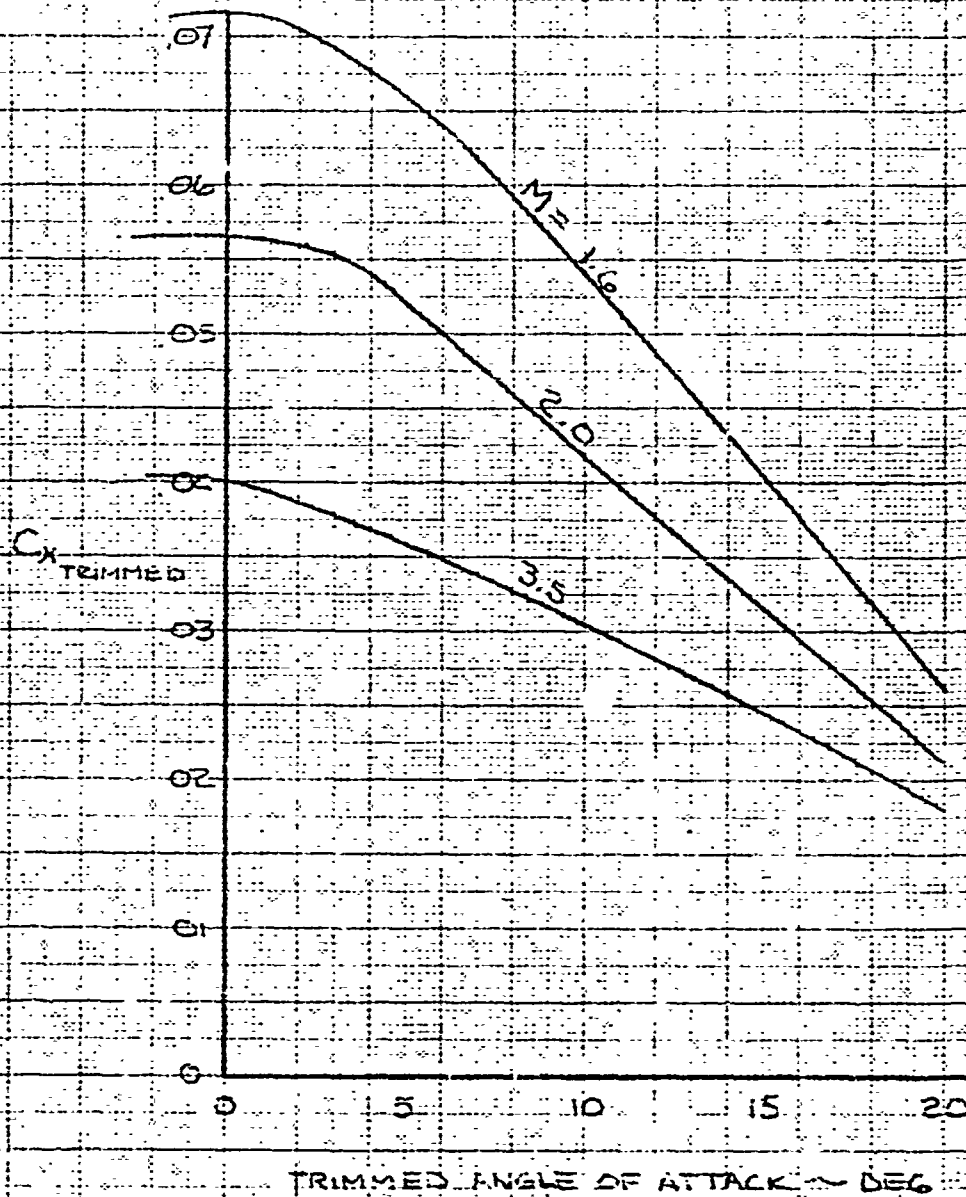


FIG. 5.47

WEJ

11/2/60

SUPERSONIC CHORD
FORCE COEFFICIENT
WING TIPS EXTENDED

B. WING AIRPLANE COMPANY

544-4035

62-6174

67

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MODEL 2035
WING TIPS RETRACTED

GLIDER IN TRIM

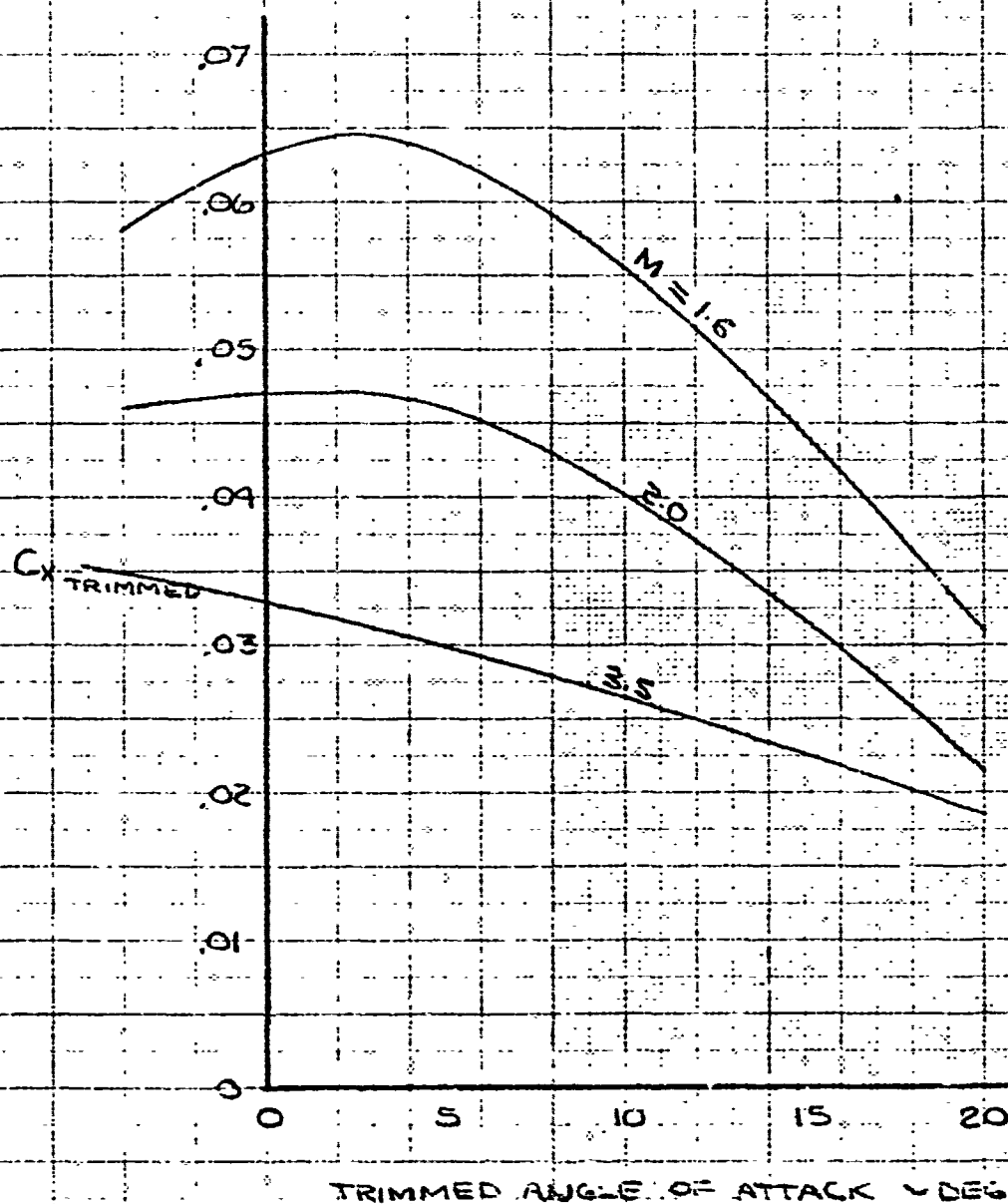


FIG. 5.48

WEJ

12/2/60

SUPERSONIC CHORD
FORCE COEFFICIENT
WING TIPS RETRACTED
BOEING AIRPLANE COMPANY

644-2035

D2-8174

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5.36

5.5

HYPERSONIC SPEEDS

Longitudinal stability and control characteristics for the 744-2035 glider configuration are shown on Figures 5.5.1 through 5.5.3. Data are shown on Figure 5.5.1 for a Mach number of 8 and the cold shape glider. This assumes the glider to have the manufactured, or jig shape, configuration. Data are shown on Figures 5.5.2 and 5.5.3 at a Mach number of 8.0 and 22.0 for the "hot shape" glider. This assumes that the glider has assumed its maximum structural deformation due to thermal effects.

The data presented are based on wind tunnel tests in the following facilities:

- 1) A.E.D.C. Tunnel B, $M=8.08$
- 2) J.P.L. 21-Inch Hypersonic Tunnel, $M=9.5$
- 3) L.R.C. 11-Inch Hypersonic Tunnel, $M=9.6$
- 4) Boeing 44-Inch Hotshot Tunnel, $M=16$ and 22

These data were corrected to the present configuration by theoretical methods (Modified Newtonian Flow Theory and Shock Expansion Theory, particularly for elevon effectiveness). The incremental effect of the "hot shape" glider was determined by Modified Newtonian Flow Theory.

The effect of altitude or Reynolds number change at a constant Mach number is not included. Work is currently in progress in this area. Some variation of characteristics between $M=8$ and 22 can also be anticipated. Wind tunnel tests are currently in progress to define this variation.

Chord force data as a function of angle of attack for Mach numbers of 8 and 22 are presented on Figure 5.5.4. These data are for the glider trimmed at the various angles of attack.

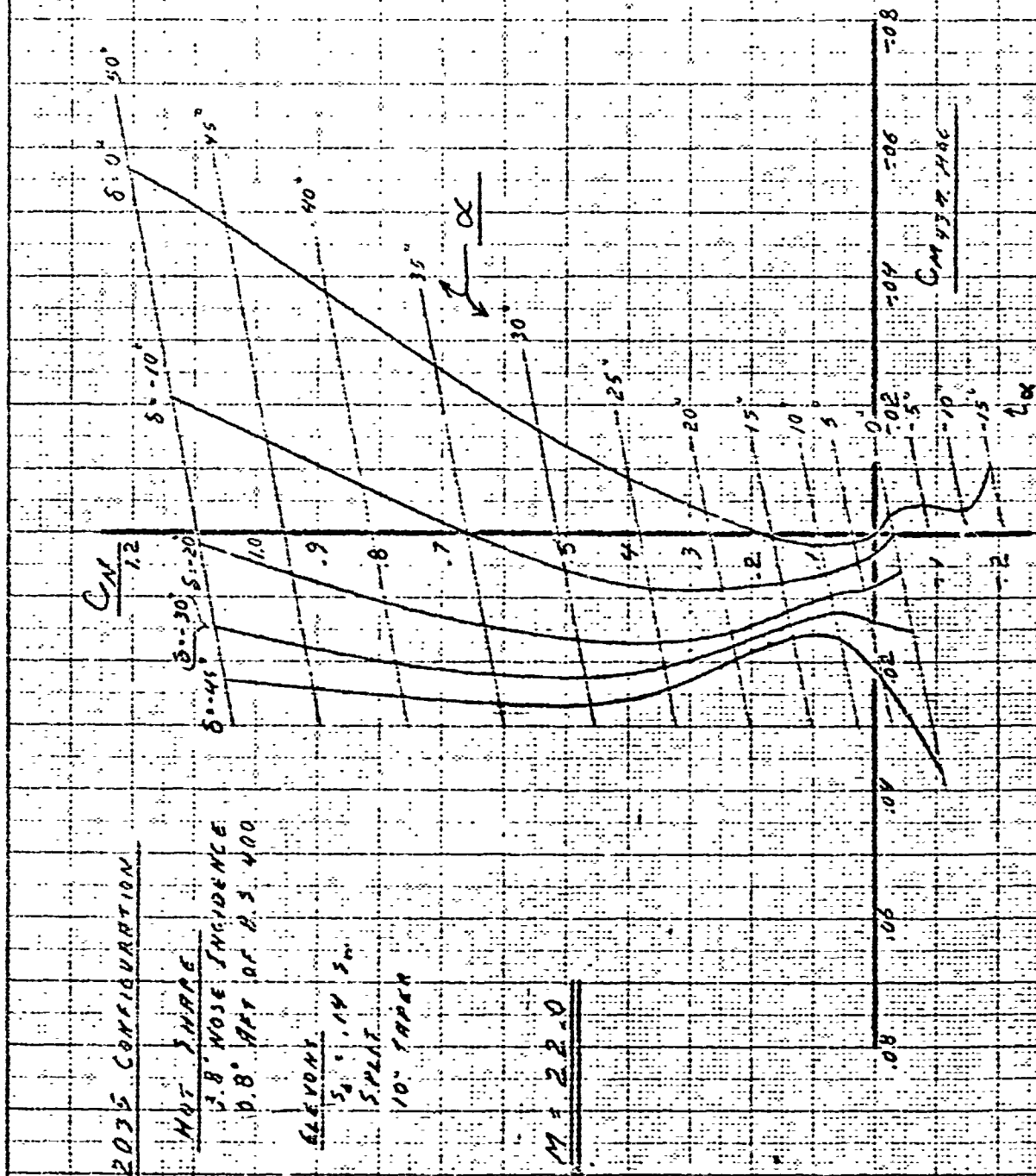


FIG 553

LONGITUDINAL STABILITY
HGT SHAPE
 $M = 22.0$

844-2035

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D2-8174

BOEING AIRPLANE COMPANY

PAGE 540

C.G. AT 43% MAC
GLIDER IN TRIM

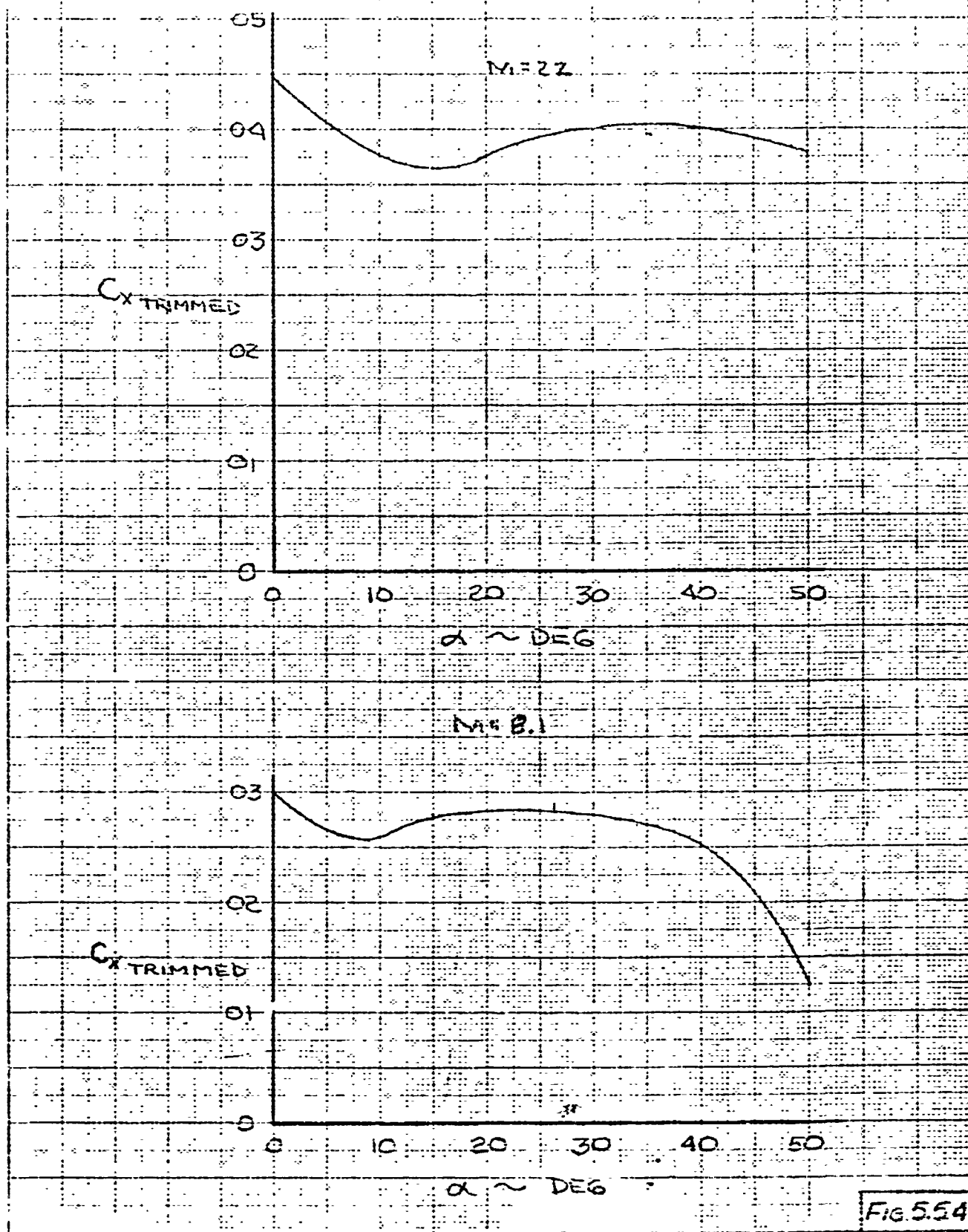


FIG 5.54

W.E.J. 12-12-0

HYPERSONIC CHORD
FORCE COEFFICIENT

844-2035

D2-8174

EDGING AIRPLANE COMPANY

73

541

5.6

SPEED BRAKES (DRAG BRAKE)

The incremental effect of extending the speed brakes on longitudinal stability is shown on Figure 5.6.1. Data are shown at the three Mach numbers where test data have been obtained. The test data were obtained in the Boeing Transonic and Supersonic Wind Tunnels and have been modified to the present configuration. Further study of speed brake location, to minimize trim and stability changes, is being conducted.

The incremental effect of the speed brakes on axial force is shown on Figure 5.6.2 at supersonic and low speed.

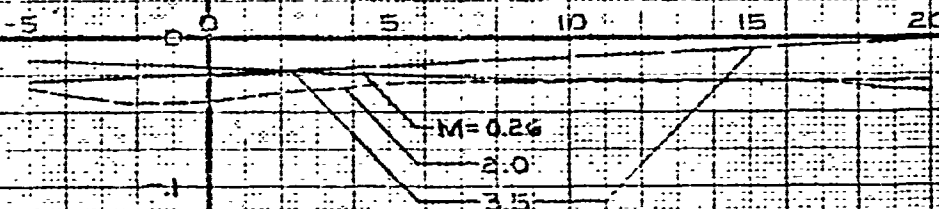
DATA BASED ON BSNT 013

$$S_{B/SW} = 0.0215$$

BRAKE DEFLECTED 60°

ΔC_N

$Q \sim \text{DEG}$



$\Delta C_{M_{15^\circ}}$

$Q \sim \text{DEG}$

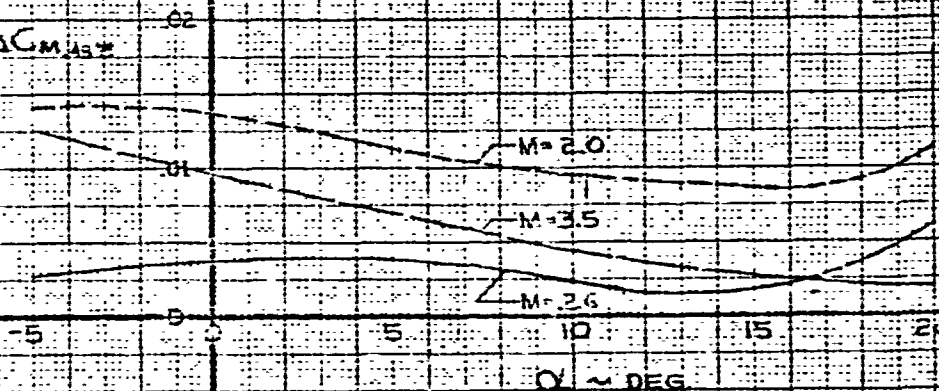


Fig. 5.6.1

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EFFECT OF
DRAG BRAKE ON
LONGITUDINAL STABILITY

BOEING AIRPLANE COMPANY

844-2035

D2-8174

PAGE

5.43

MODEL 2035

$S_E/S_W = 0.218$

BRAKE DEFLECTED 60°

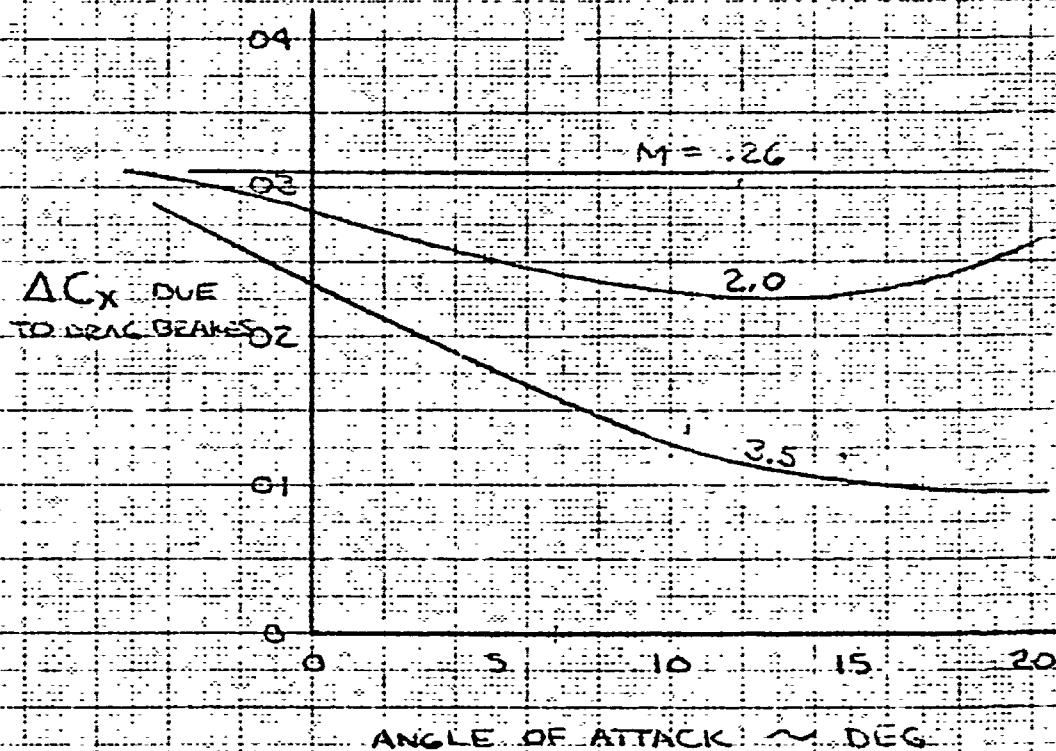


FIG 5.2

WEV

12-22 0

EFFECT OF DRAG BRAKE
ON CHORD FORCE
COEFFICIENT

76

02-3174

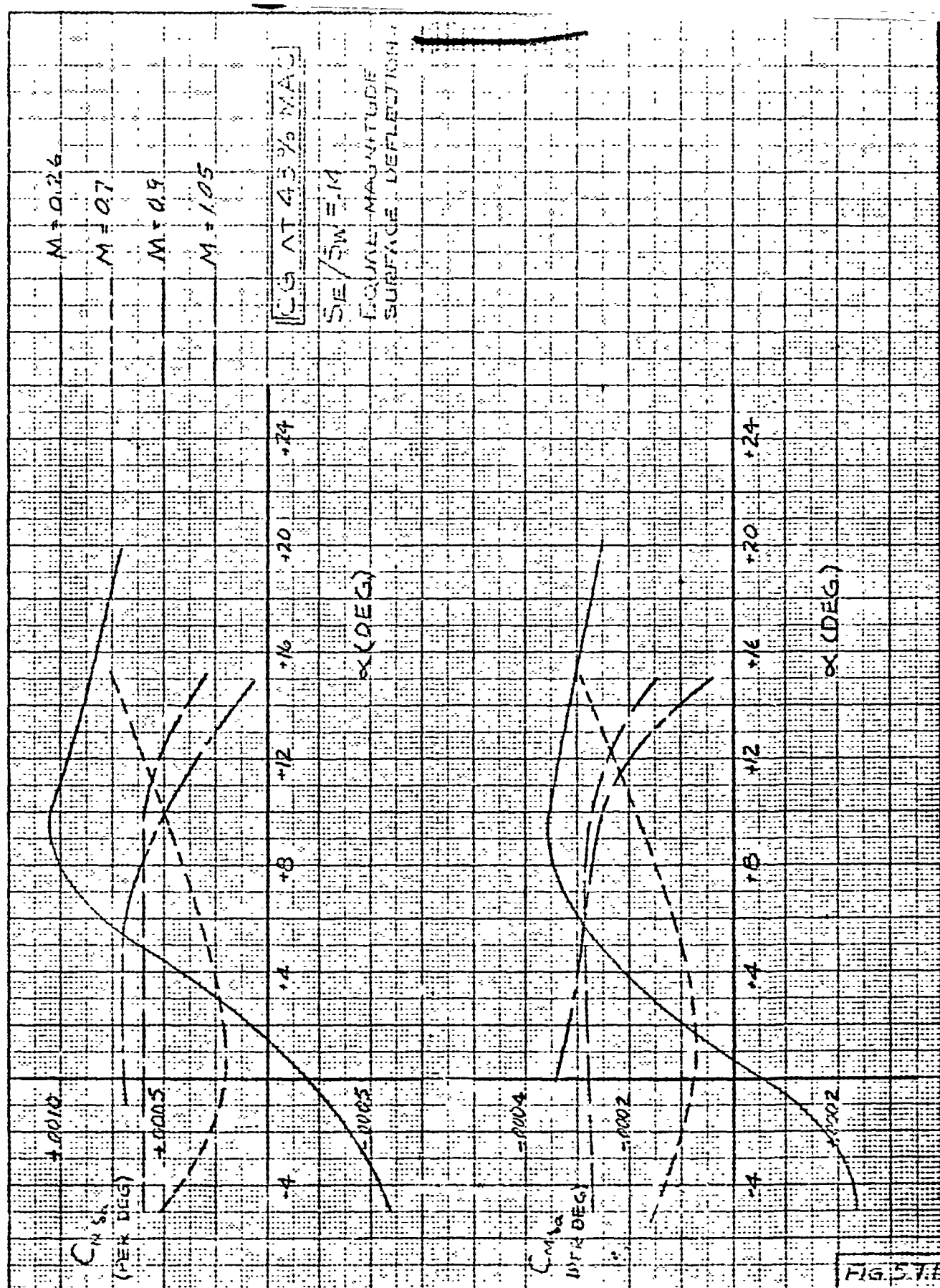
BOEING AIRPLANE COMPANY

5.7

ELEVON AS AILERON PITCH COUPLING

The effects of symmetrical elevon deflection for roll control on pitch stability and trim at subsonic through supersonic speeds are shown on Figures 5.7.1 and 5.7.2. The data were estimated from limited wind tunnel data and can be subject to major revision.

At hypersonic speeds, the changes in pitching moment and normal force are presented as functions of elevon deflection and angle of attack for one elevon deflected. Test data have shown that the deflection of one elevon has a negligible effect upon the flow about the other elevon at hypersonic speeds. Therefore, the effect of aileron deflection can be obtained by adding the individual effects of the two elevons. The increments in normal force and pitching moment due to deflection of one elevon are shown on Figures 5.7.3 through 5.7.8 for $M=8$ and 22. Elevon pitch trim requirements for various roll control deflection are shown on Figure 5.7.3 for $M=8$ and Figure 5.7.6 for $M=22$.



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PITCH EFFECTS DUE TO
 AILERON DEFLECTION
 SUBSONIC - TRANSONIC SPEED
 BOEING AIRPLANE COMPANY

844-2035
 D2-8174
 PAGE 5.46

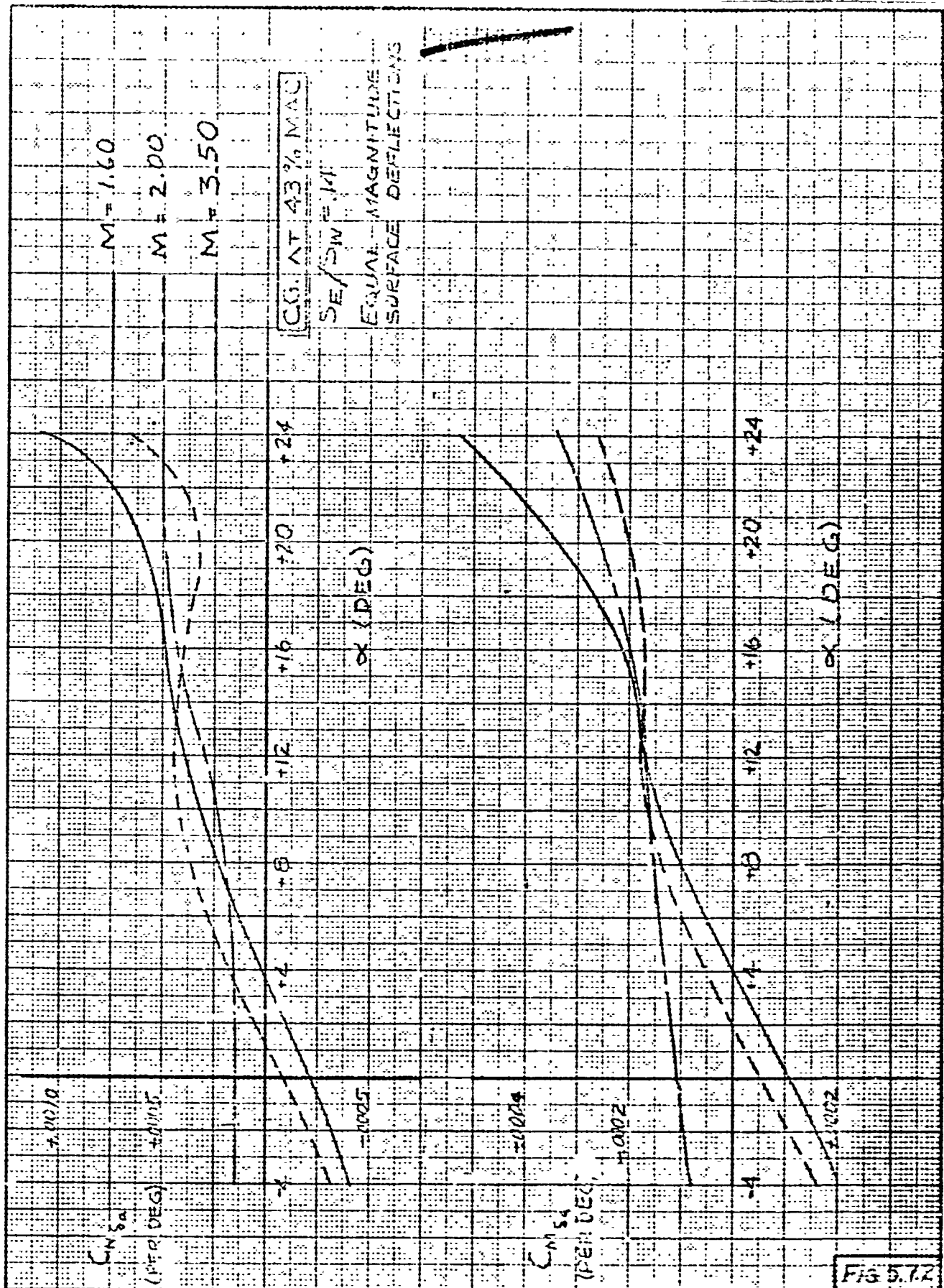


FIG 5.7.2

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PITCH EFFECTS DUE TO
 AILERON DEFLECTION
 SUPERSONIC SPEED
 BOEING AIRPLANE COMPANY

344-2035
 D2-8174
 PAGE
 5.47

79

2035 CONFIGURATION

M=8.1

HOT SHAPE

CG AT 43% MAC

3.8° NOSE INCIDENCE

0.8° AFT OF B.S. 400

ELEVON

10° TAPER

SPLIT

$S_E/S_A = 1.4$

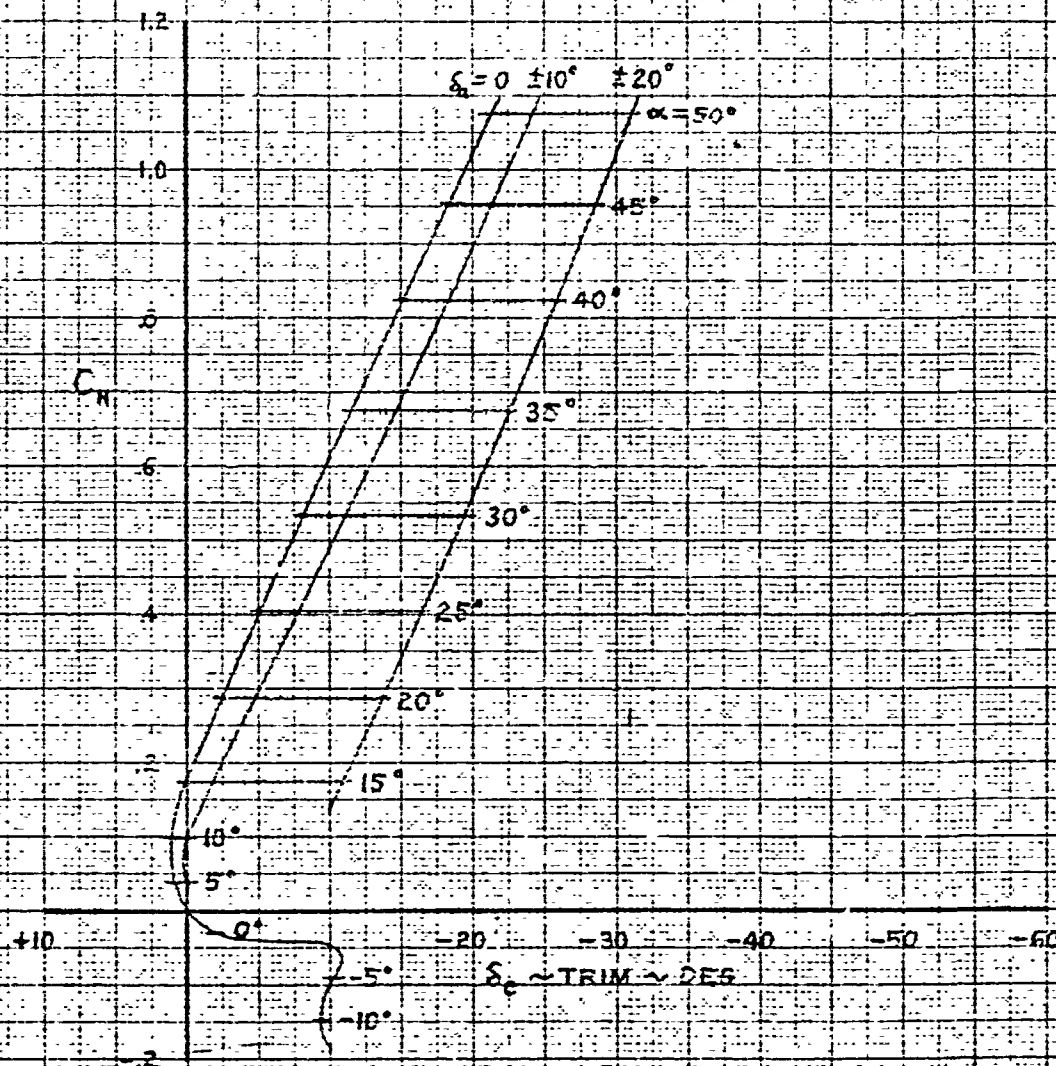


FIG 5.7.3

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AILERON PITCH TRIM

REQUIREMENTS

HOT SHAPE M=8.1

BOEING AIRPLANE COMPANY

SEATTLE & WASHINGTON

844-2035

D2-3174

PAGE 543

BAC 461 C-R4

K2 AUGUST 1954

60629

NOSE CONFIGURATION

$M = 0.1$

HOT SHAPE

3.8° NOSE INCIDENCE

C.B. AFT. OF B.S. 400

CG AT 43% MAC

ELEVON

10° TAPER

SPLIT

$S_E/S_W = 1.4$

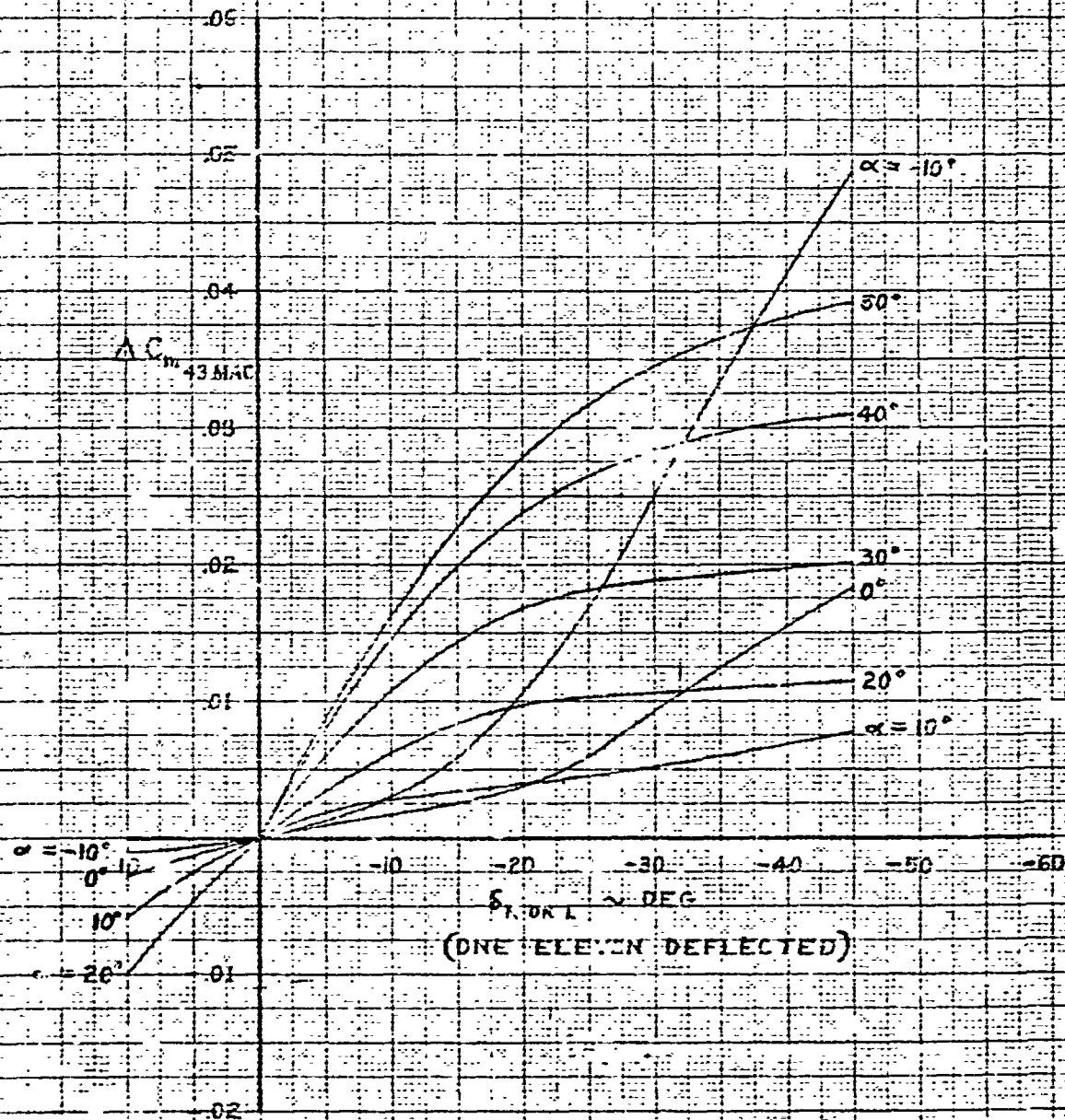


FIG 5.7.4

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EFFECT OF AILERONS ON
PITCHING MOMENT

HOT SHAPE $M = 0.1$

BOEING AIRPLANE COMPANY
SEATTLE 24, WASHINGTON

44-2035

D2-3.74

PAGE 5.49

81

2035 CONFIGURATION

M = 5.1

HOT SHAPE

CG AT 40% MAC

3.2° NOSE INCIDENCE

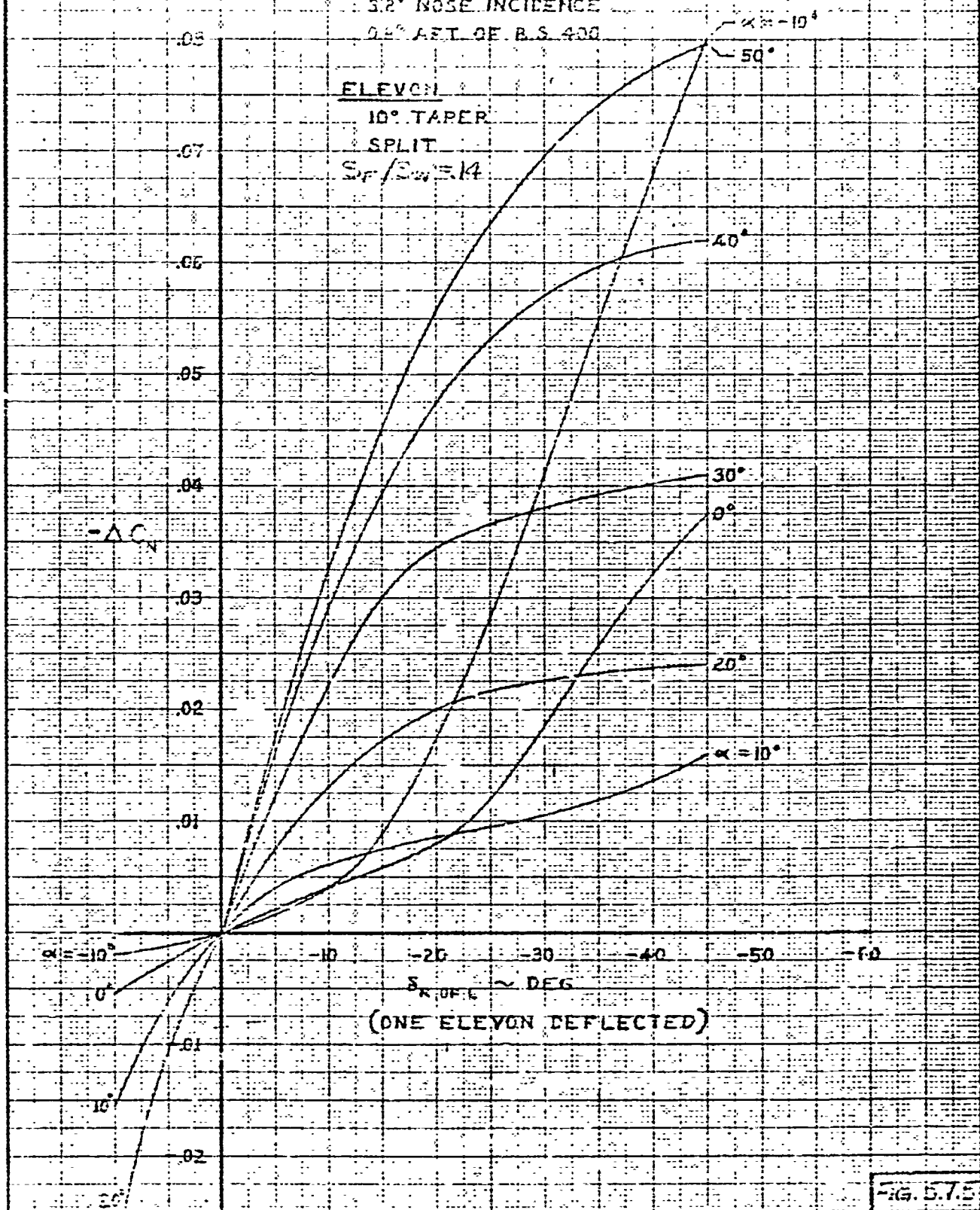
GEOMET. OF B.S. 400

ELEVON

10° TAPER

SPLIT

$S_F/S_W = .14$



(ONE ELEVON DEFLECTED)

FIG. 5.7.5

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EFFECT OF AILERONS ON
NORMAL FORCE

HOT SHAPE M = 5.1

BOEING AIRPLANE COMPANY

SEATTLE 24 WASHINGTON

844-2035

D2-S174

PAGE
5.50

235 CONFIGURATION

$M = 22.0$

HOT SHAPE

$C_G = 43\%$ MAC

3.5° NOSE INCIDENCE

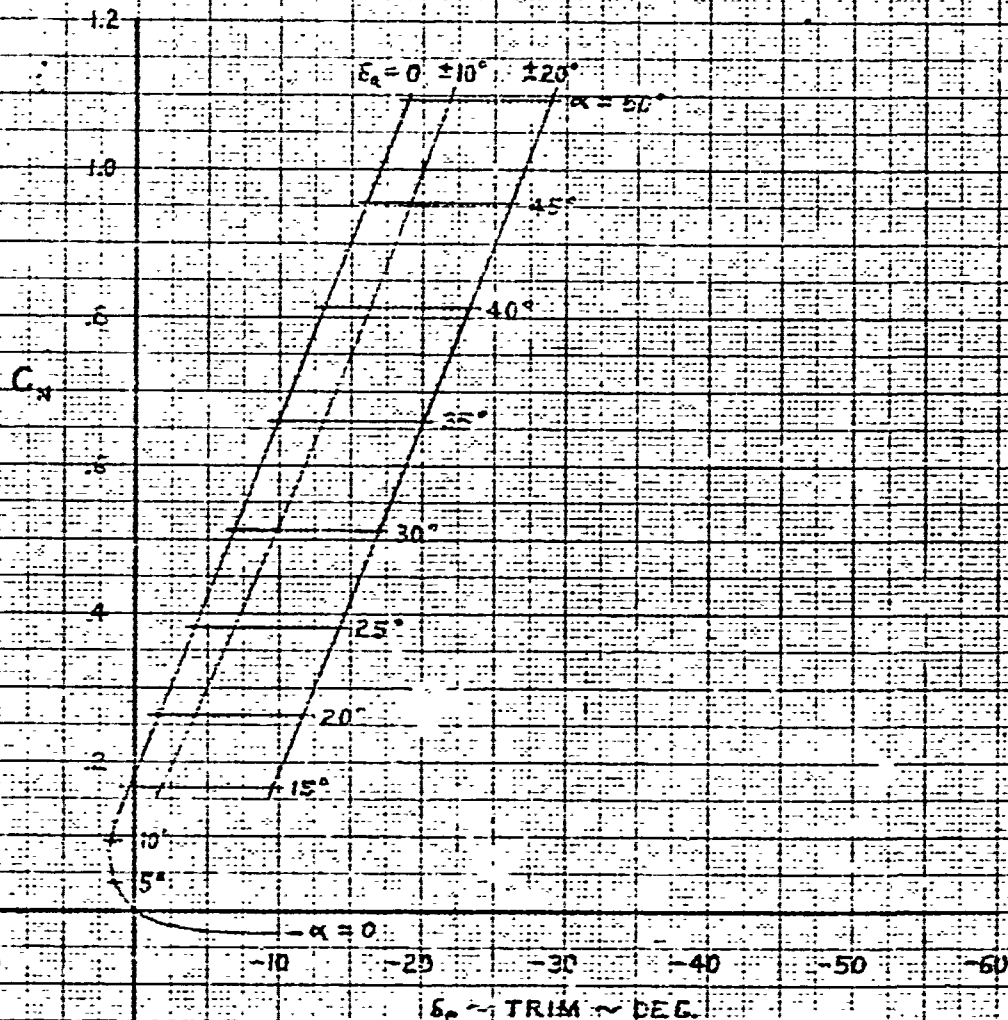
2.6° AFT OF B.S. 400

ELEVON

10° TAPER

SPLIT

$S_F / S_{ref} = .14$



F.E. 5.7.6

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AILERON PITCH TRIM
REQUIREMENTS **83**
HOT SHAPE $M = 22.0$
BOEING AIRPLANE COMPANY
SEATTLE 24, WASHINGTON

44-2035
22-8174
PAGE
551

HOT SHAPE

3.5° NOSE INCIDENCE

0.8° AFT. OF B.S. 400

C.G. AT 42% MAC

ELEVON

10° TAPER

SPLIT

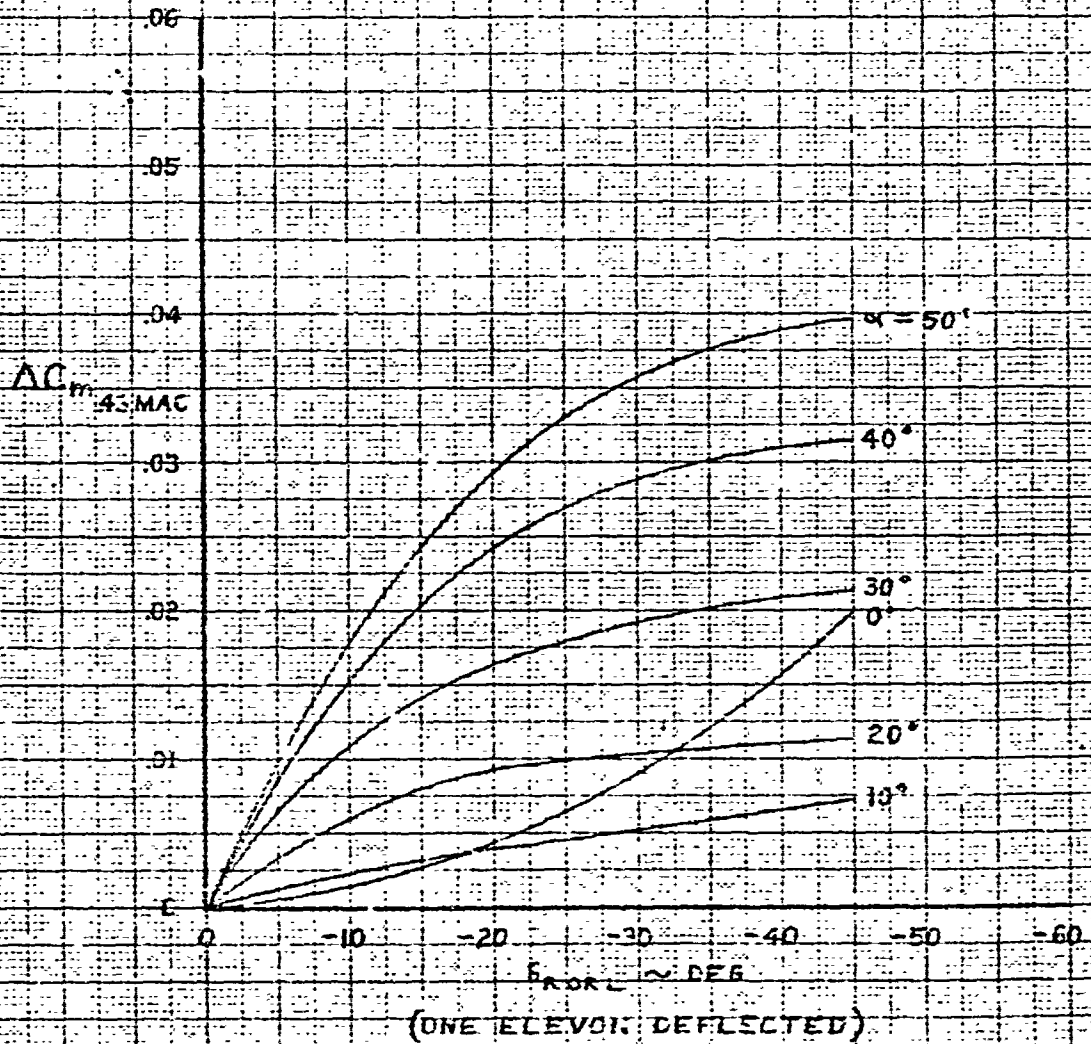
 $S_e/S_w = .14$ 

FIG. 57.7

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EFFECT OF AILERONS ON
PITCHING MOMENT **84**
HOT SHAPE M = 22.0
BOEING AIRPLANE COMPANY
SEATTLE 24 WASHINGTON

B44-2035

D2-5174

PAGE
5.52

ROSE CONFIGURATION

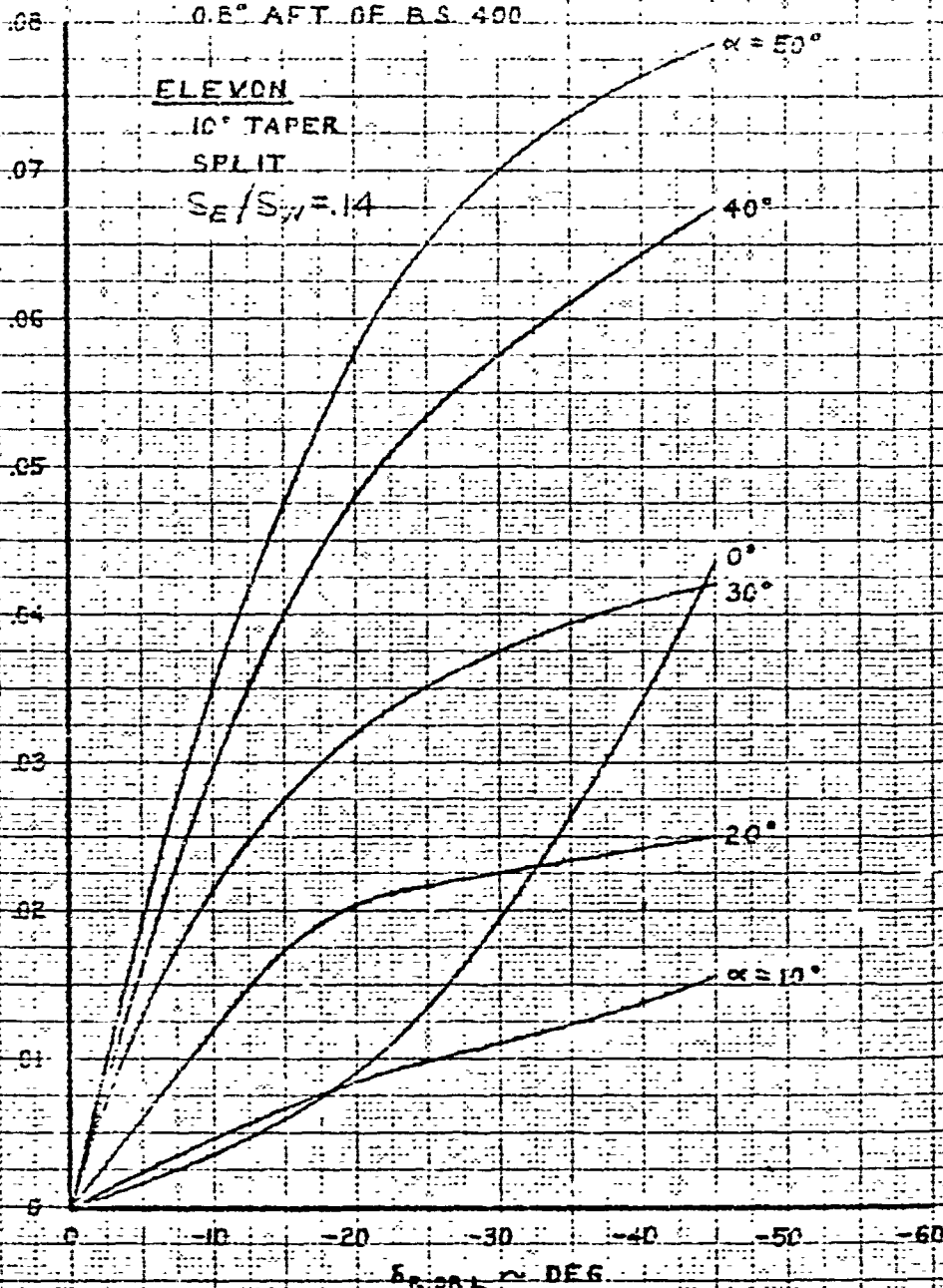
M = 28.0

HOT SHAPE

U. A. 1/2 M.

3.8° NOSE INCIDENCE

0.6° AFT OF B.S. 400



(ONE ELEVON DEFLECTED)

FIG. 5.75

CALC	SP	1/10/60	REVISED	DATE
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EFFECT OF AILERONS ON
NORMAL FORCE

85

BOEING AIRPLANE COMPANY
SEATTLE 4 WASHINGTON

44-2025

D2-3174

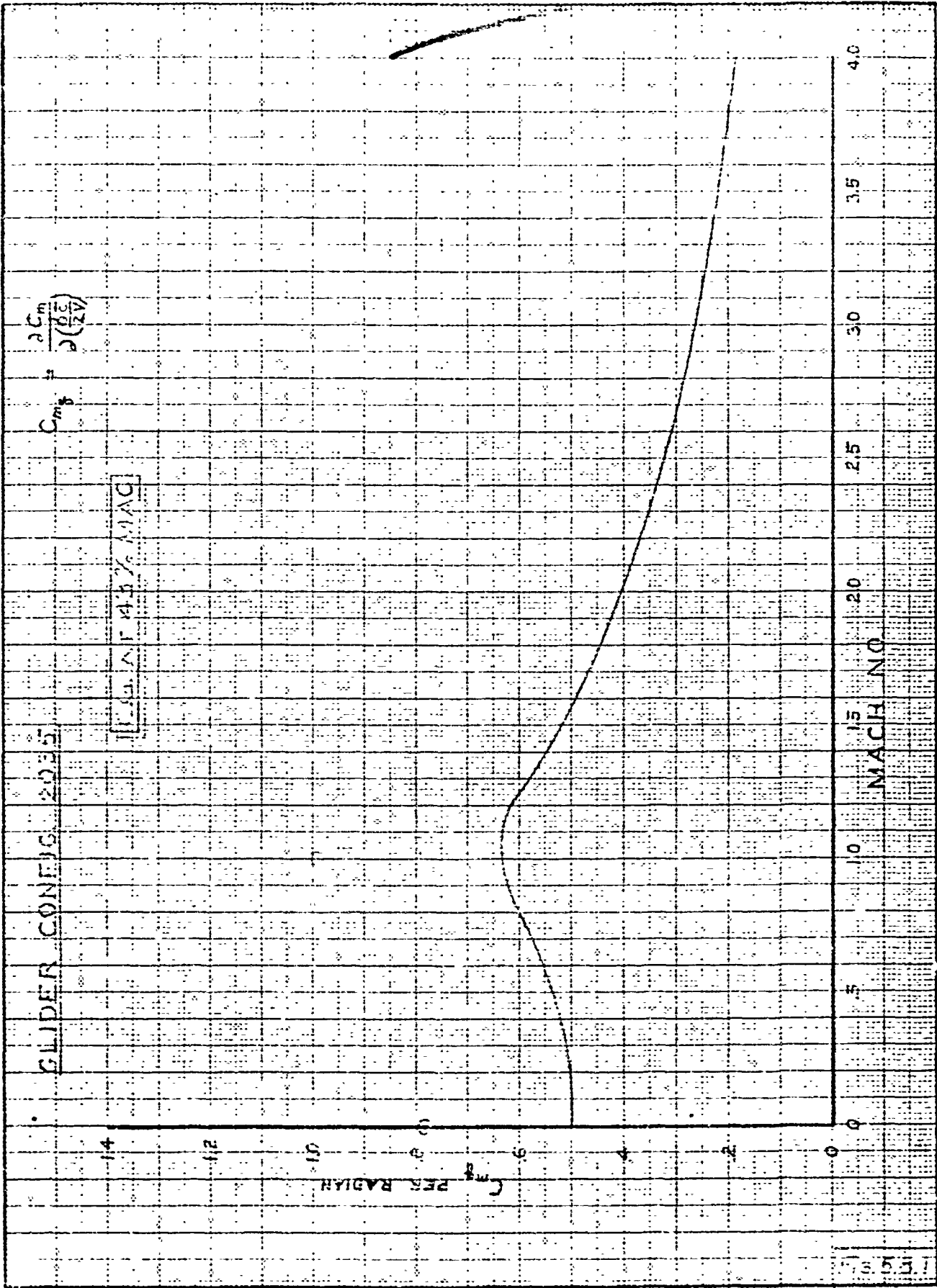
PAGE
5.53

The pitch damping derivative, $C_{m\dot{\alpha}}$ (shown on Figure 5.8.1), was obtained from NASA reports of similar configurations. These data were also compared with linear theory which was found to be in reasonable agreement at supersonic speeds but was nearly double the empirical value at subsonic speeds. Recent wind tunnel data were run showing the effects of angle of attack and oscillation frequency on $C_{m\dot{\alpha}}$ and $C_{m\ddot{\alpha}}$ at low speed in the L.P.C. Free Flight Wind Tunnel. These data are currently being analyzed. Additional analytical and test work is being done and is planned, to define the necessary rotary derivatives further.

$$C_{m\delta} = \frac{\partial C_m}{\partial (\delta/V)}$$

11.5% Δ F 14.5% MAC

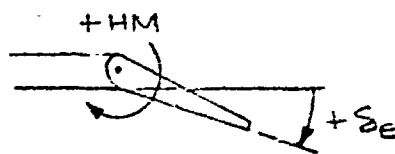
GLIDER CONFIG 2035



<table border="1"> <tr> <td>CALC</td> <td>Cm</td> <td>12/5/60</td> <td>REVISED</td> <td>DATE</td> </tr> <tr> <td>CHECK</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>APP</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>ACR</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>	CALC	Cm	12/5/60	REVISED	DATE	CHECK					APP					ACR					PITCHING MOMENT DUE TO PITCHING VELOCITY BOEING AIRPLANE COMPANY SEATTLE 24 WASHINGTON	844-2035 02-8174 PAGE 1.55
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Variation of $C_{H\alpha}$ and $C_{H\delta}$ with Mach number is shown on Figure 5.9.1. These data were obtained from published N.A.S.A. reports on similar configurations.

Wind tunnel tests in the A.R.C. Unitary Wind Tunnel have been completed recently and further testing is planned to define these characteristics better as a function of Mach number, angle of attack and angle of elevon deflection.



COEFFICIENTS BASED
ON TWICE THE MOMENT
OF AREA BEHIND HINGE
LINE ABOUT HINGE LINE.

$$C_H = \frac{HM}{2Ma^2 q}$$

$$S_E/S_W = .14$$

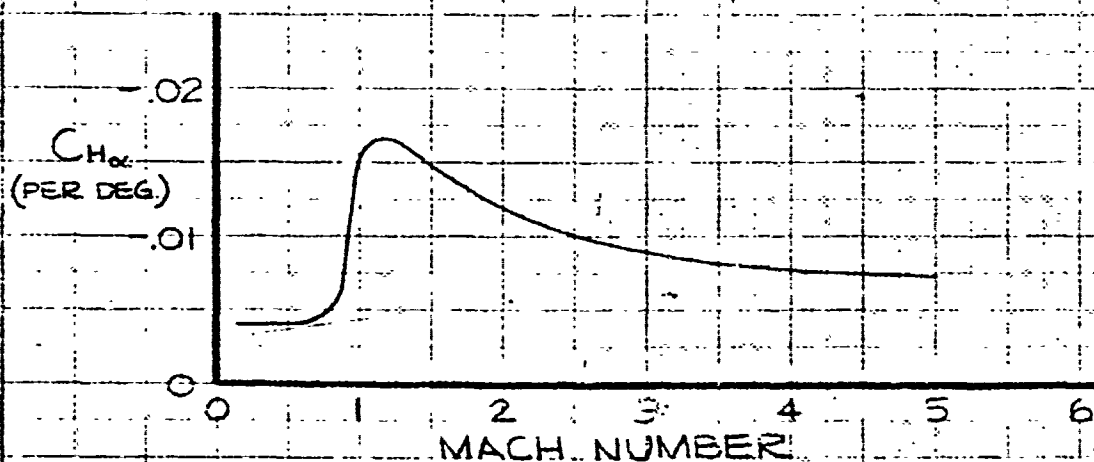
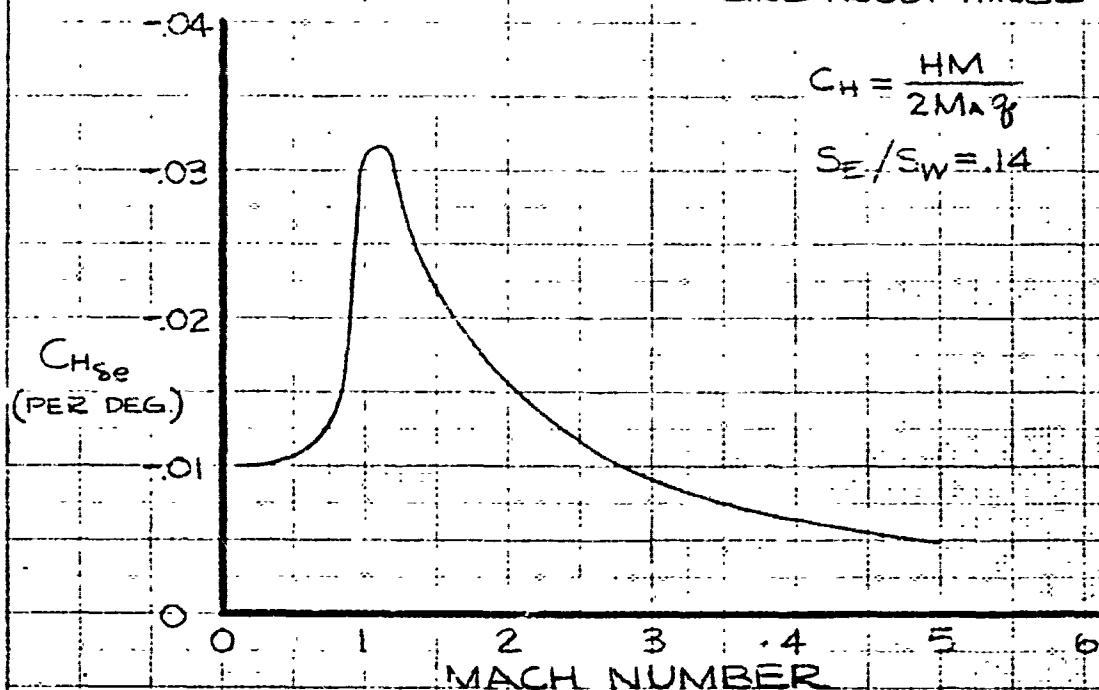


FIG. 59.1

ELEVON HINGE MOMENT COEFFICIENTS

BOEING AIRPLANE COMPANY

800-2035

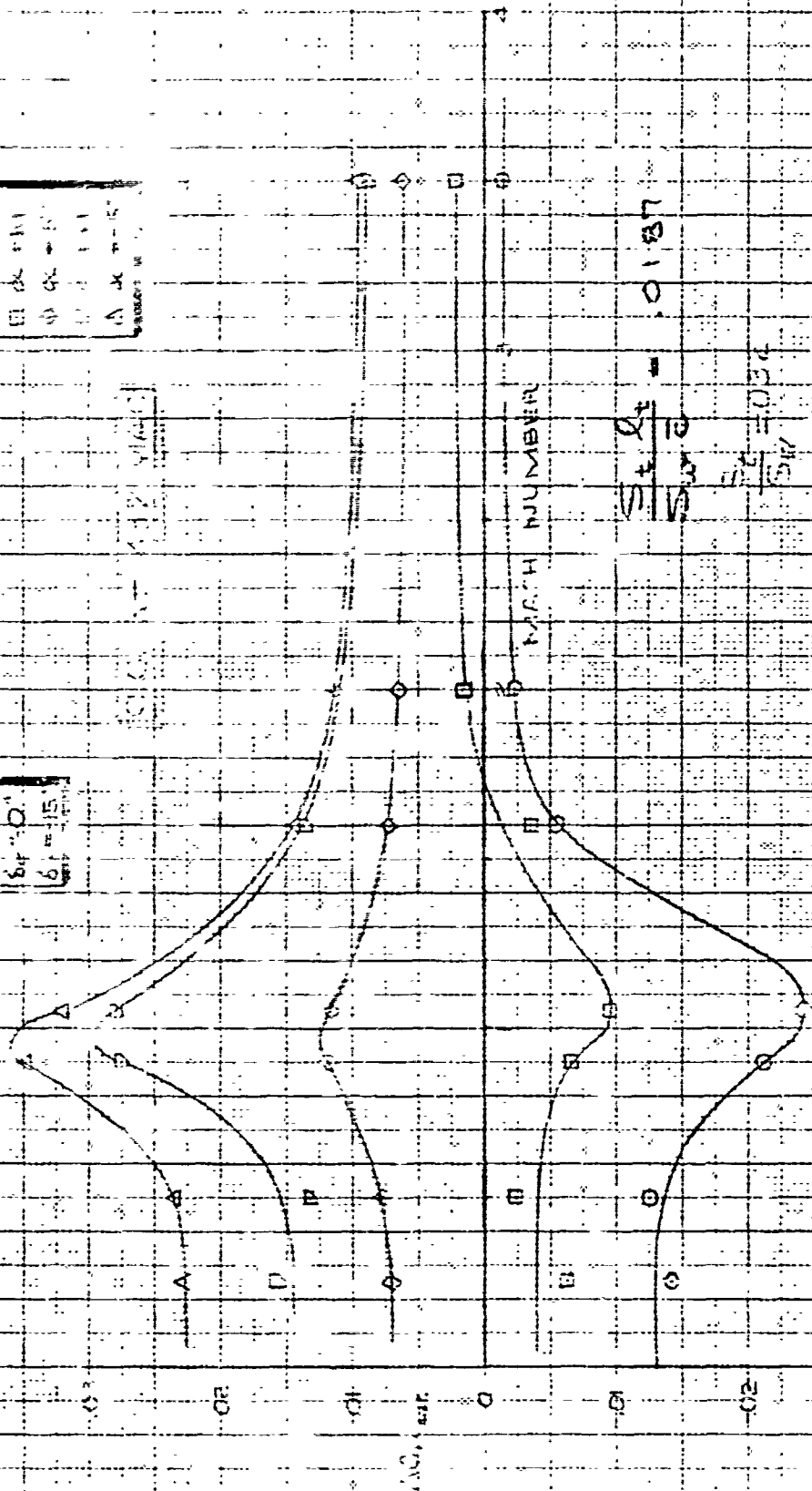
D2-8174

PAGE 5.57

The incremental effect of wing tip extensions, located on the vertical tails, on pitching moment and normal force coefficients is shown on Figures 5.10.1 and 5.10.2. These data are based on tests performed in the A.R.C. 12-Foot Pressure Wind Tunnel and the Boeing Transonic and Supersonic Wind Tunnels. It was assumed that the tip extension would have only secondary effects on elevator effectiveness. The data obtained were not with the precise tip extension configuration for the C-2035 glider; consequently some variation in the increments shown may be anticipated.

$\delta_1 = 15$
 $\delta_2 = 15$
 $\delta_3 = 15$
 $\delta_4 = 15$
 $\delta_5 = 15$

$\delta_1 = 15$
 $\delta_2 = 15$



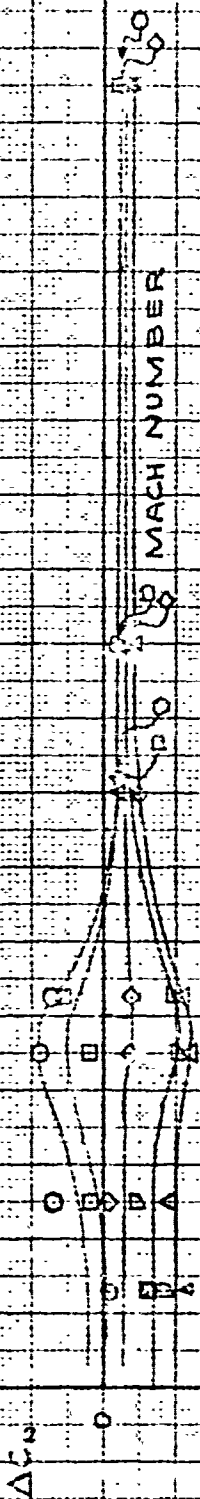
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APR				

1. L. F. WILSON TIF
 EXTENSION ON
 MOMENT
 BOEING AIRPLANE COMPANY

844-2055
 91
 02-8-70
 PAGE
 557

15°	10°	5°	0°	-5°
X	X	X	X	X
0	0	0	0	0

$\alpha = 0^\circ$
 $\alpha = -15^\circ$



$\frac{1}{2} \rho V^2$
 0.32

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EFFECT OF WING TIP
EXTENSIONS ON
NORMAL FORCE
BOEING AIRPLANE COMPANY

FIG. 1
824-203
D2-3174
PAGE 560

6.0

LATERAL - DIRECTIONAL STABILITY AND CONTROL

The predicted force, moment, and directional control effectiveness characteristics are included in this section. The data are grouped in the following areas. A list of the data in each area is presented at the front of each group.

6.1 Lateral - Directional Stability Characteristics

6.2 Aileron Characteristics and Effectiveness

6.3 Rudder Characteristics and Effectiveness

6.4 Roll and Yaw Rotary Derivatives

The characteristics are presented for the 844-2035 configuration, Figure 3.1.1. The reference dimensions on which the characteristics are based are shown on Figure 3.3.3. All characteristics are presented for conventional body axes fixed in the vehicle.

6.1

LATERAL - DIRECTIONAL STABILITY CHARACTERISTICS

The lateral - directional stability is presented in Figures 6.1 through 6.24 for landing speed to high hypersonic speed. The yawing moment, rolling moment, and side force are presented versus sideslip angle and angle of attack at representative Mach numbers in order to show the non-linearity of the stability characteristics. The stability derivatives $C_{Y\beta}$, $C_{Y\alpha}$, and C_{Yp} are also presented versus Mach number in order to indicate the interpolation between Mach numbers (Figures 6.1, 6.2, and 6.3). These derivatives are presented only for zero sideslip, and because of the non-linear nature of the stability characteristics, should not be used for large sideslip angles. Stability characteristics are presented for wing-tip extensions both retracted and extended from landing speed to $M=3.5$.

The stability characteristics are presented at representative speeds corresponding approximately to wind tunnel test speeds, namely, $M=0.25$, .70, .95, 1.05, 2.0, 3.5, 8.0 and 22.0. The landing speed data are based primarily on low speed tests on a similar configuration at the ARC 12-Ft Pressure Tunnel, test 122, and preliminary data from BTWT 619. Effects of Reynolds number (altitude) were shown to be small. The stability at $\alpha=15^\circ$ and β greater than 12° was extrapolated. The incremental effect of extending the landing gear and extending the speed brakes is shown on Figures 6.7 and 6.8. No data on the influence of the ground is currently available; however, any effect of the ground on yawing moment and side force will probably be negligible, with the major effect a small reduction in aileron effectiveness and roll due to sideslip (dihedral effect).

The transonic characteristics were estimated from preliminary data from BTWT 623 on a similar glider configuration. The data have been extrapolated to the current configuration on the basis of body shape, vertical tail size, location, and planform, and fold-down wing tip size. The static stability is currently minimum in this speed range.

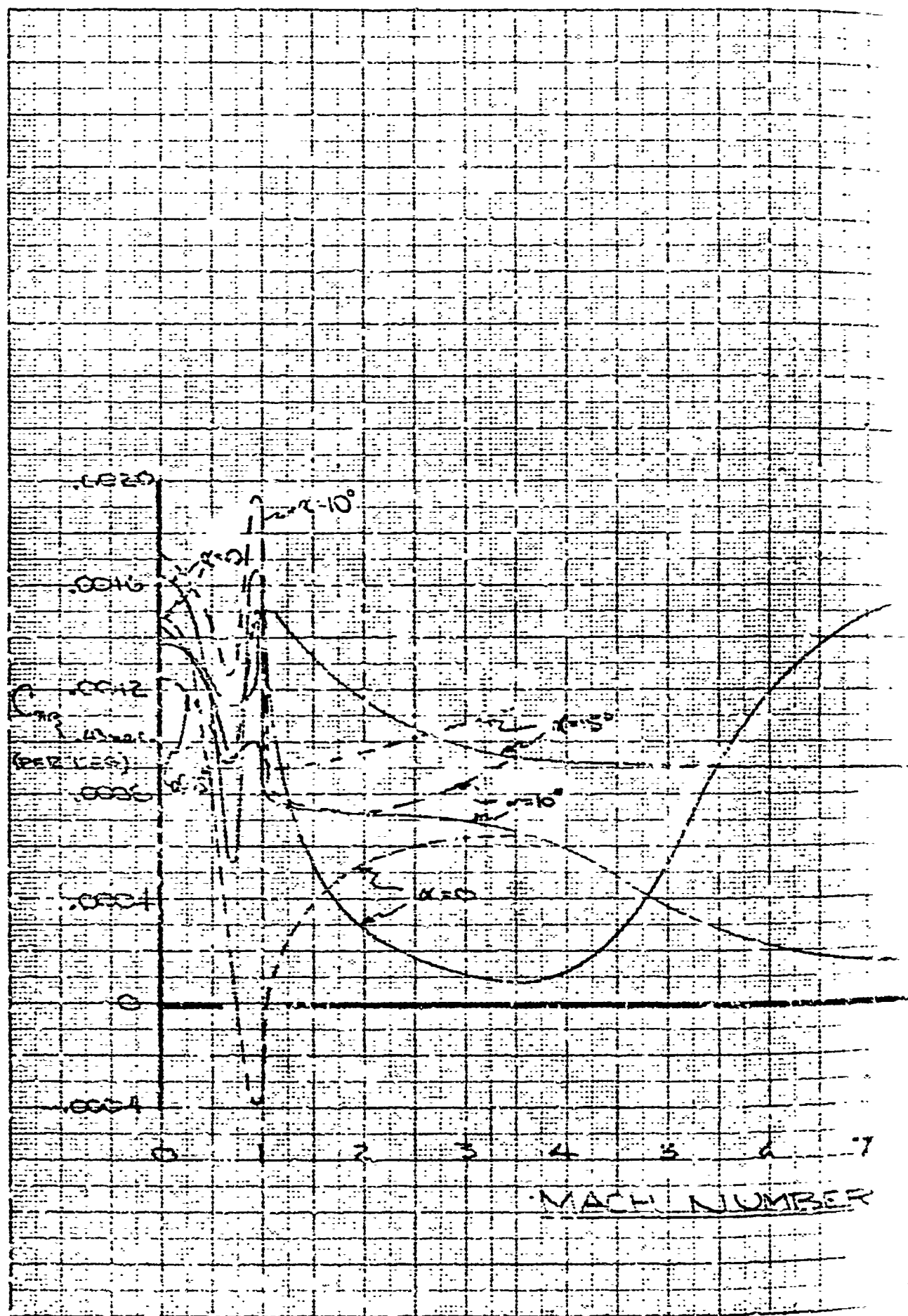
The supersonic stability characteristics were obtained from tests in the Boeing Supersonic Wind Tunnel at Mach numbers 2.0 and 3.5. Since $C_{Y\beta}$, $C_{Y\alpha}$, and C_{Yp} are quite linear with β in this Mach number region, data are presented for $M=3.5$ only (wing tips extended and retracted) on Figures 6.22 and 6.24. These Figures are representative of the variation of these coefficients versus β throughout the supersonic region. Figures 6.15 through 6.20 present $C_{Y\beta}$, $C_{Y\alpha}$, and C_{Yp} versus α for $M=2.0$ and 3.5, and for wing tips extended and retracted.

Lateral - directional stability at low hypersonic speeds were obtained from wind tunnel tests on the model 344-2005, a similar

configuration, at Mach numbers of 8.08 (AFDC-3, BAC 13) and 9.6 (LRC 11-Inch, Test 47 in air). The data have been adjusted for vertical tail size, planform and cant angle (Figure 3.1.1). The results are presented in Figure 6.23.

High hypersonic speed data were obtained at Mach 17.8 (LRC 11-Inch, Test 47 in helium) and Mach 16 and 22 (FEST 006). The helium data were obtained on a model identical to the low hypersonic speed model. The hot shot data, however, were on a cone-cylinder body configuration, and additional corrections had to be made for the body shape. This was performed by comparing the cone-cylinder and S4-2005 body effects at Mach 9.6 and adjusting the Mach 22.0 data accordingly. Figure 6.24 shows the lateral - directional stability characteristics at high hypersonic speeds. Characteristics at angles of attack above 20° were extrapolated from lower Mach number data.

No information is currently available on the influence of altitude (i.e., Reynolds number) variation at high hypersonic speeds on the lateral - directional force-moment characteristics. Until data become available, it is assumed that the effect of altitude will be negligible on C_N , C_l , and C_y . The primary effect of altitude will be to increase boundary layer thickness. However, the areas of the glider that are most important in establishing directional stability are the glider fore-body and vertical tail; regions which are not expected to have significant boundary layer growth because of short boundary layer runs.



BODY AXES

2025

$S = 34.5$

$b = 19.7$

CGS - 15000 INCHES

WING TIPS RETRACTED

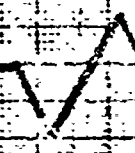
WING TIPS EXTENDED

$\gamma = 0$

$\gamma = 0$

$\gamma = 35^\circ$
 $\gamma = 40^\circ$
 $\gamma = 45^\circ$

$\gamma = 0^\circ$
 $\gamma = 35^\circ$
 $\gamma = 45^\circ$



8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

FIG 0.1

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104-0

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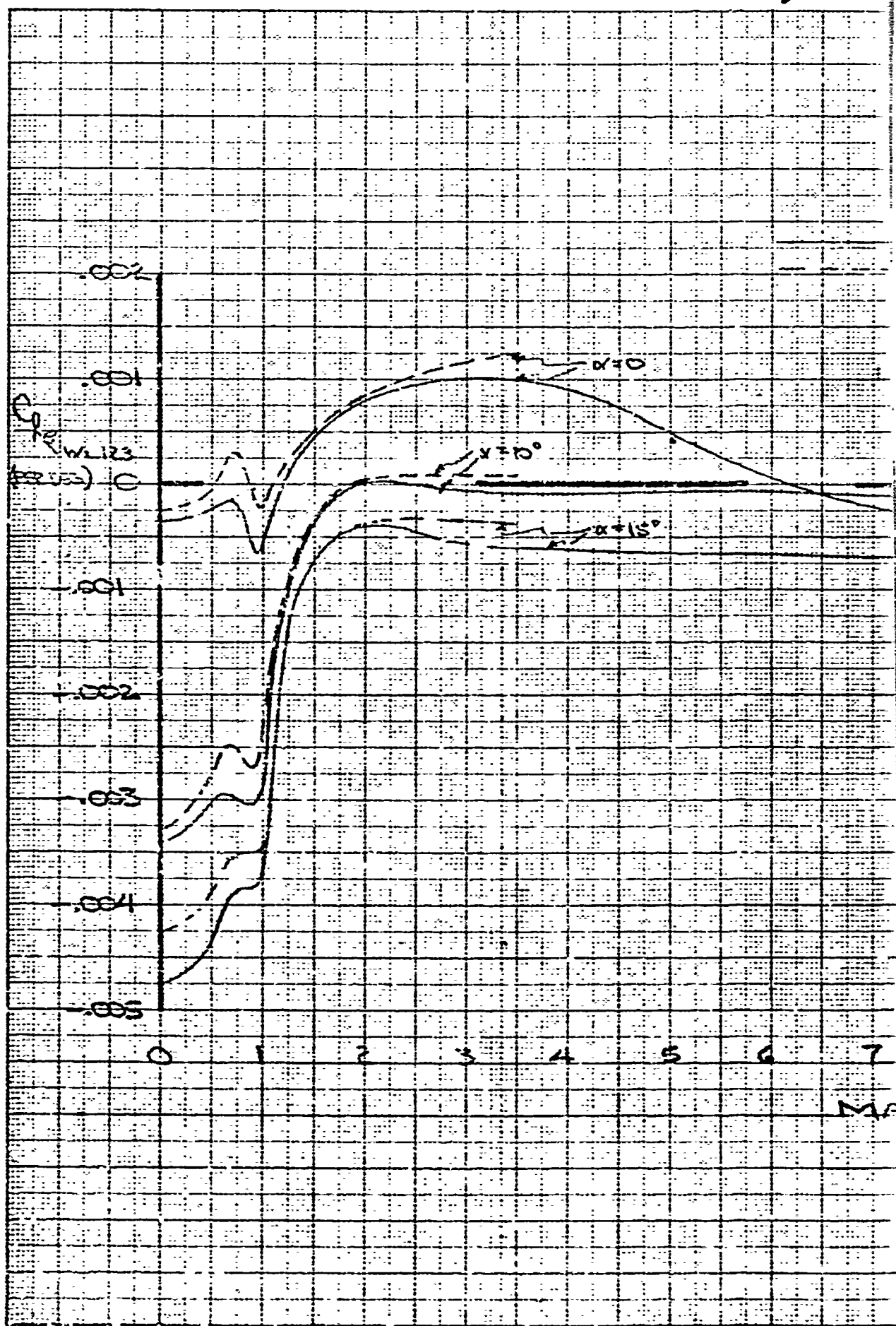
DIRECTIONAL STABILITY

2055

07-2174

104-0

0.4



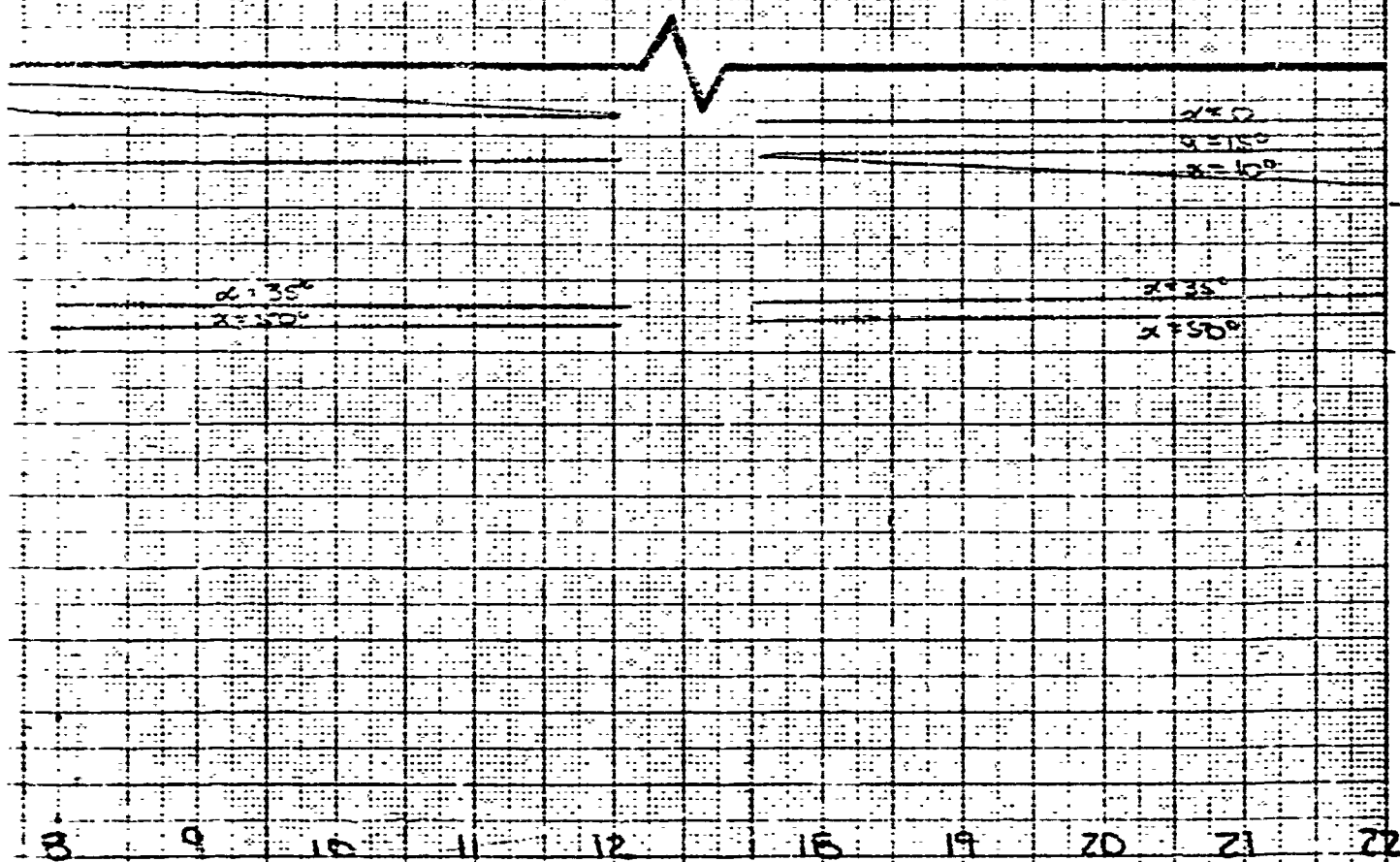
BODY AXES

E44-2035

$S = 34.3$ ft
 $b = 19.7$ ft
 $CG = WL125$

WING TIPS RETRACTED
 WING TIPS EXTENDED

$\beta = 0$
 $\delta = 0$

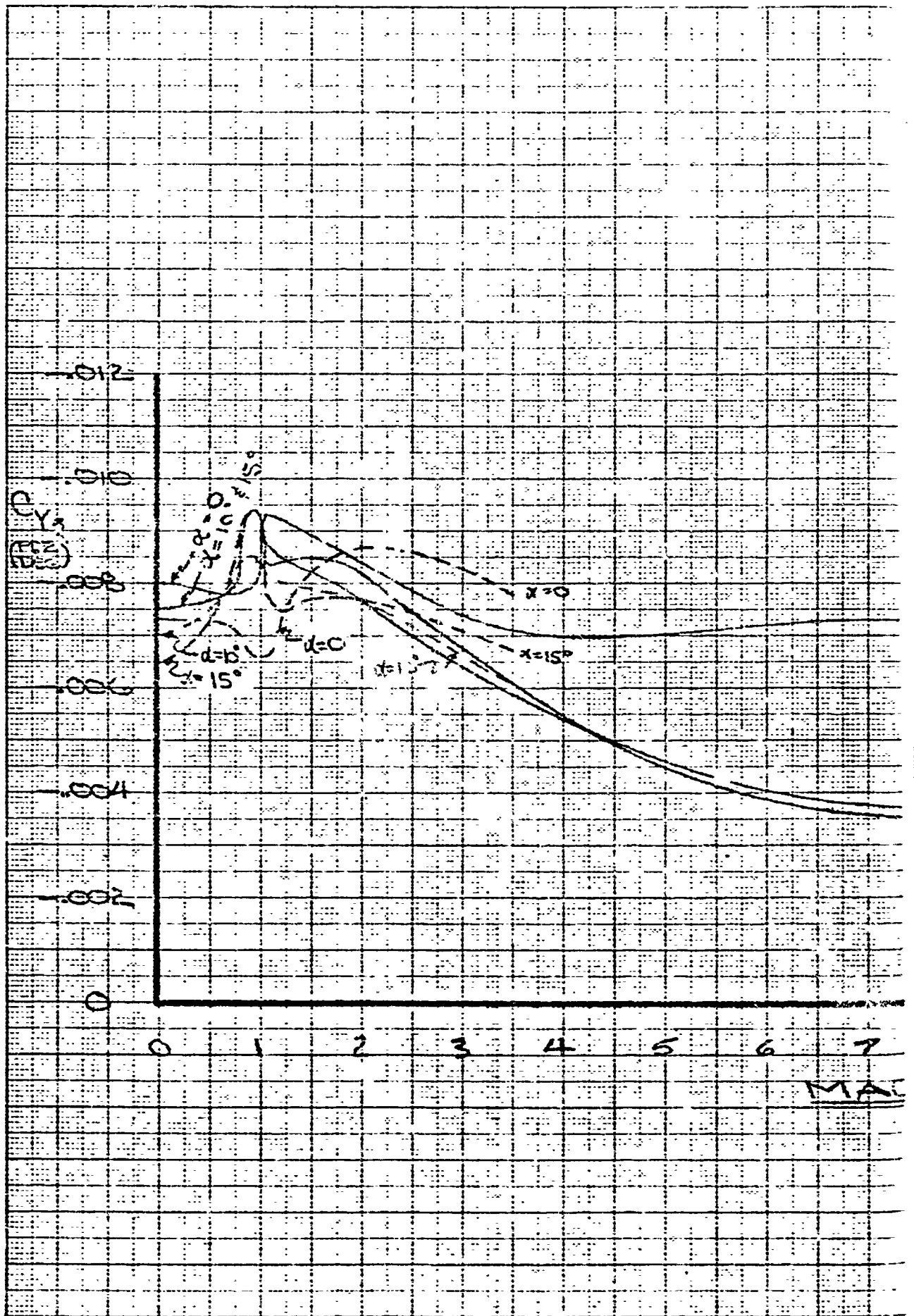


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LATERAL STABILITY

FIG. 6.2
 E44-
 2035
 D2-8174
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 6.5



644-2055

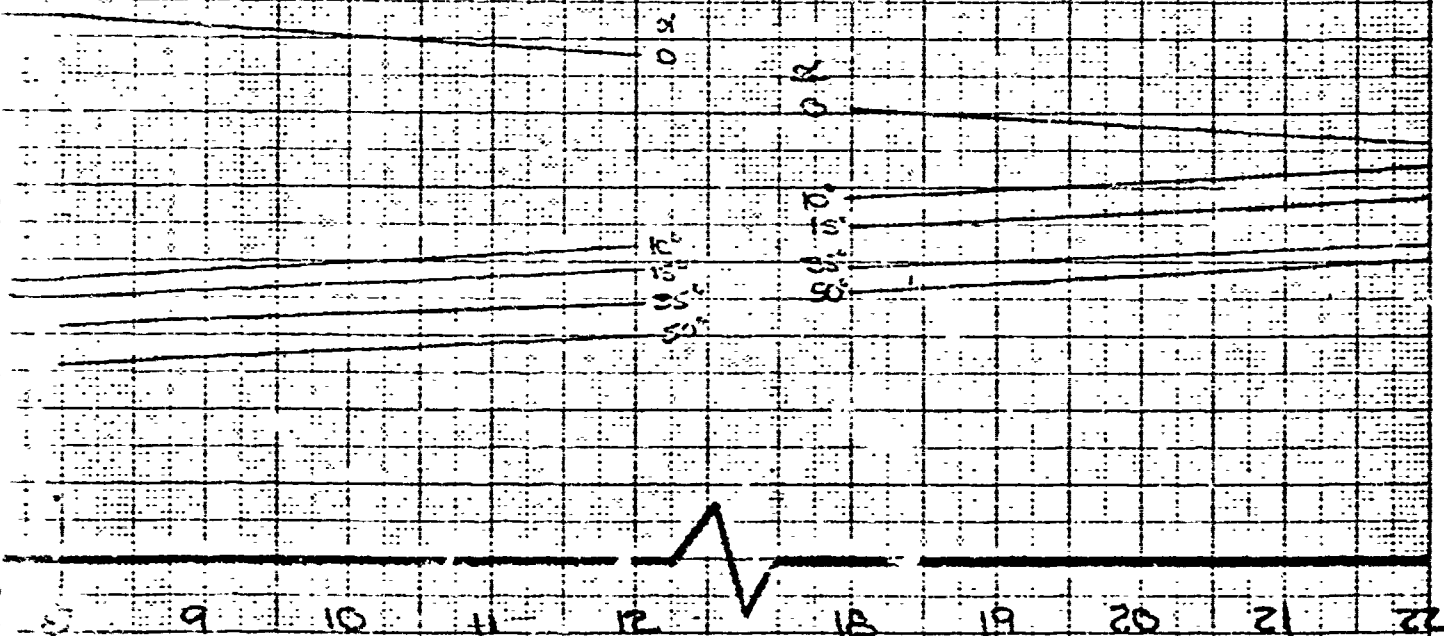
ST-243-1
67 19.7

E: 0

E: 10

WING TIPS RETRACTED

WING TIPS EXTENDED



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APP'D			

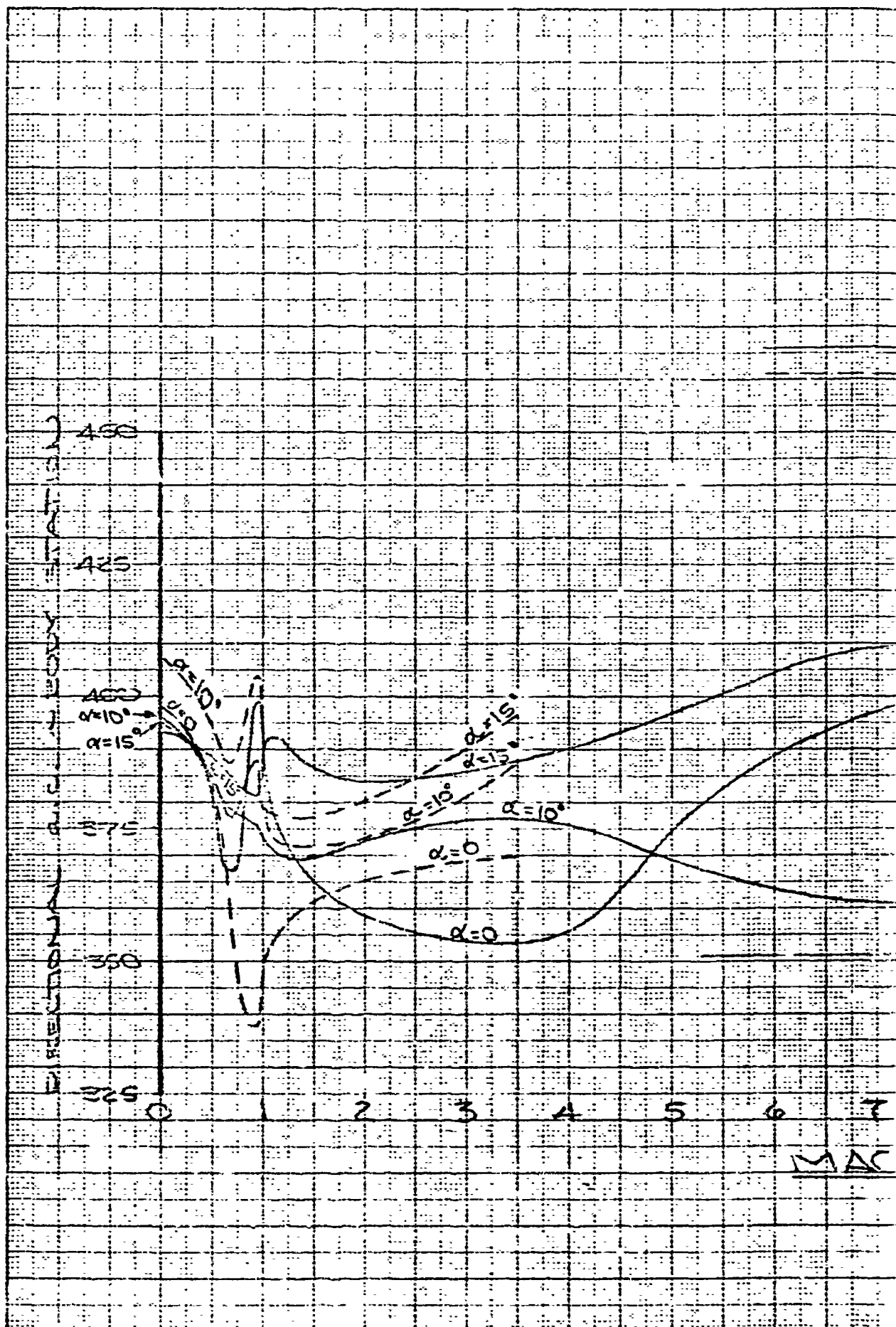
SIDE FORCE

FIG 6.2

644 -
2055

02-8174

6.6



BODY AXES

844-2035

$S = 343 \text{ ft}^2$

$b = 19.7 \text{ ft}$

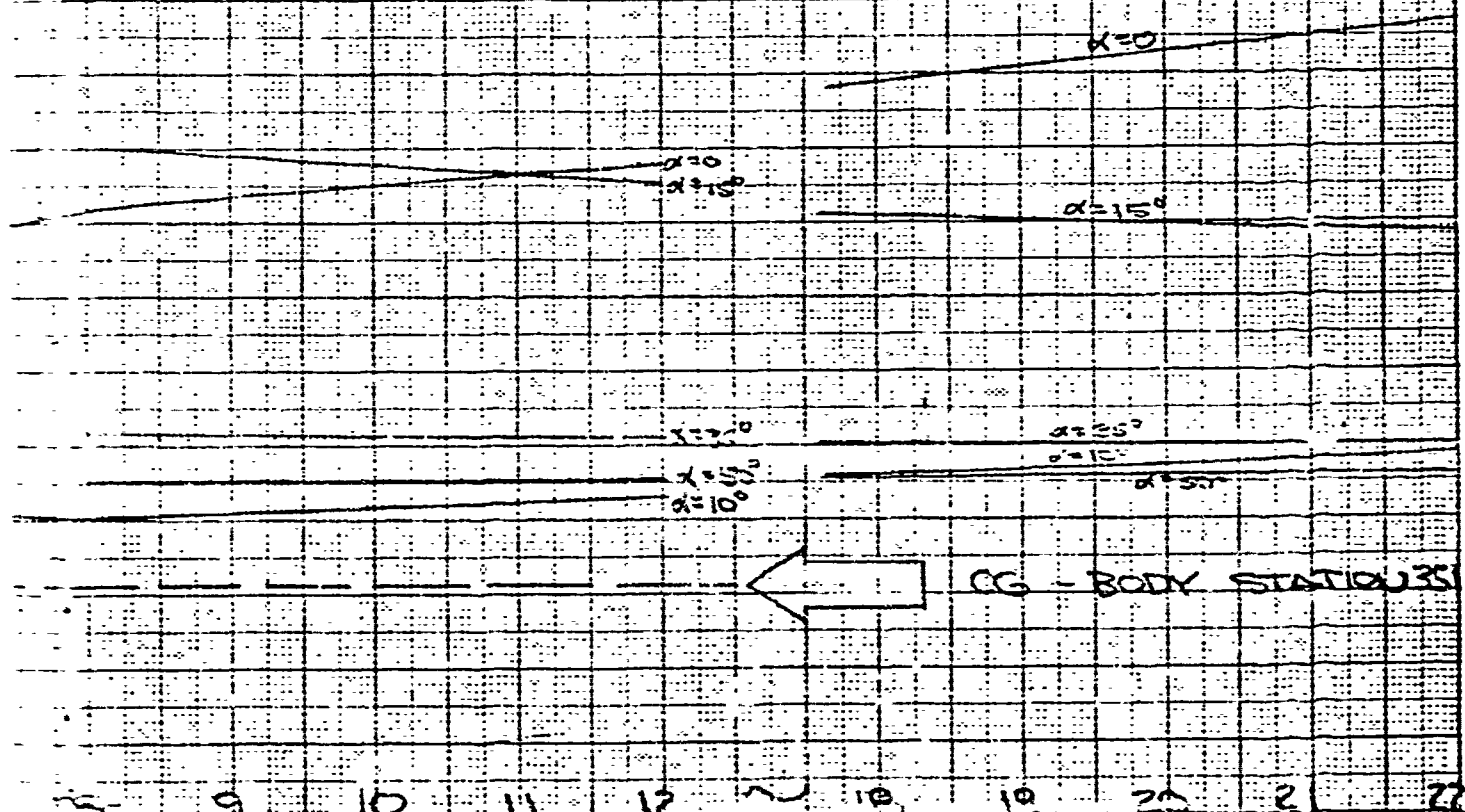
CG = .43 MAC = BODY STA 351

$\beta = 0$

$\delta = 0$

WING TIPS RETRACTED

WING TIPS EXTENDED



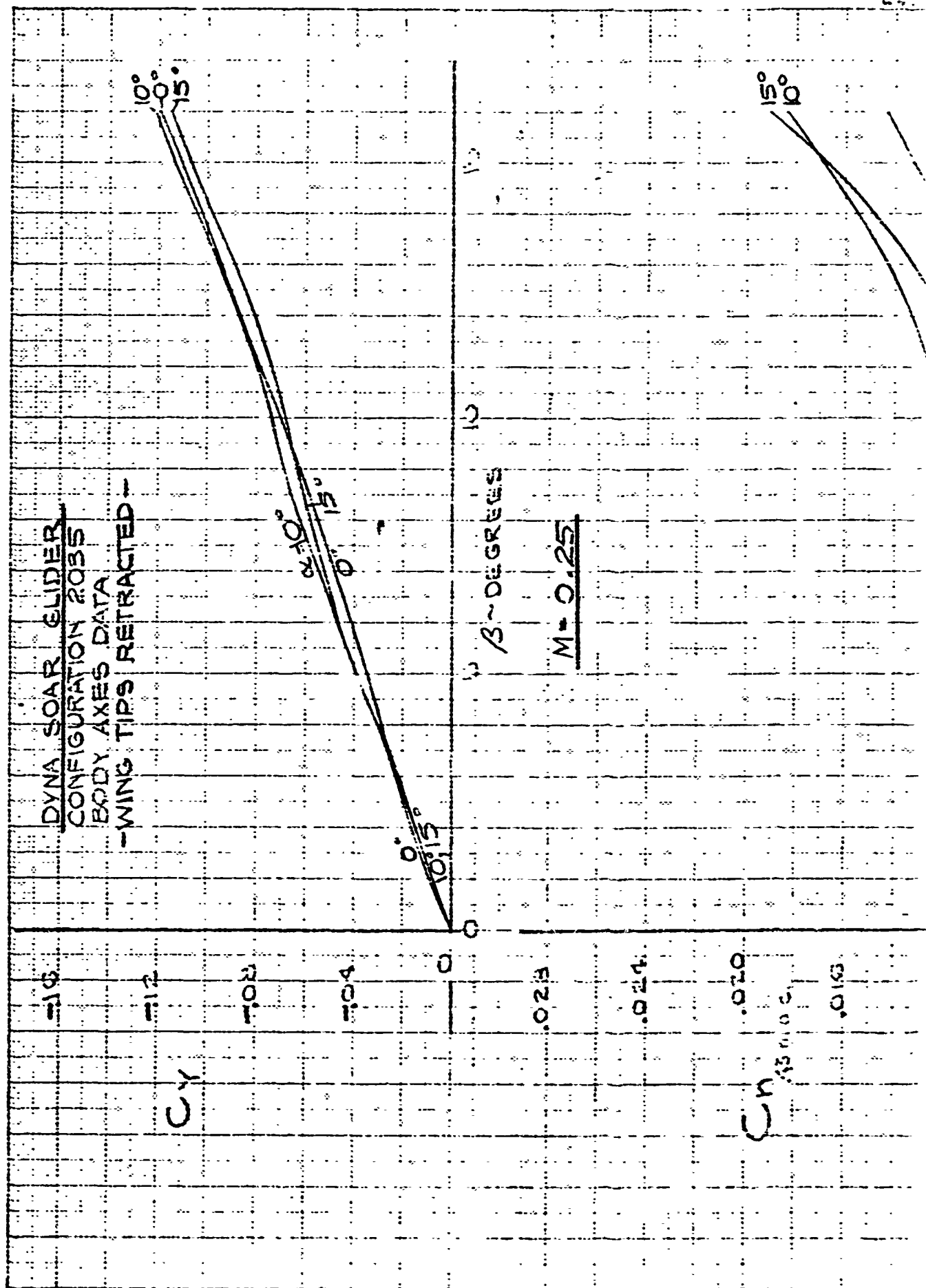
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

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ATVD				

DIRECTIONAL a.c.

FIG 6.4
844-
2035
02-8174
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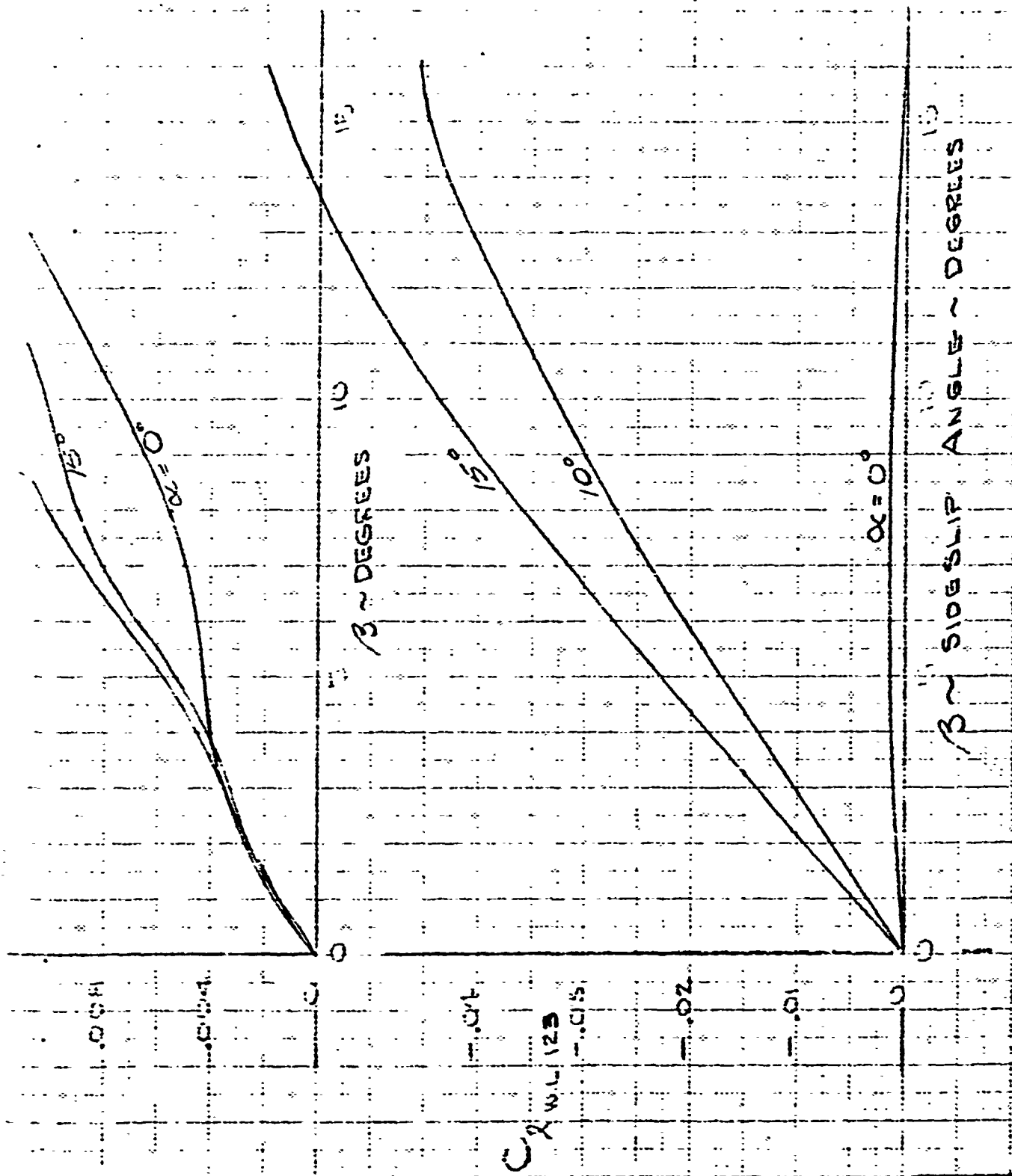
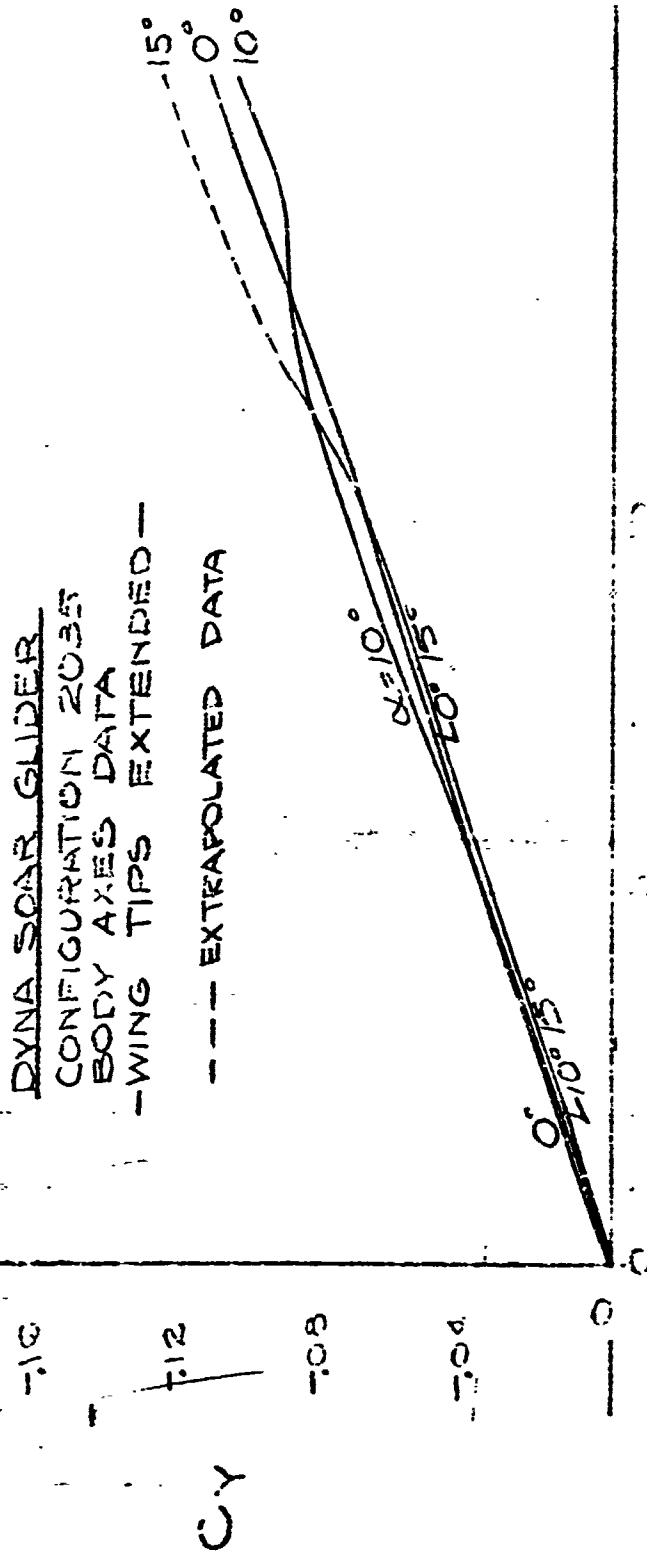


FIG 6.5

RKR/PTV 12-7	LATERAL - DIRECTIONAL	844 -
	STABILITY CHARACTERISTICS	2035
	- WING TIPS RETRACTED -	02-874
	- LANDING SPEED -	6.8

DYNA SOAR GLIDER
 CONFIGURATION 2035
 BODY AXES DATA
 -WING TIPS EXTENDED-
 --- EXTRAPOLATED DATA



EXTRAPOLATED

M=0.25

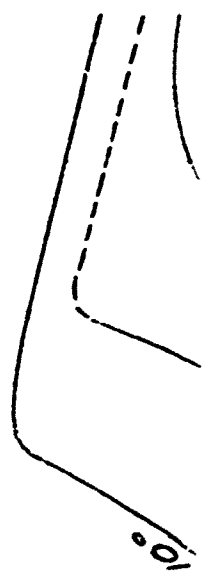
.023

.024

.020

C_n
 .43 m.o.c.

.013



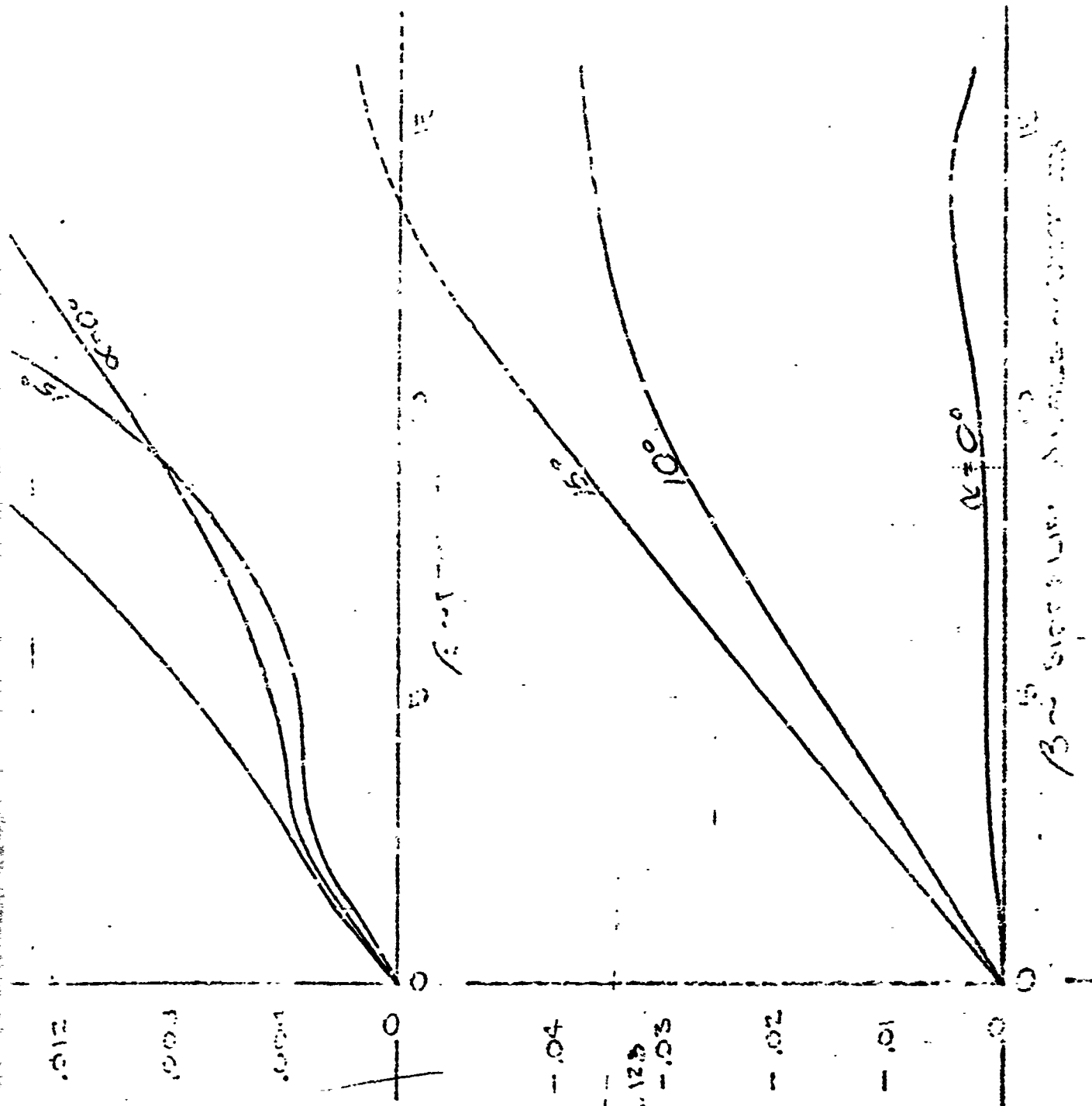
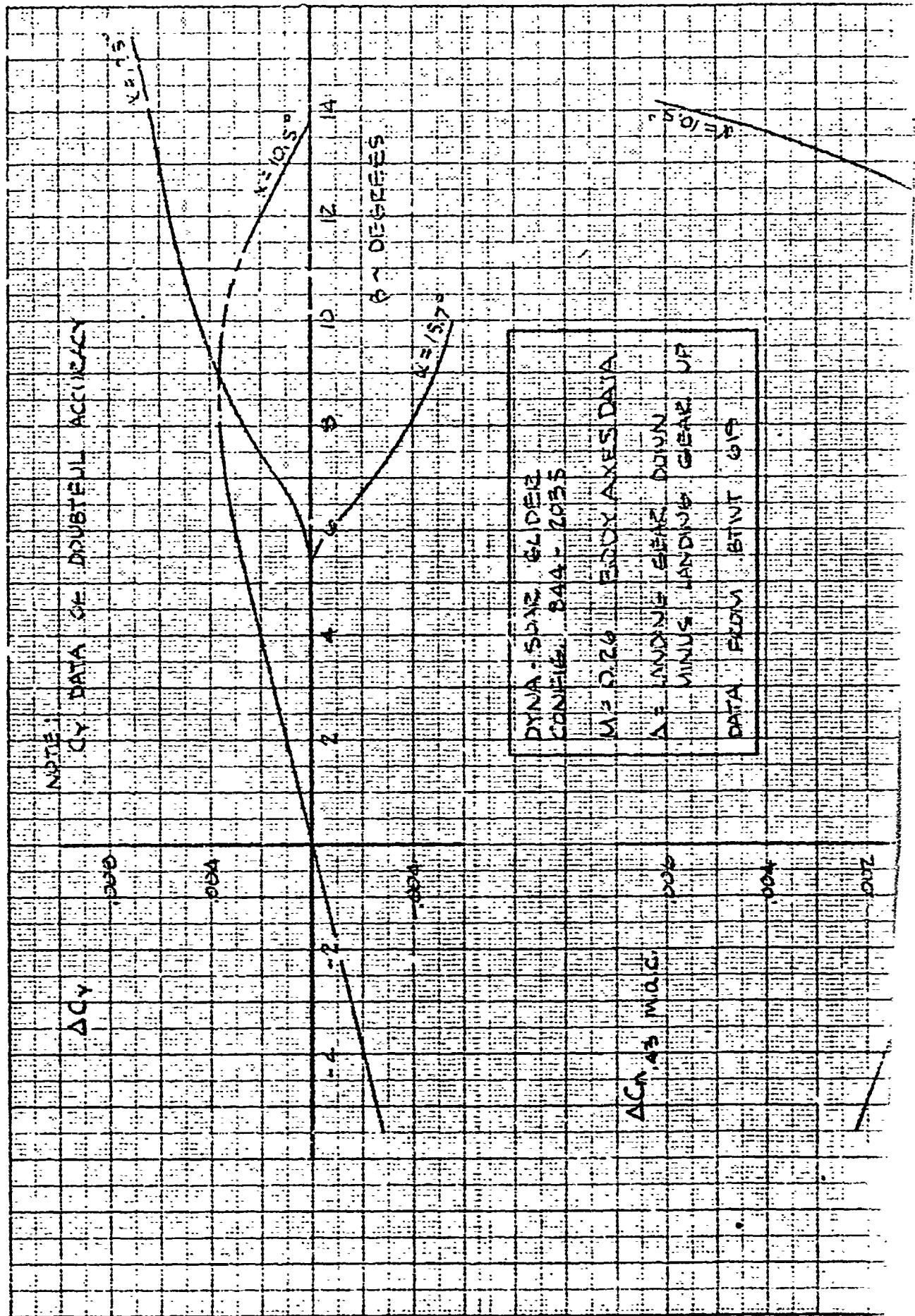
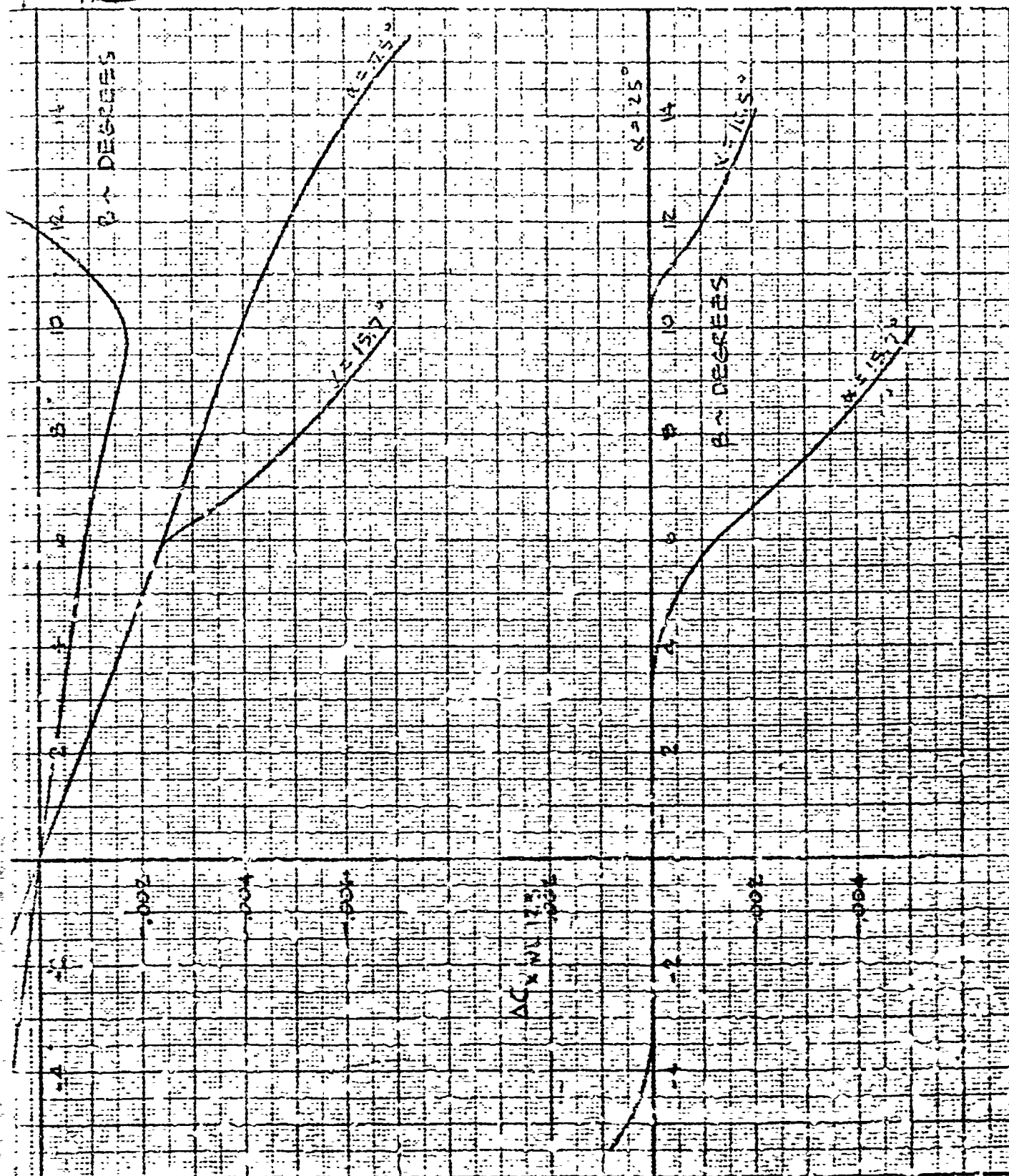
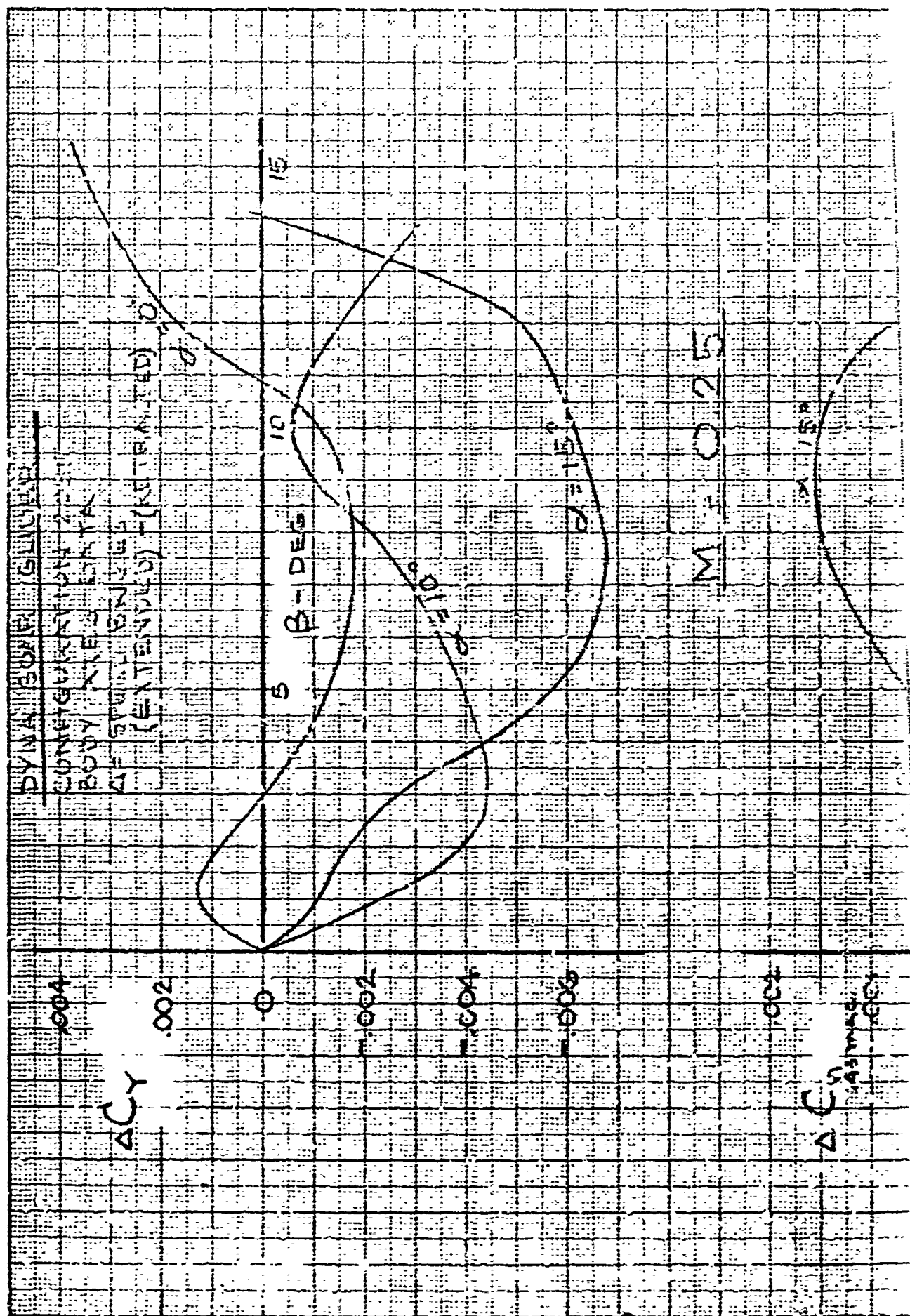


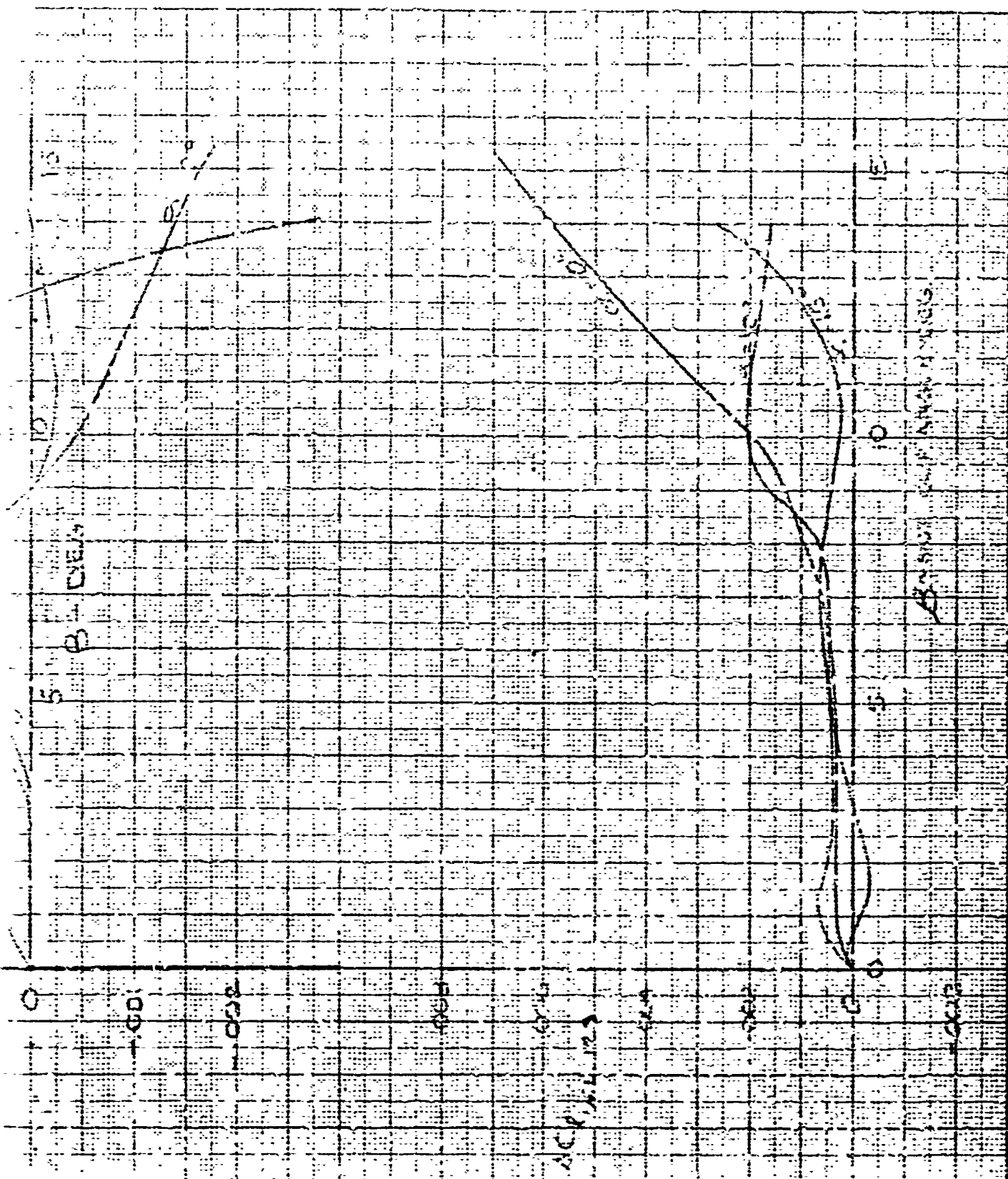
FIG 6.2					
844-2035	LATERAL - DIRECTIONAL STABILITY CHARACTERISTICS				
02-8174	— WING TIPS EXTENDED —				
PAGE 6.9	— LANDING SPEED —				
	CALC	REVIEW	12 5	REVISED	DATE
	CHECK				
	APPRO				
	APPRO				





DATE	MOUSE	12-9-60	REVISED	DATE	EXPERIMENTAL REPORT OF	FIG 6.7
BY					LOUIS G. R.	844-7035
APPROVED						D2-8174
					BOEING AIRPLANE COMPANY	PAGE
					SEATTLE & WASHINGTON	6.10





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96	96	96	96	96	96	96
97	97	97	97	97	97	97
98	98	98	98	98	98	98
99	99	99	99	99	99	99
100	100	100	100	100	100	100

FIG 60
344-
2035
D2-4174
PAGE
611

DYNA SOAR GLIDER

MODEL 844-2035

BODY AXES DATA

—WING TIPS RETRACTED—

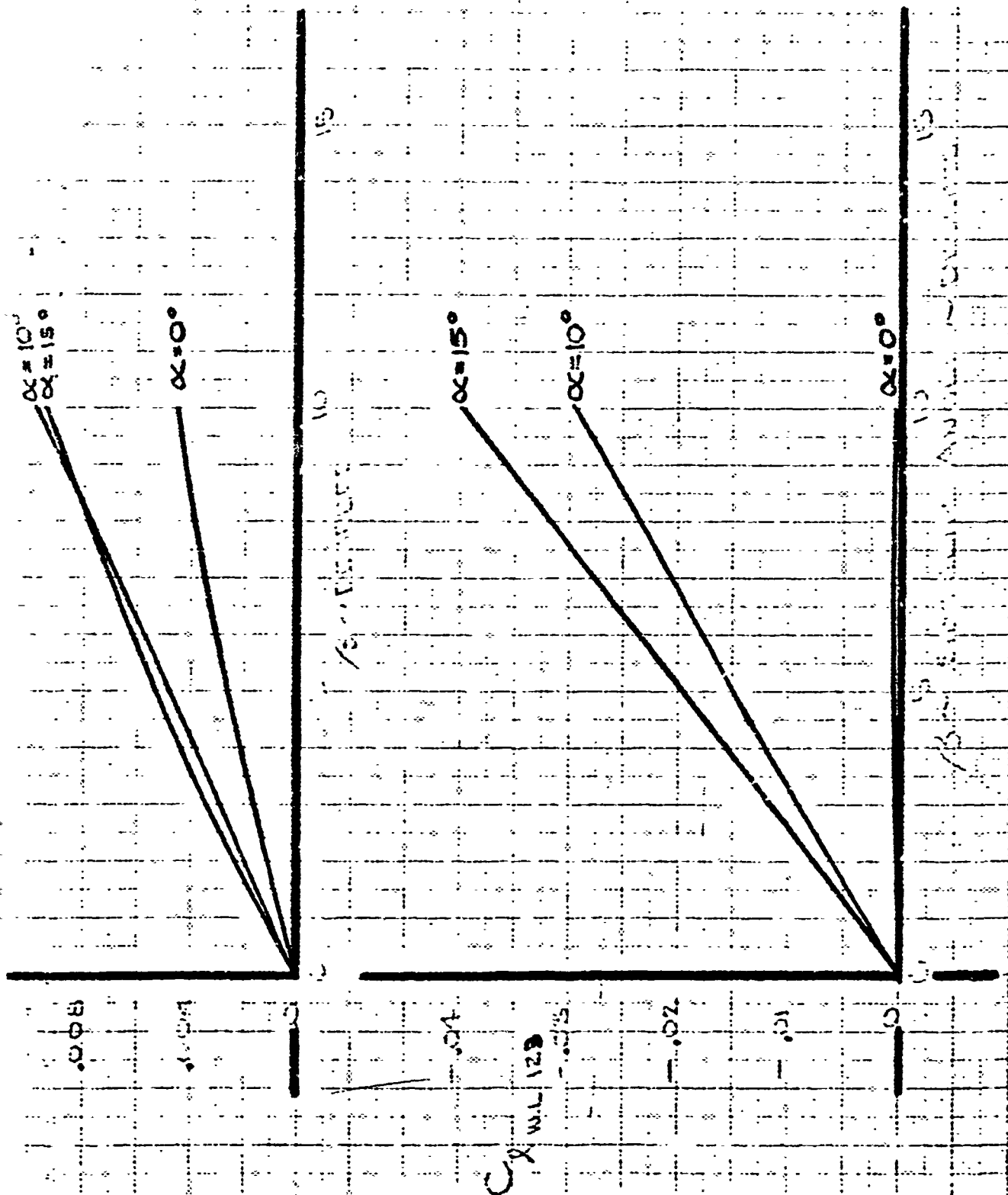
C_Y

$\alpha = 10^\circ$
 $\alpha = 15^\circ$

$M = 0.70$

C_D

1/3 MAC



RKR	12-2060	LATERAL-DIRECTIONAL	FK 6.9
		STABILITY CHARACTERISTICS	844 -
		WING TIPS RETRACTED	2055
		<u>M = 0.70</u>	02-8174
			6.12

DYNA SOAR GLIDER
MODEL 644-2035

BODY AXES DATA

— WING TIPS EXTENDED —

C_Y

0.10

0.12

0.14

0.16

0

$\alpha = 10^\circ$
 $\alpha = 15^\circ$
 $\alpha = 0^\circ$

0 10 20 30 40 50 60 70 80 90 100

0.020

0.024

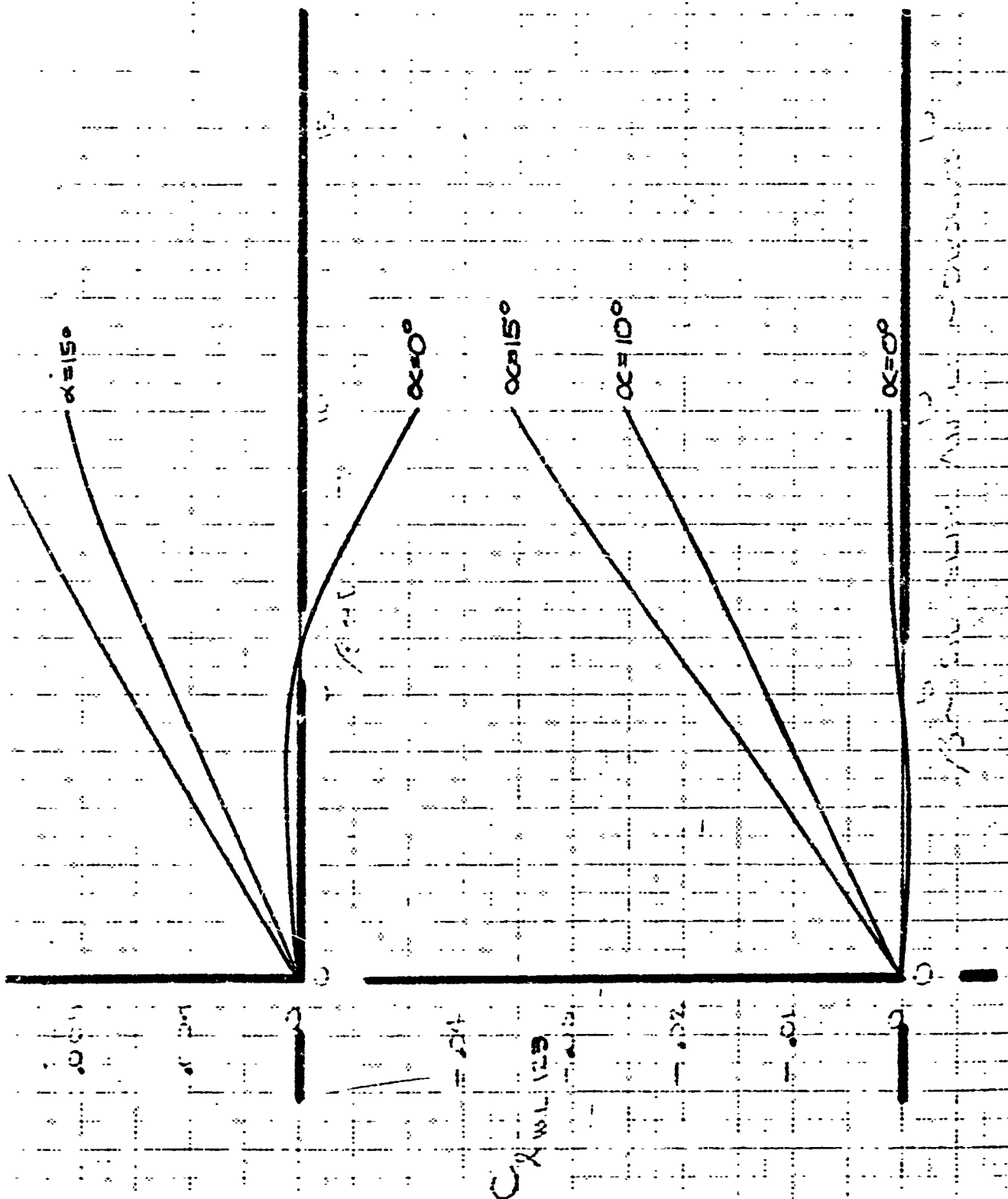
0.028

0.032

0.036

C_N

$M = 0.70$



RKR 12-20-64

LATERAL - DIRECTIONAL
STABILITY CHARACTERISTICS
— WING TIPS EXTENDED —

$M = 0.70$

FIG 6.10

244-
2095

D2-8174

6.13

115

DYNA SOAR GLIDER
 MODEL 844-2035
 BODY AXES DATA
 — WING TIPS RETRACTED —

$\alpha = 10^\circ$
 $\alpha = 15^\circ$

$M = .95$

$\alpha = 0^\circ$
 $\alpha = 15^\circ$

-.10

-.12

-.100

-.04

0

.023

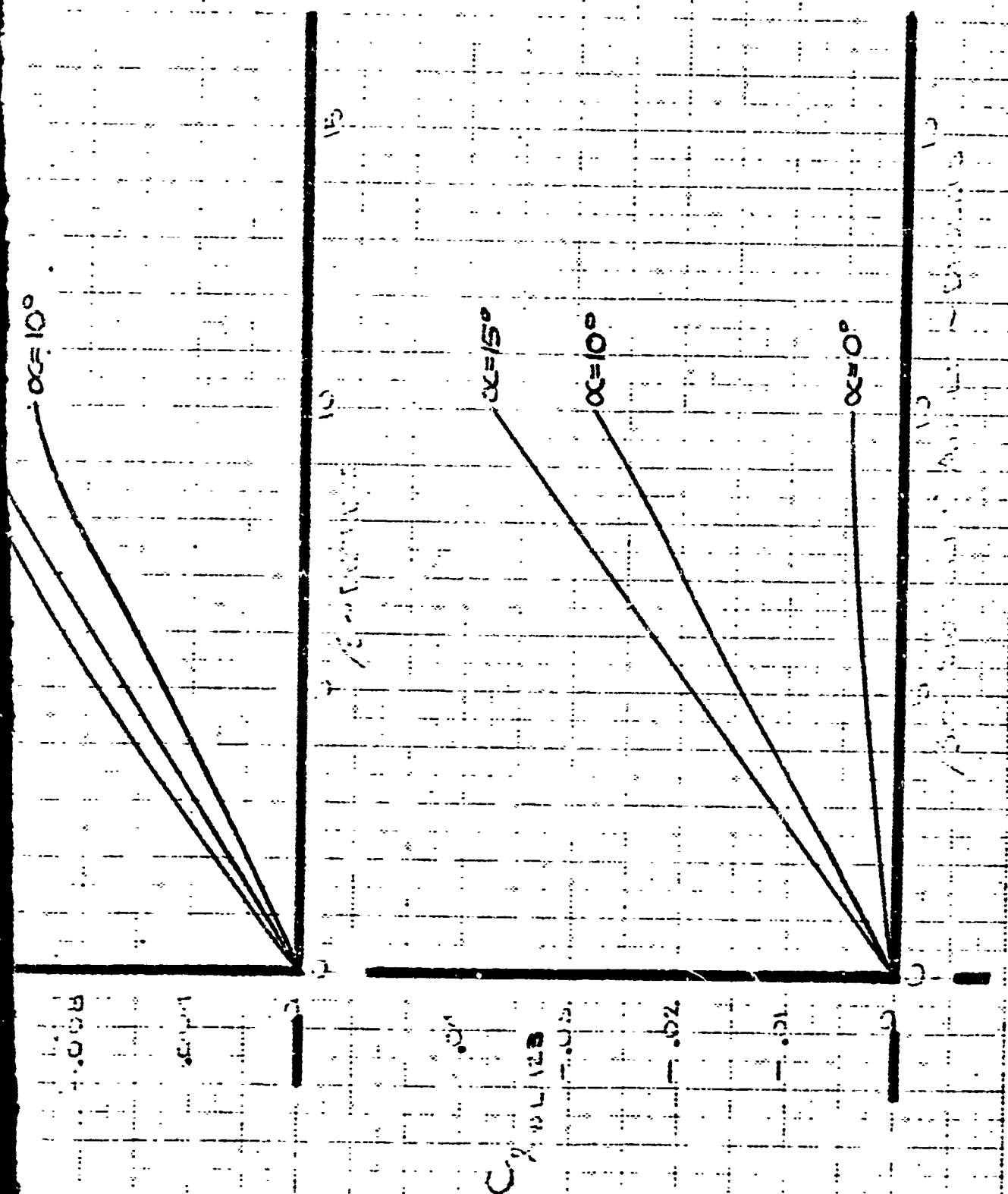
.024

.020

15 min.

.016

.011



RKR

12-22-60

LATERAL-DIRECTIONAL
STABILITY CHARACTERISTICS
WING TIPS RETRACTED

M = .95

117

FIG 6.11

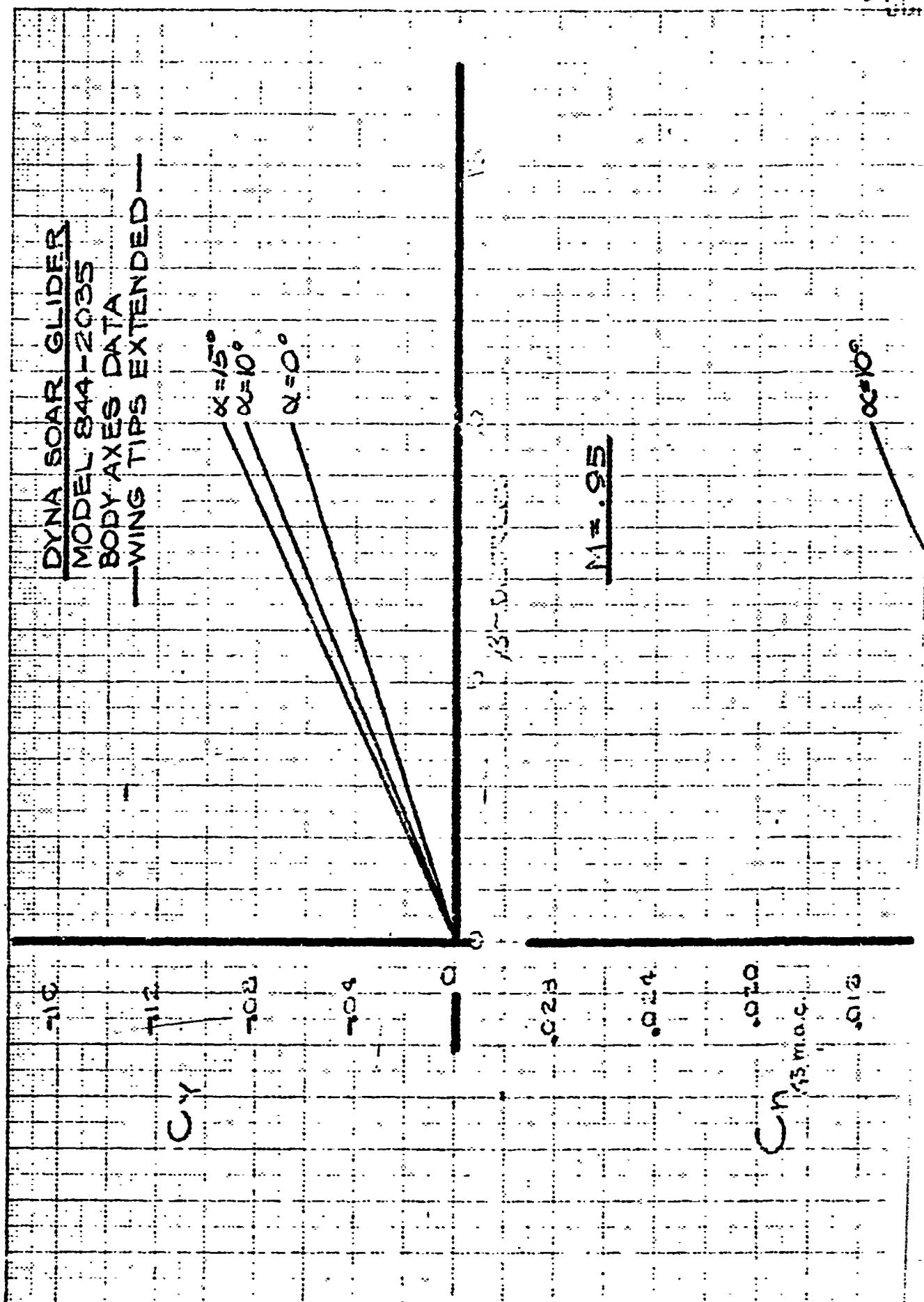
844-

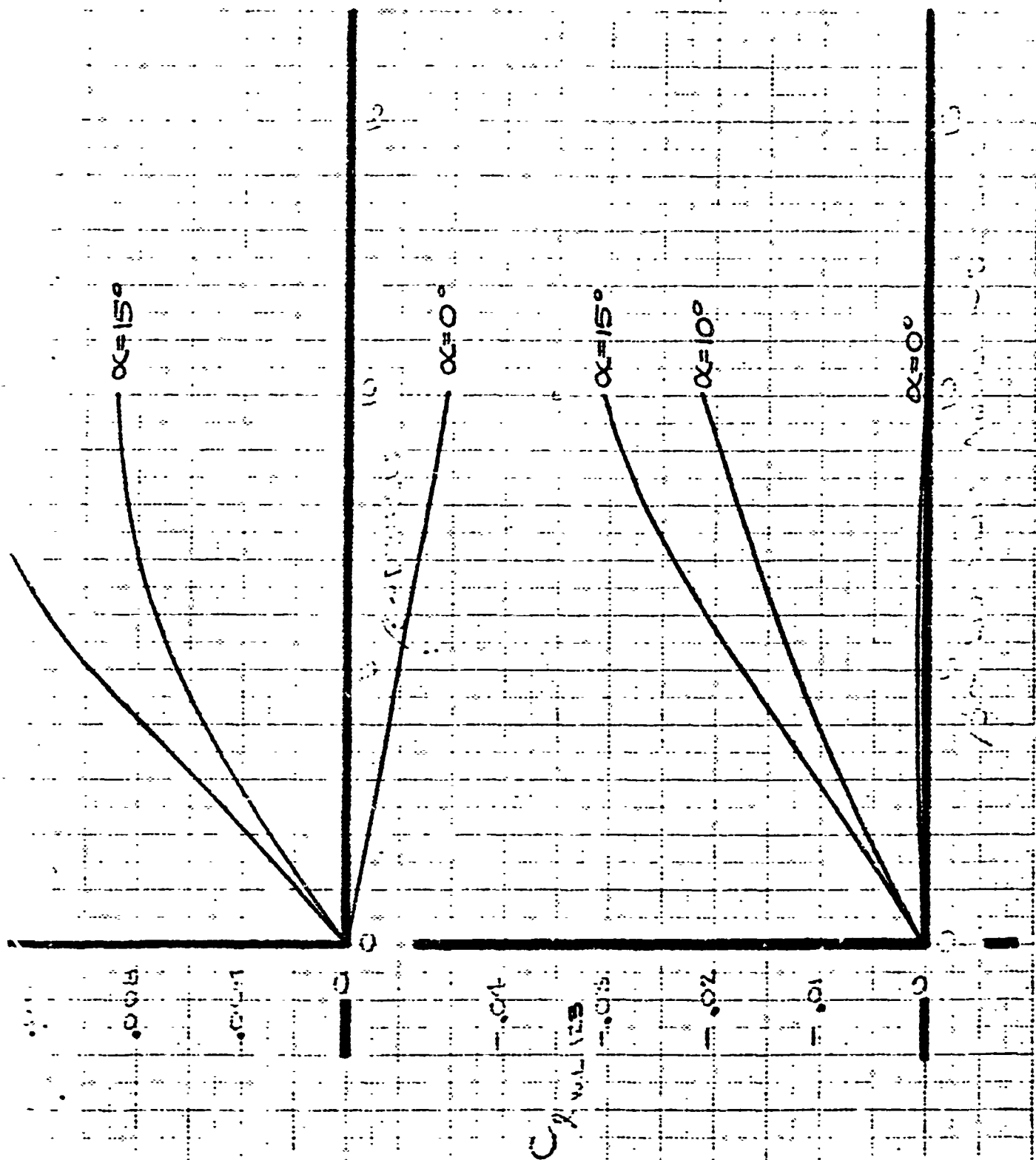
2055

D2-8174

6.14

DYNA SOAR GLIDER
MODEL 844-2035
 BODY AXES DATA
 — WING TIPS EXTENDED —





RKR/NTU 12-22-60

LATERAL - DIRECTIONAL

STABILITY CHARACTERISTICS

- WING TIPS EXTENDED -

M = .95

FIG 6.12

6-14-

2035

D2-8174

6.15

DYNA SOAR GLIDER
 MODEL B44-2035
 BODY AXES DATA
 -- WING TIPS RETRACTED --

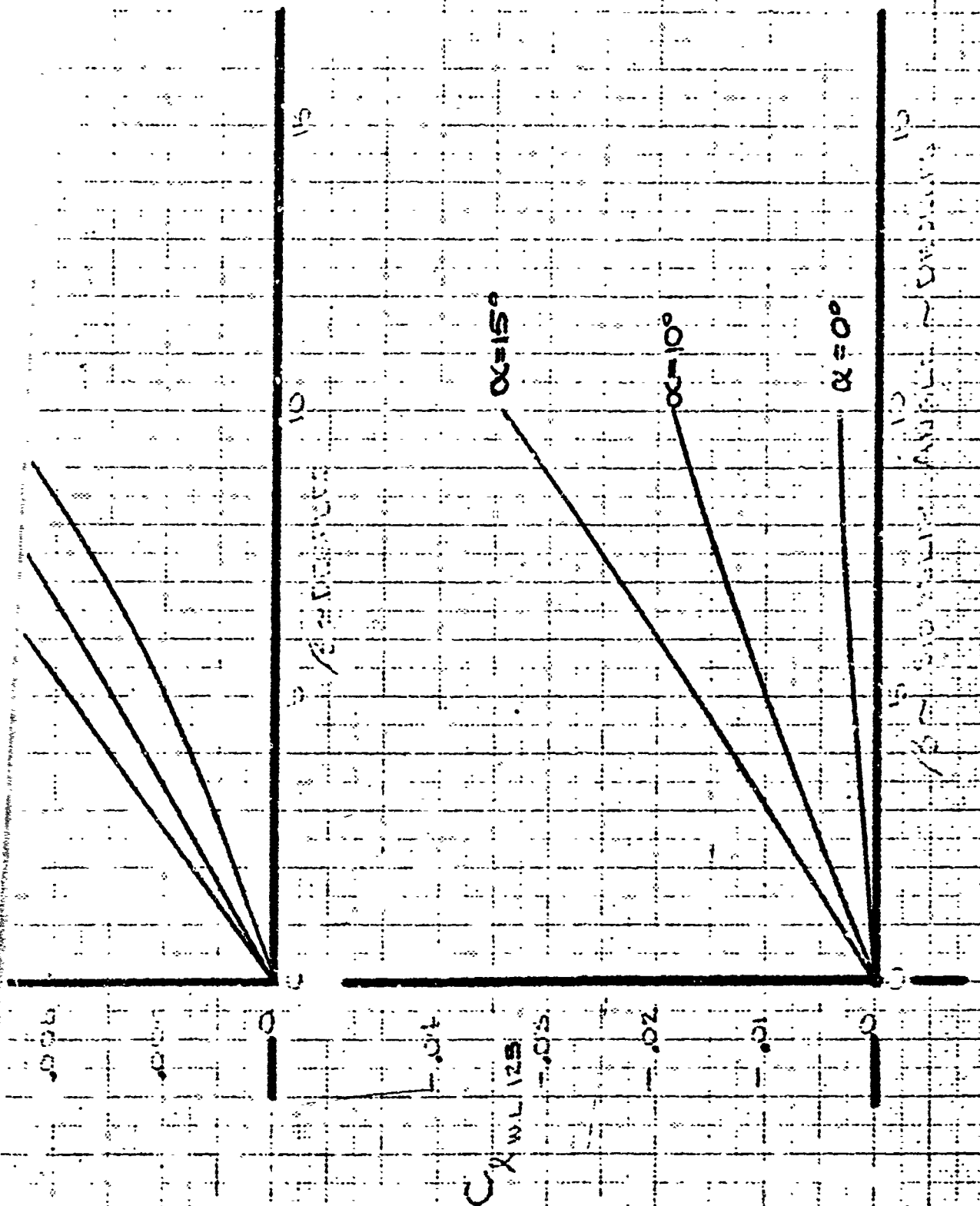
$\alpha = 0^\circ$
 $\alpha = 10^\circ$
 $\alpha = 15^\circ$

$M = 1.05$

$\alpha = 15^\circ$

$\alpha = 0^\circ$

$\alpha = 10^\circ$



LATERAL - DIRECTIONAL
STABILITY CHARACTERISTICS
WING TIPS RETRACTED

$M = 1.05$

FIG. 6.13

844-2005

02-8174

6.16

DYNA SOAR GLIDER

MODEL 844-2035

BODY AXES DATA

— WING TIPS EXTENDED —

$\alpha = 10^\circ$
 $\alpha = 8^\circ$

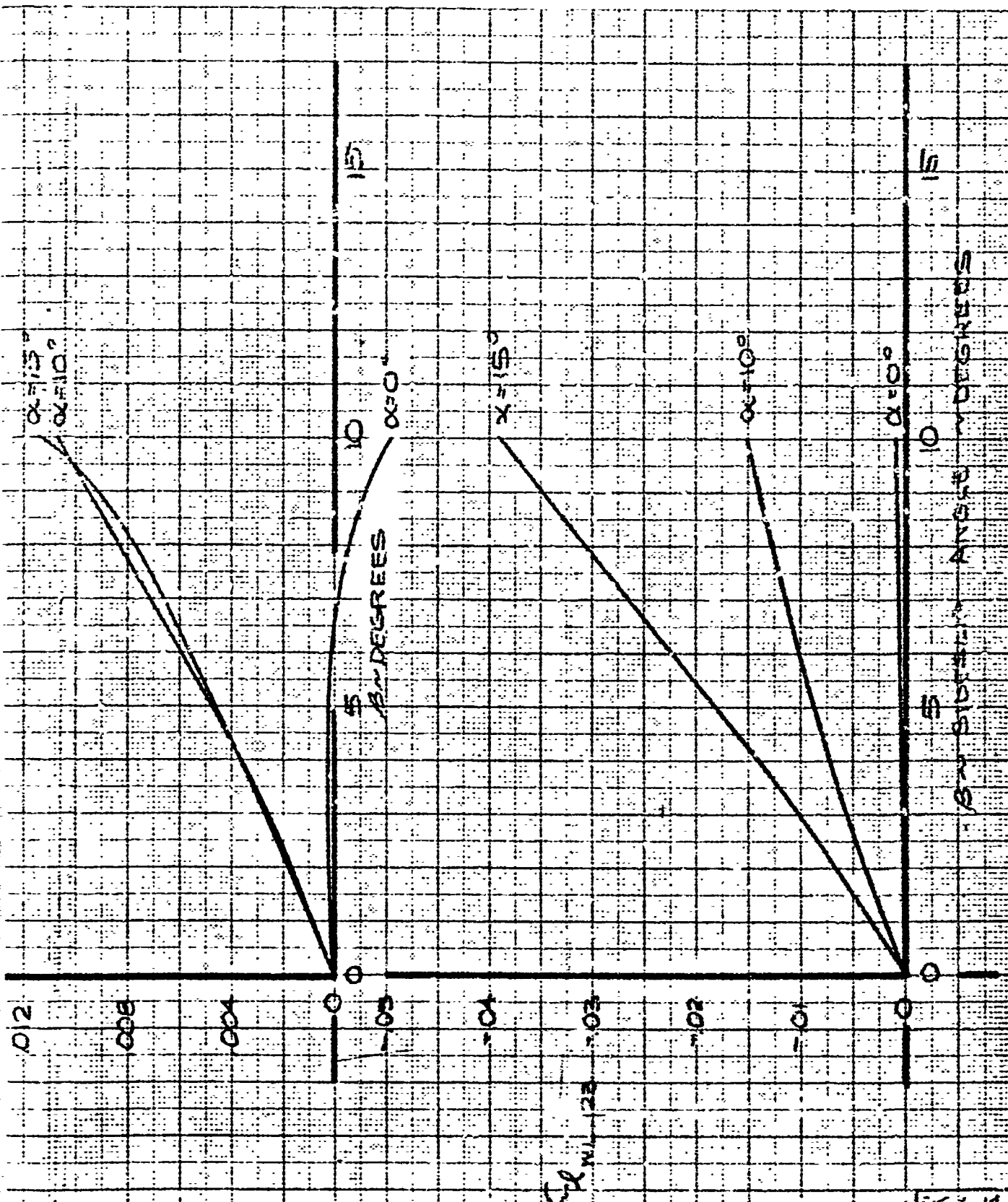
5 10 15
DEGREES

$M = 1.05$

C_x

C_{DAS}

CONFIDENTIAL



CALC	RKR	210771	REVISED	DATE
CHECK				
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LATERAL - DIRECTIONAL
STABILITY CHARACTERISTICS

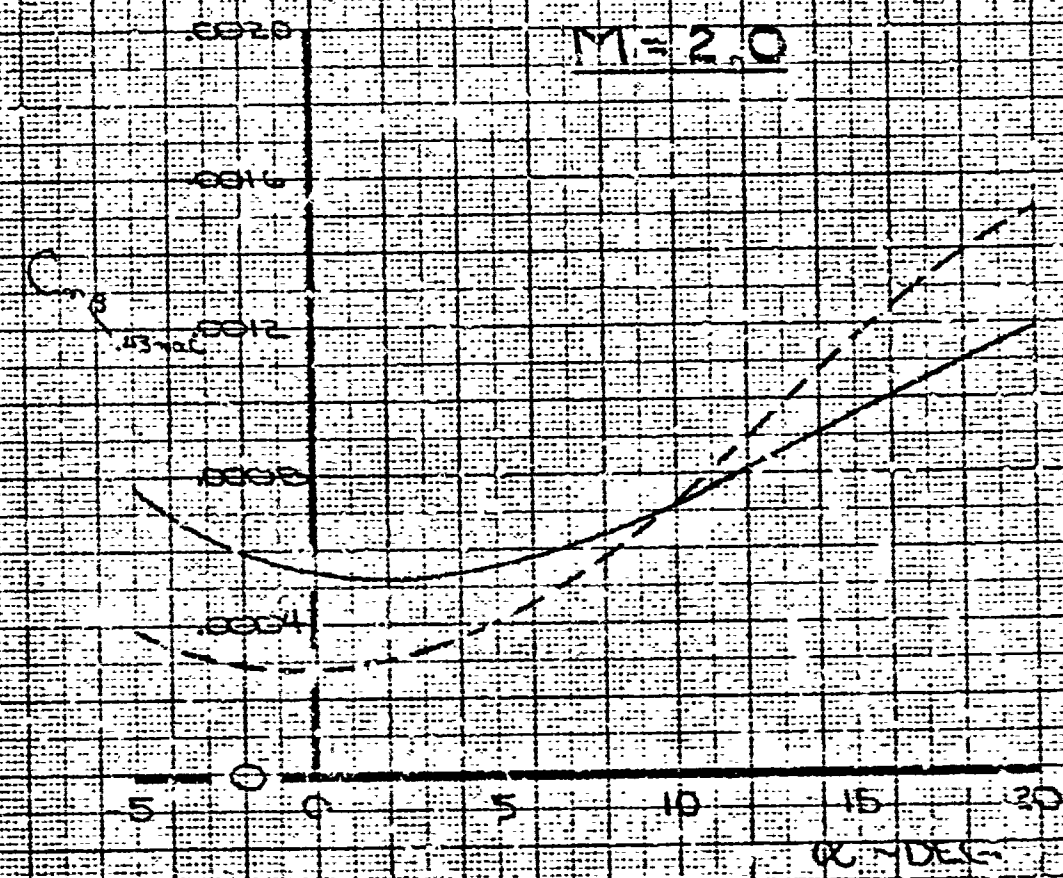
TWING TIPS EXTENDED -
M=1.03

FIG 6-14
20035
02-8174
PAGE 6.17

84-1-1035

$S = 24.3 \text{ m}^2$
 $b = 19.7 \text{ ft}$
 $C_D = 0.025$

WINGTIPS EXTENDED
 RETRACTED



CALC	CHK	12-2-0	REVISED	DATE
CHECK				
APR				
APR				

DIRECTIONAL STABILITY
 M=2.0
 BOEING AIRPLANE COMPANY

FIG. 1.15
 2035
 D2-8174
 PAGE 6.18

244-2035

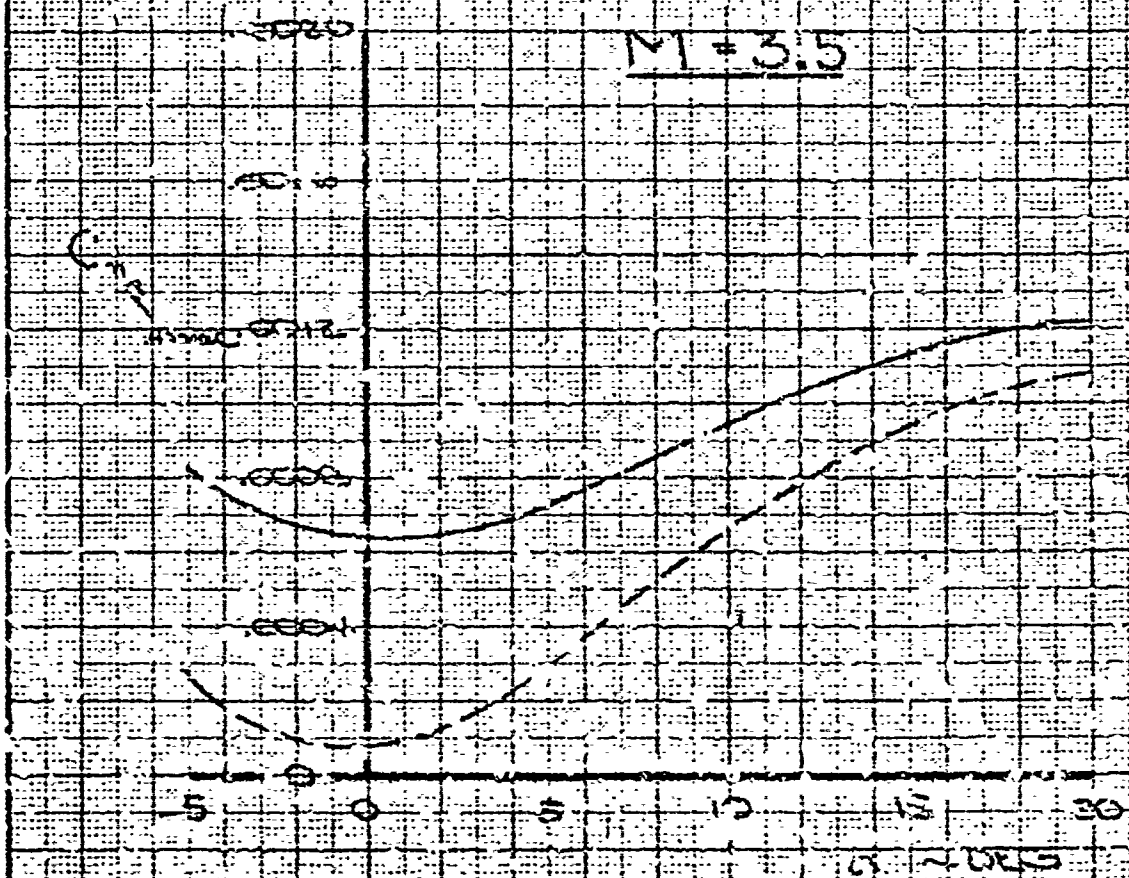
$S = 845 \text{ ft}^2$

$b = 19.7 \text{ ft}$

$CG = \text{BODY STA } 33.43 \text{ in}$

WING TIPS EXTENDED
RETRACTED

$M = 3.5$



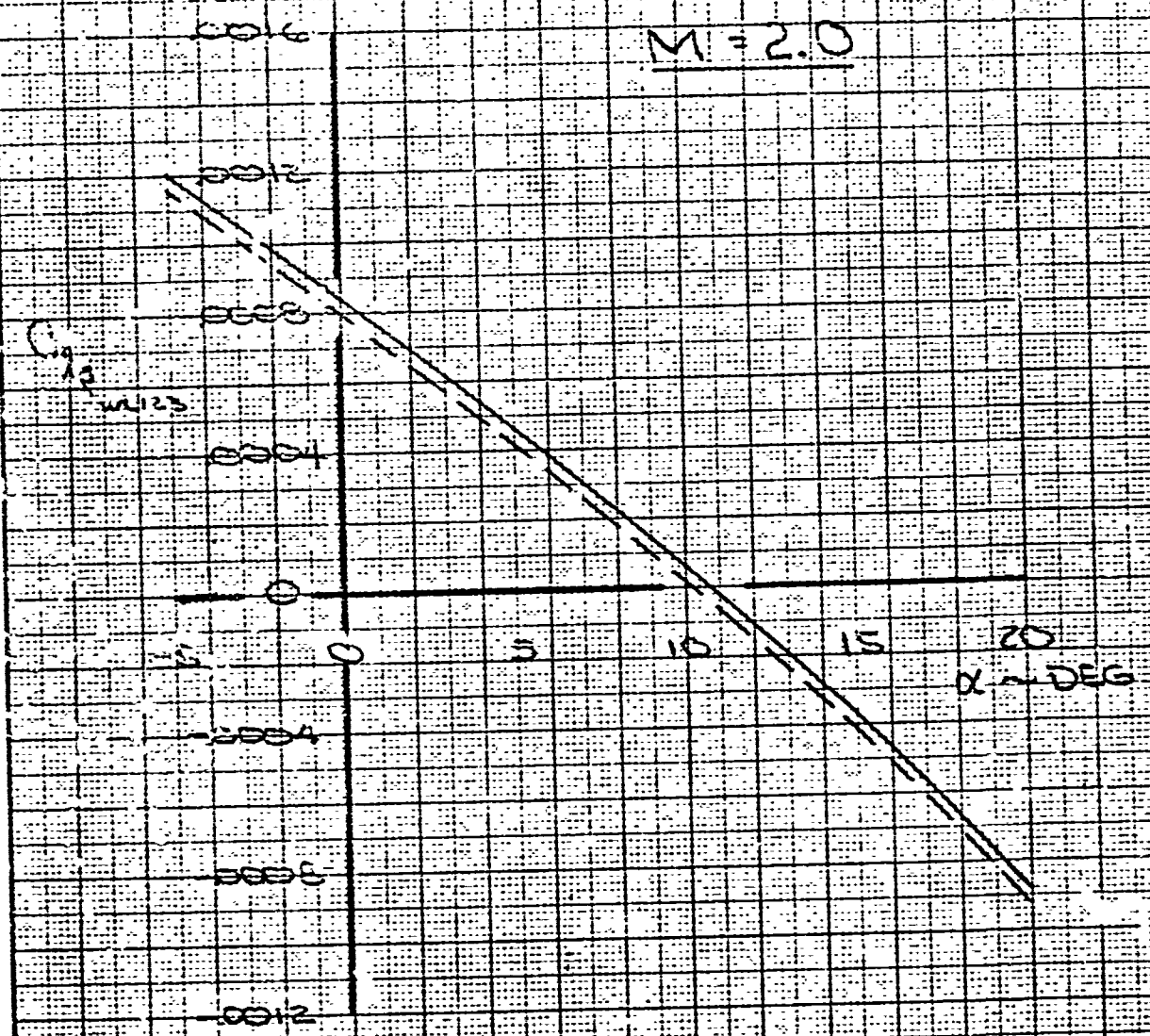
CALC	APR	12-0	REVISED	DATE	DIRECTIONAL STABILITY $M = 3.5$ 125 BOEING AIRPLANE COMPANY	FIG. 6.16 244- 2035 DE-6174 P. 65 6.19
CHECK						
APR						
APR						

E44-2035

$S = 343 \text{ FT}^2$
 $b = 19.75 \text{ FT}$
 $CG = W/123$

—— WING TIPS EXTENDED
---- WING TIPS RETRACTED

$M = 2.0$



CALC	EJK	12-20	REVISED	DATE
CHECK				
APR				
APR				

LATERAL STABILITY
 $M = 2.0$ 126
BOEING AIRPLANE COMPANY

FIG. 6.17
E44-2035
D2-8174
PAGE 6.20

E44-2035

S = 24.3 FT

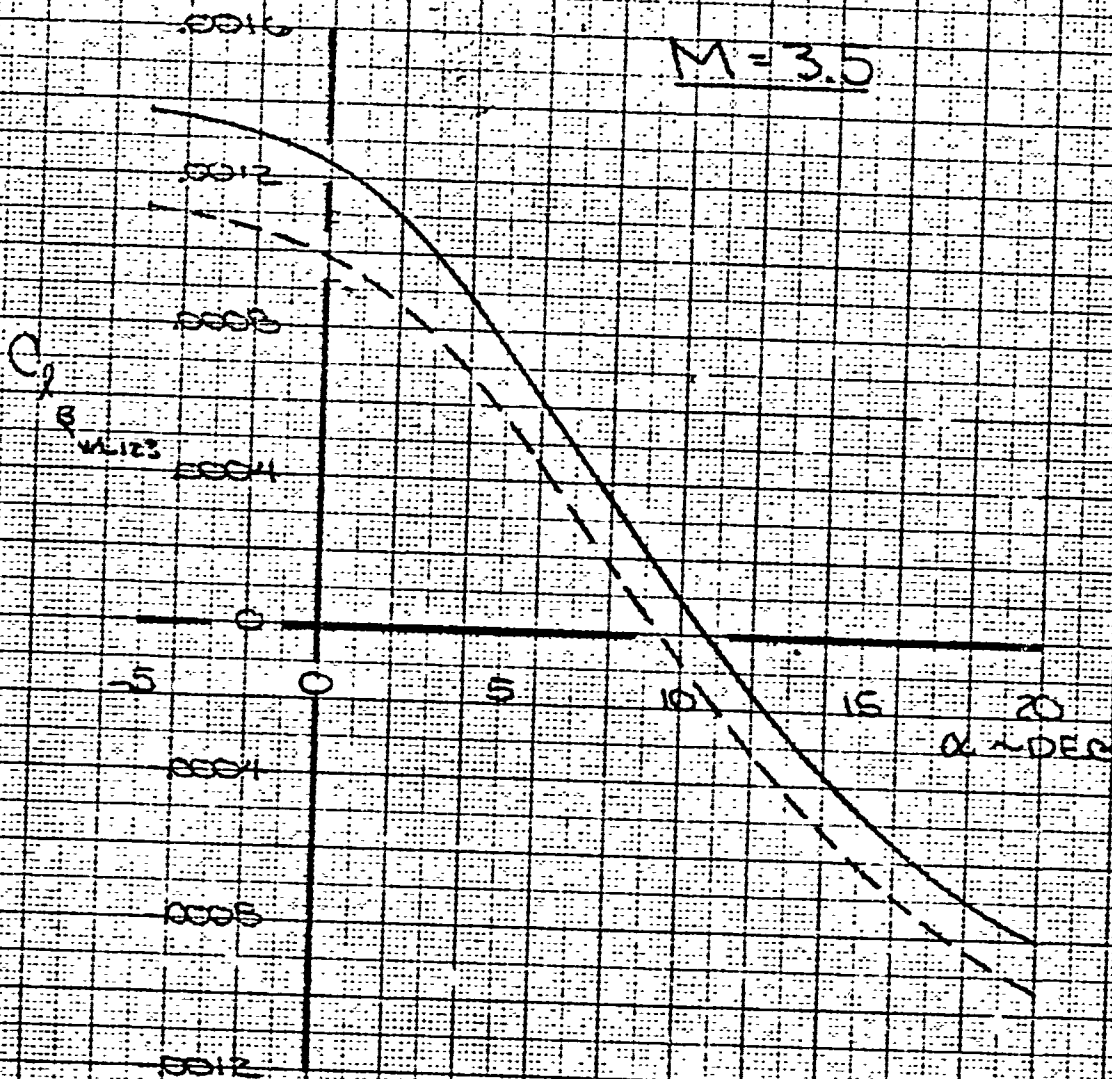
b = 19.7 FT

CG = WL 123

WING TIPS EXTENDED

RETRACTED

M = 3.5



CALC	E7R	12-0	REVISED	DATE	LATERAL STABILITY M = 3.5 127 BOEING AIRPLANE COMPANY	76.6.18
CHECK						E44-2035
APR						DR-8174
AFR						PAGE 6.21

844-2035

$S = 343 \text{ FT}^2$

WING TIPS EXTENDED
WING TIPS RETRACTED

$M = 2.0$

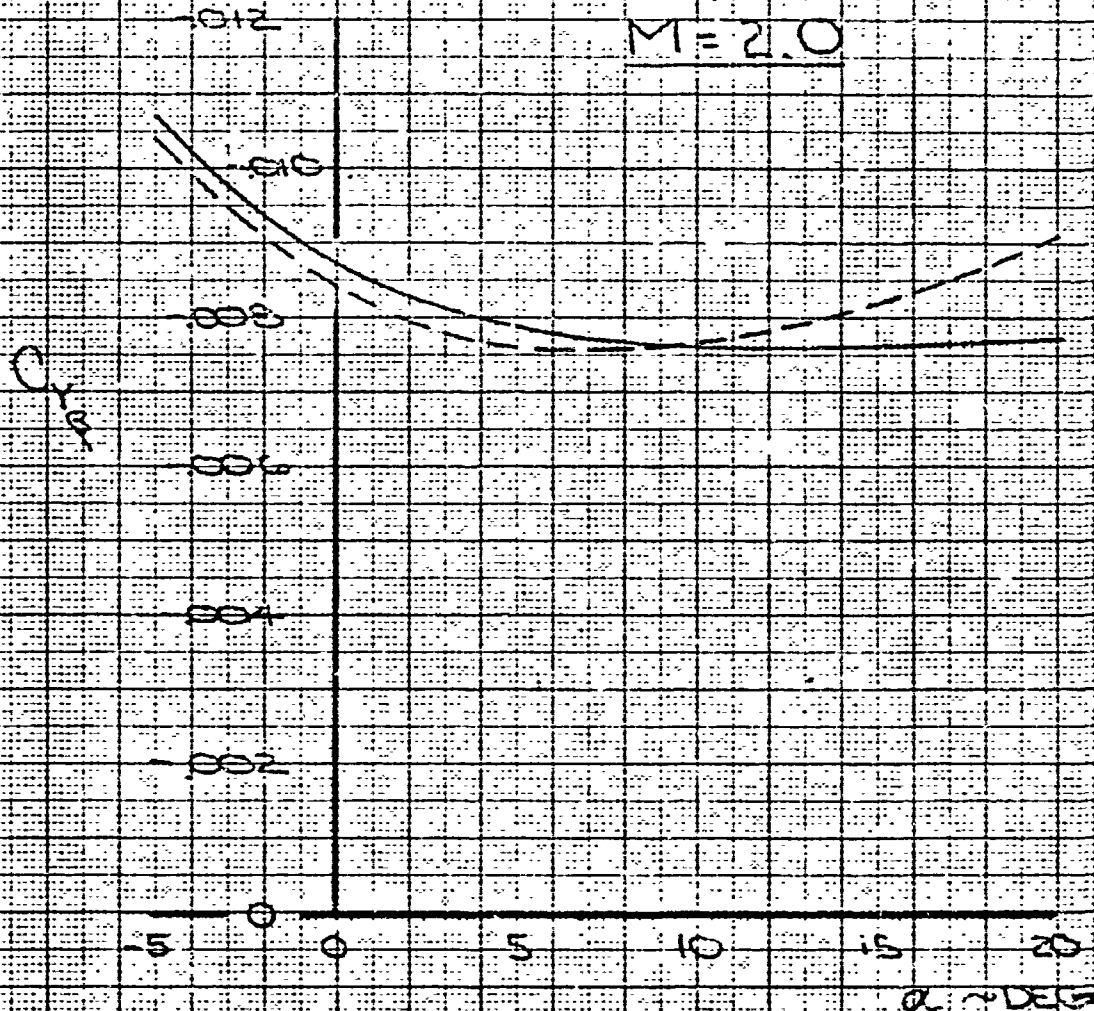


FIG. 6.19

CALC	KJK	12-2-0	REVISED	DATE
CHECK				
APR				
APR				

SIDE FORCE
 $M = 2.0$ 128

BOEING AIRPLANE COMPANY

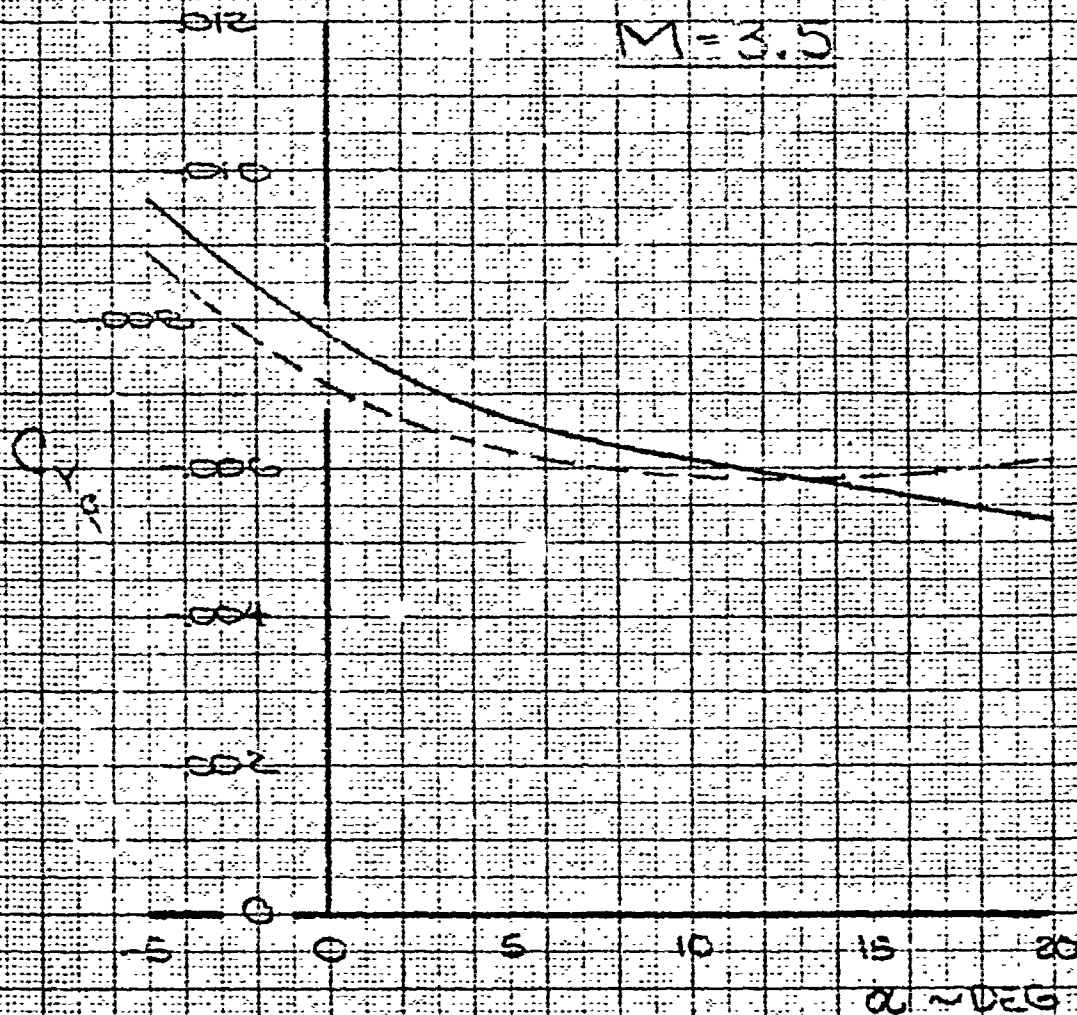
844-2035
02-8174
PAGE
6-22

PA-2035

5.343 ft²

WING TIPS EXTENDED
RETRACTED

M=3.5



CALC	BTR	7-2-0	REVISED	DATE
CHECK				
APR				
APR				

SIDE FORCE

M=3.5 129

BOEING AIRPLANE COMPANY

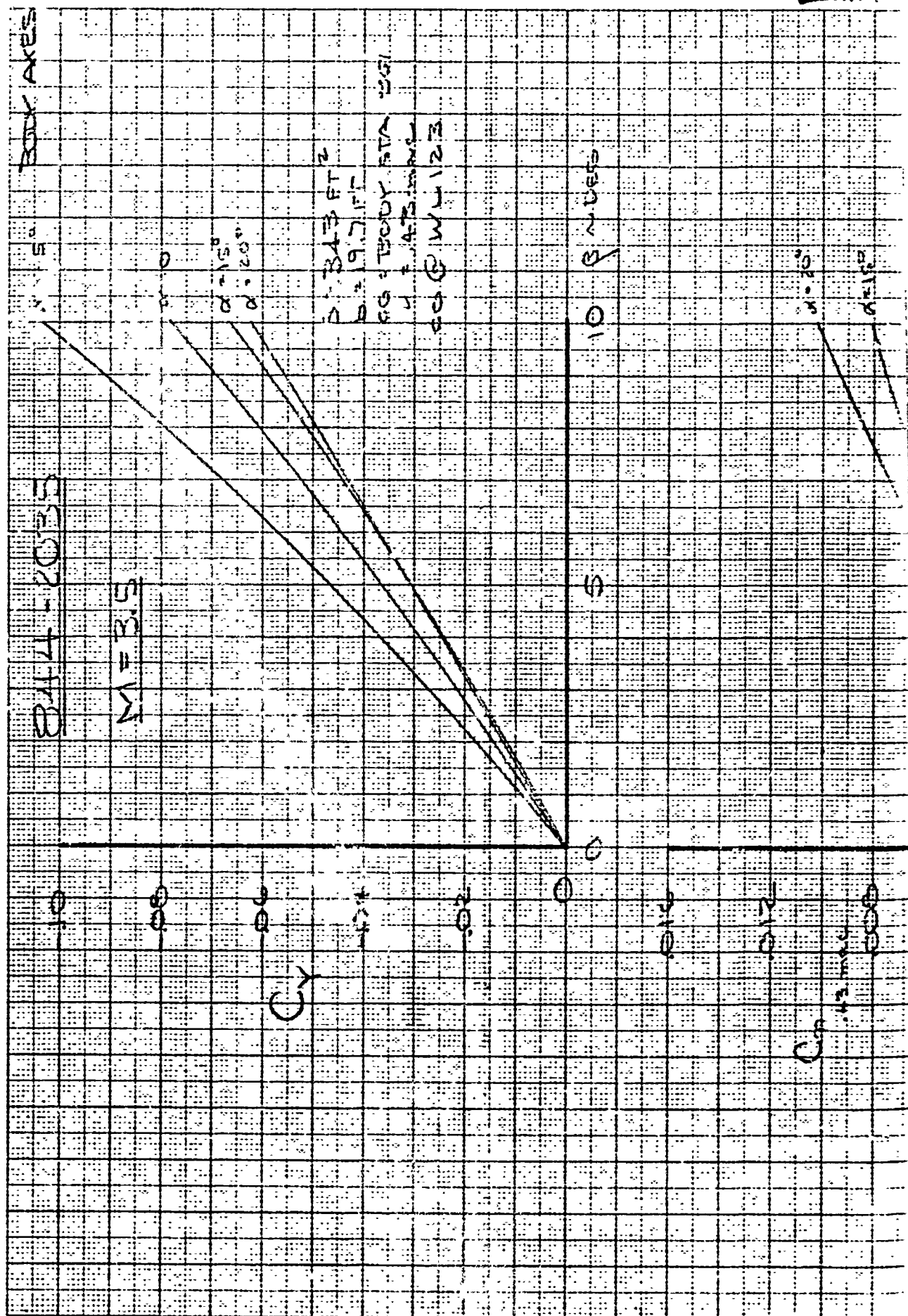
FIG. 6-20

PA-2035

DL-E174

PAGE

6.23



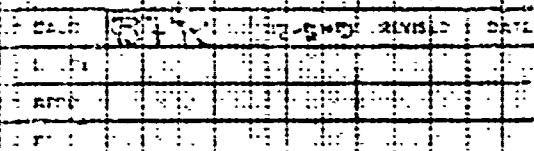


FIG. 6.21	
244-	
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02-8174	
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$$10 = 19.7$$

LG BODY STA 351

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221225

155

MODEL B44-203E

MACH = 3

$\alpha = 0^\circ$
 $\alpha = 10^\circ$
 $\alpha = 15^\circ$
 $\alpha = 35^\circ$
 $\alpha = 50^\circ$

-0.06

Cy -0.04

-0.02

0

0.02

0.05

Cm = 0

0.00

5

10

$\alpha = 15^\circ$

$\alpha = 0^\circ$ DATA FROM AED-10, MATSUDA, 1966
 $\alpha = 10^\circ$ DATA FROM AED-10, MATSUDA, 1966
 $\alpha = 15^\circ$ DATA FROM AED-10, MATSUDA, 1966
 $\alpha = 35^\circ$ DATA FROM AED-10, MATSUDA, 1966
 $\alpha = 50^\circ$ DATA FROM AED-10, MATSUDA, 1966
 OF ATTACK DATA

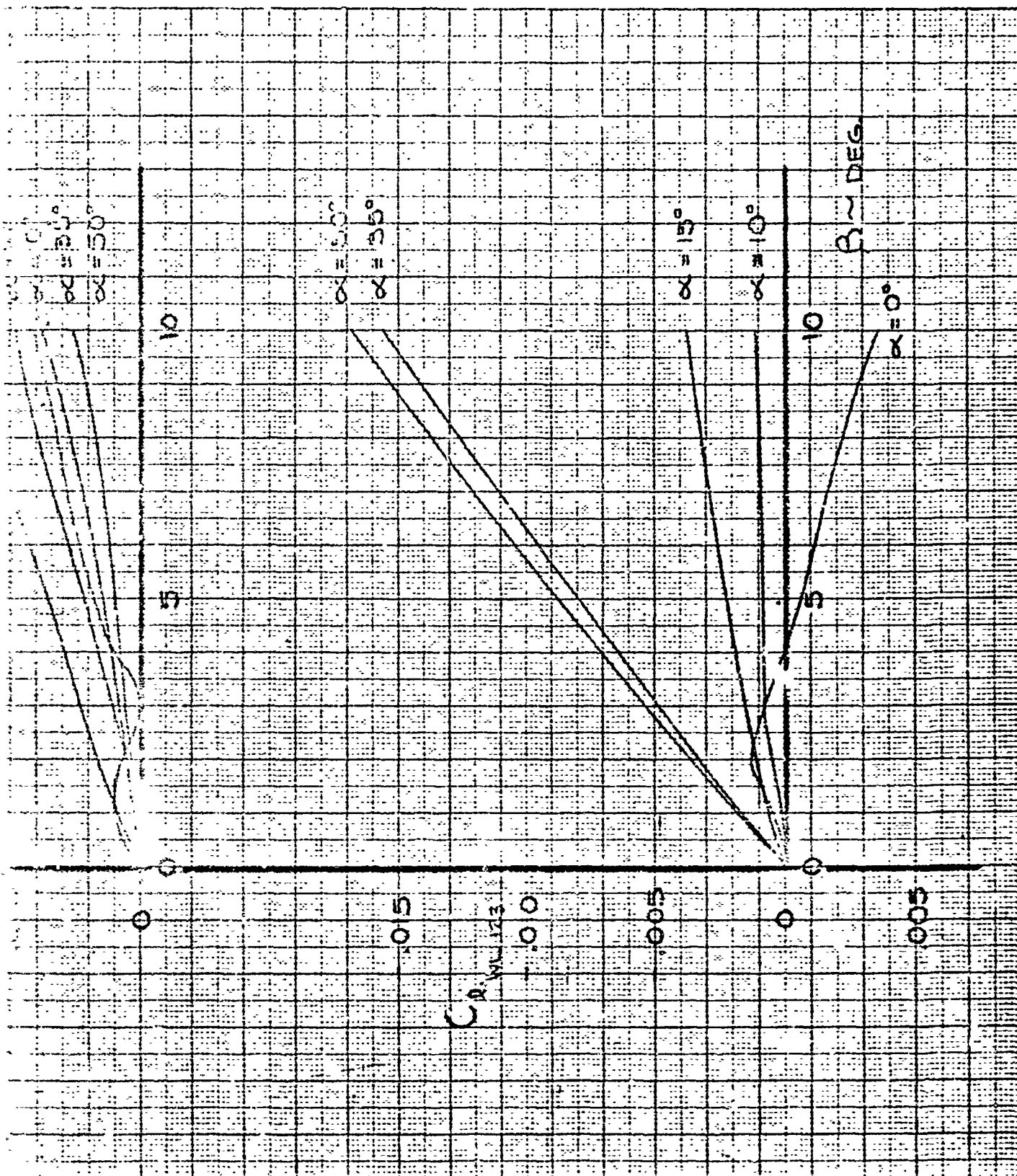


FIG. 623

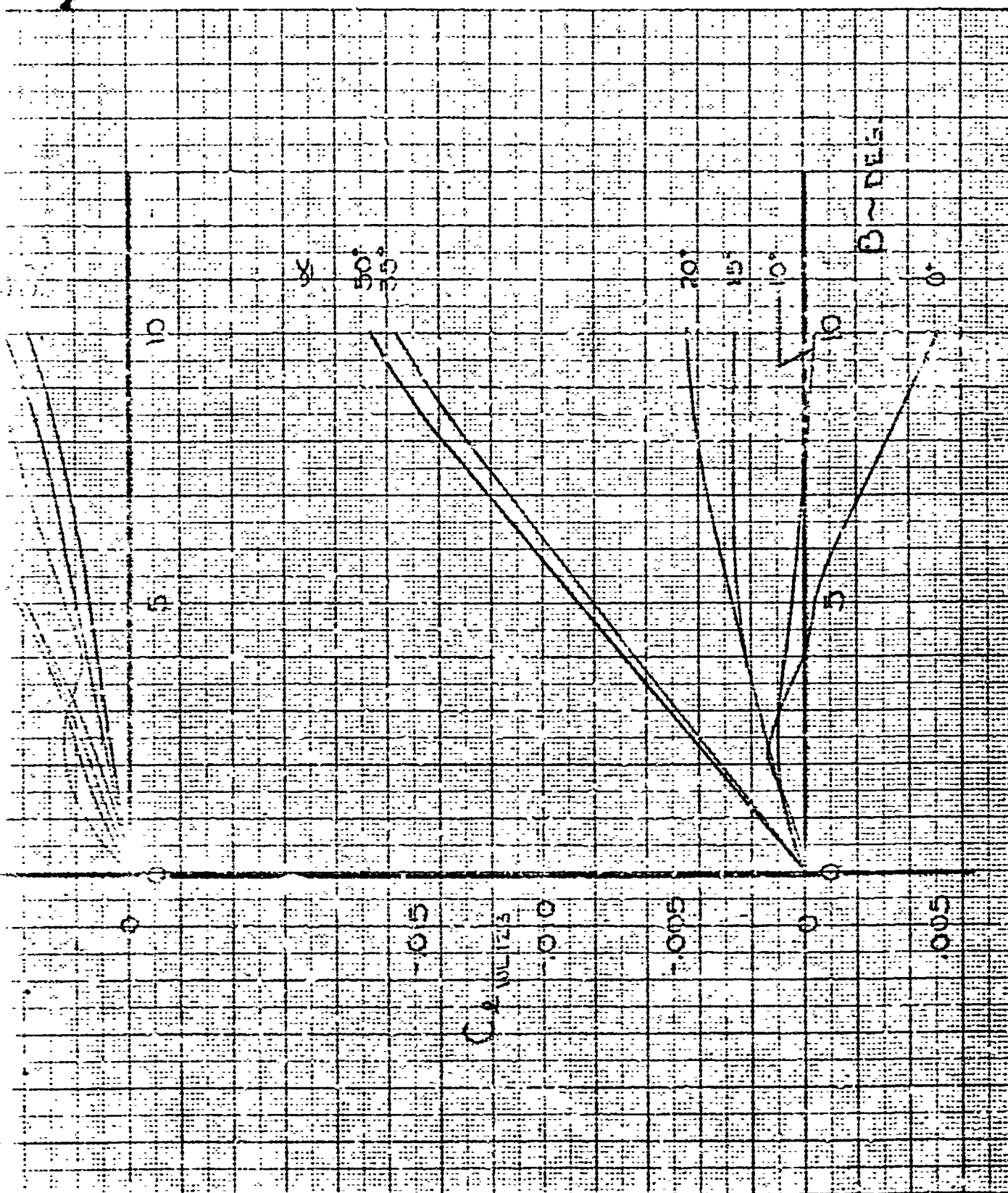
844-

2035

02-974

PAGE

6.26



CALC	JED	1/8/55	REVISD	DATE	FIG. 6.24
CHECK					FIG. 6.24
APPRO					2035
APPRO					02-874
					PAGE
					6.27

Aileron effectiveness data for the 844-2035 configuration are presented in Figures 6.25 through 6.42. Summary curves of $C_{D\alpha}$, $C_{Y\alpha}$ and $C_{Y\delta}$ versus Mach number are presented on Figures 6.25, 6.26 and 6.27 to show the variation between the Mach numbers; more detailed data are presented on Figures 6.28 through 6.42.

The data presented are based on wind tunnel data on similar configurations adjusted to the dimensions of the 844-2035 configuration. All data are based on configurations with 10° swept clevon hinge lines, with the exception of the transonic region where the hinge line was unswept. The effects of hinge line sweep have not been established precisely, consequently $C_{D\alpha}$ and $C_{Y\delta}$ may be changed when wind tunnel data on the 844-2035 configuration become available.

The hypersonic aileron characteristics are presented for both surfaces deflected symmetrically about δ_e of 0 and -30° and also for one clevon deflected through a range of 10° to -45° while the other is at 0° deflection. The "one-surface-deflected" data are presented in order to facilitate estimation of the effects of deflecting the ailerons unequally.

The effect of altitude (i.e., Reynolds number) on aileron effectiveness is similar to the effect on clevon effectiveness in pitch. Aileron effectiveness is influenced by a thickening boundary layer with increasing altitude which decreases the effectiveness. High hypersonic speed hot-shot data show little change in effectiveness however, and at this time it is assumed that aileron characteristics should not be changed significantly with altitude.

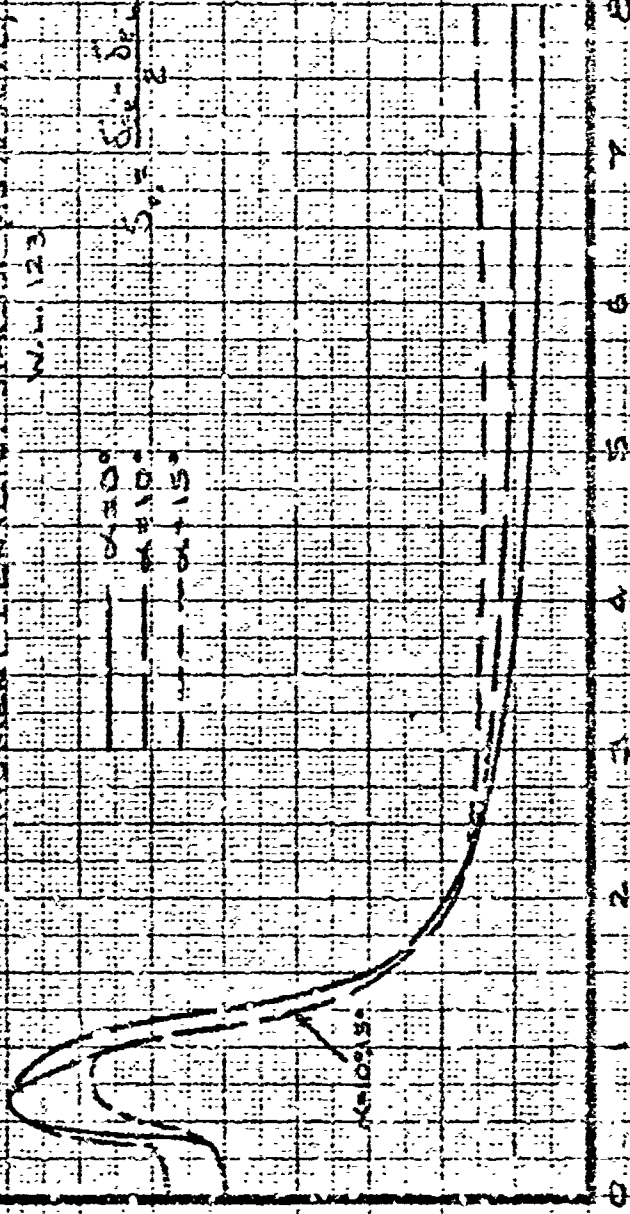
BOOM AXES

CONFIGURATION 844-2035

W = 347 SQ. FT.
 S = 233.7 IN.
 S₁ = 14 %

MOMENT CENTER: STAGE 3 (AS 100000)
 W.L. 123

W = 347
 S = 233.7
 S₁ = 14 %



WING NUMBER

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APR				

ROLLING MOMENT
 DUE TO AILERON

BOEING AIRPLANE COMPANY

139

FIG. 6.25

844-2035

DZ-B174

PAGE 6.29

BODY AXES

CONFIGURATION: 344-2035

$S_v = 343$ sq. ft.

$D = 236.7$ in.

$S_{ac} = 14\%$

SW

MOMENT CENTER: SIA. 351 (43% m.a.c.)

W.L. 123

$\alpha = 0^\circ$

$\alpha = 10^\circ$

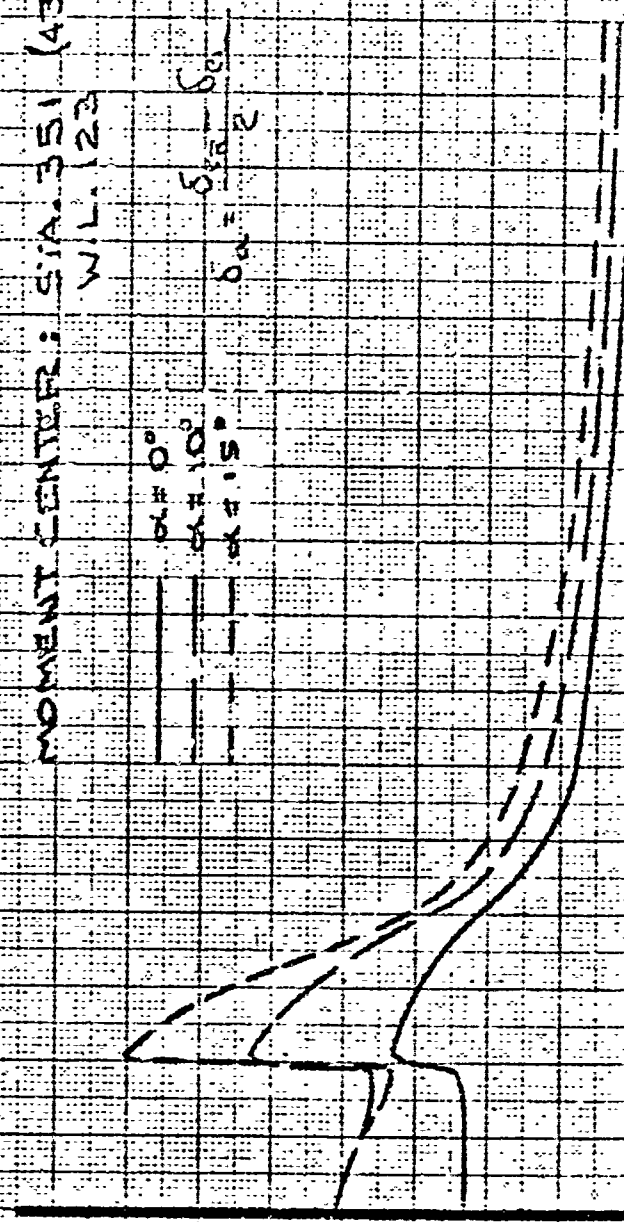
$\alpha = 15^\circ$

$\delta_{ac} = \frac{S_{ac}}{S_v}$

$\delta_{ac} = \frac{S_{ac}}{S_v}$

C_{Ysa}

(PER DEG)



MACH NUMBER

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YAWING MOMENT DUE TO AILERON

BOEING AIRPLANE COMPANY

FIG. 6.26

344-2035

D2-8174

PAGE

6.30

844-2035

$S_e = 343 ft^2$

$S_e = 48 ft^2$

$\alpha = 0$

$\alpha = 0$

NOTES:

DASHED PORTION OF CURVE INDICATES ESTIMATED, WHEN TEST DATA IS NOT AVAILABLE

$$\delta a = \frac{\delta a_{\alpha} + \delta a_{\delta}}{2}$$

0.0

0.4

0.8

0.8

0.8

0.0

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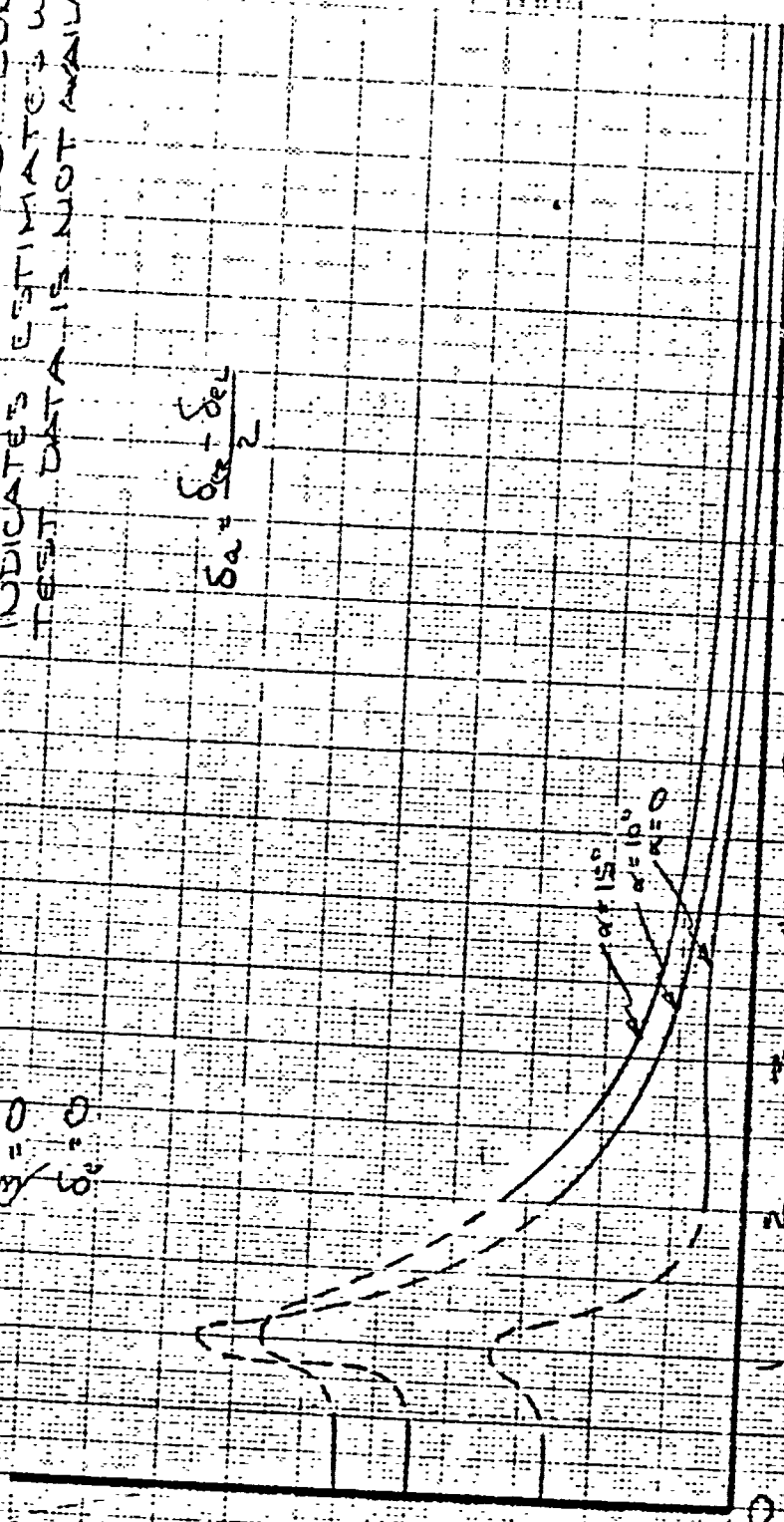
SIDE FORCE DUE TO AILERON **141**

BOEING AIRPLANE COMPANY

FIG. 6.27
844-2035
DX-8174

PAGE 6.31

MACH NUMBER



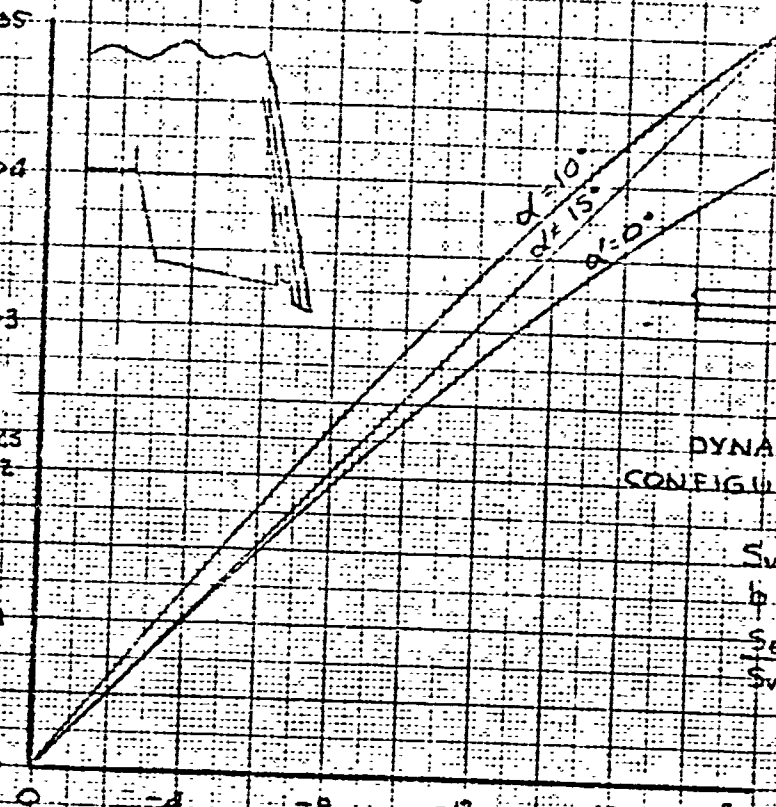
$M = 0.25$

$\beta = 0^\circ$

$\delta_e = 0^\circ$

BODY AXIS

C_L
W 123
0.05
0.04
0.03
0.02
0.01
0



DYNA SOAR GLIDER
CONFIGURATION 944-2035

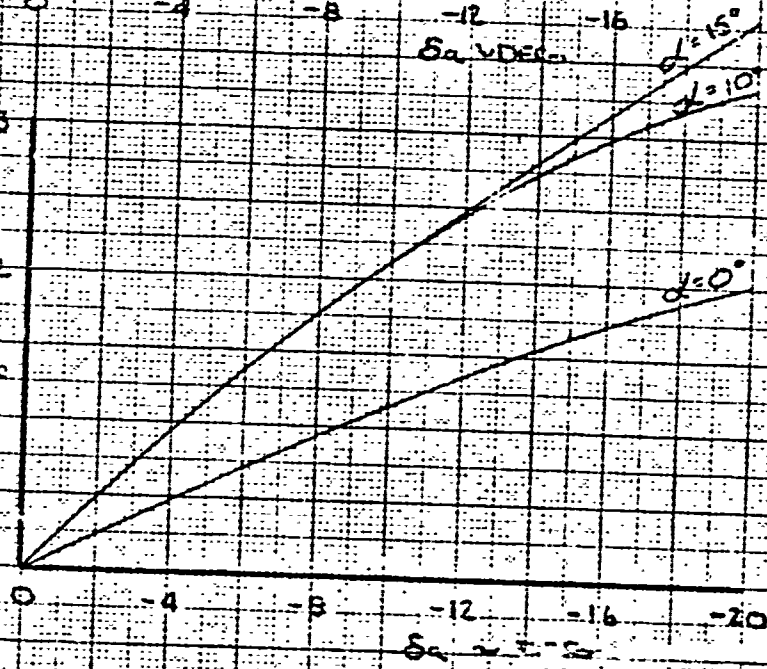
$S_w = 343 \text{ FT}^2$

$b = 236.7 \text{ IN}$

$\frac{S_e}{S_w} = 14\%$

$$\delta_a = \frac{\delta_{eR} - \delta_{eL}}{2}$$

C_n
93 mac
0.03
0.02
0.01
0



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AILERON EFFECTIVENESS
LANDING SPEED

$\delta_e = 0$

142

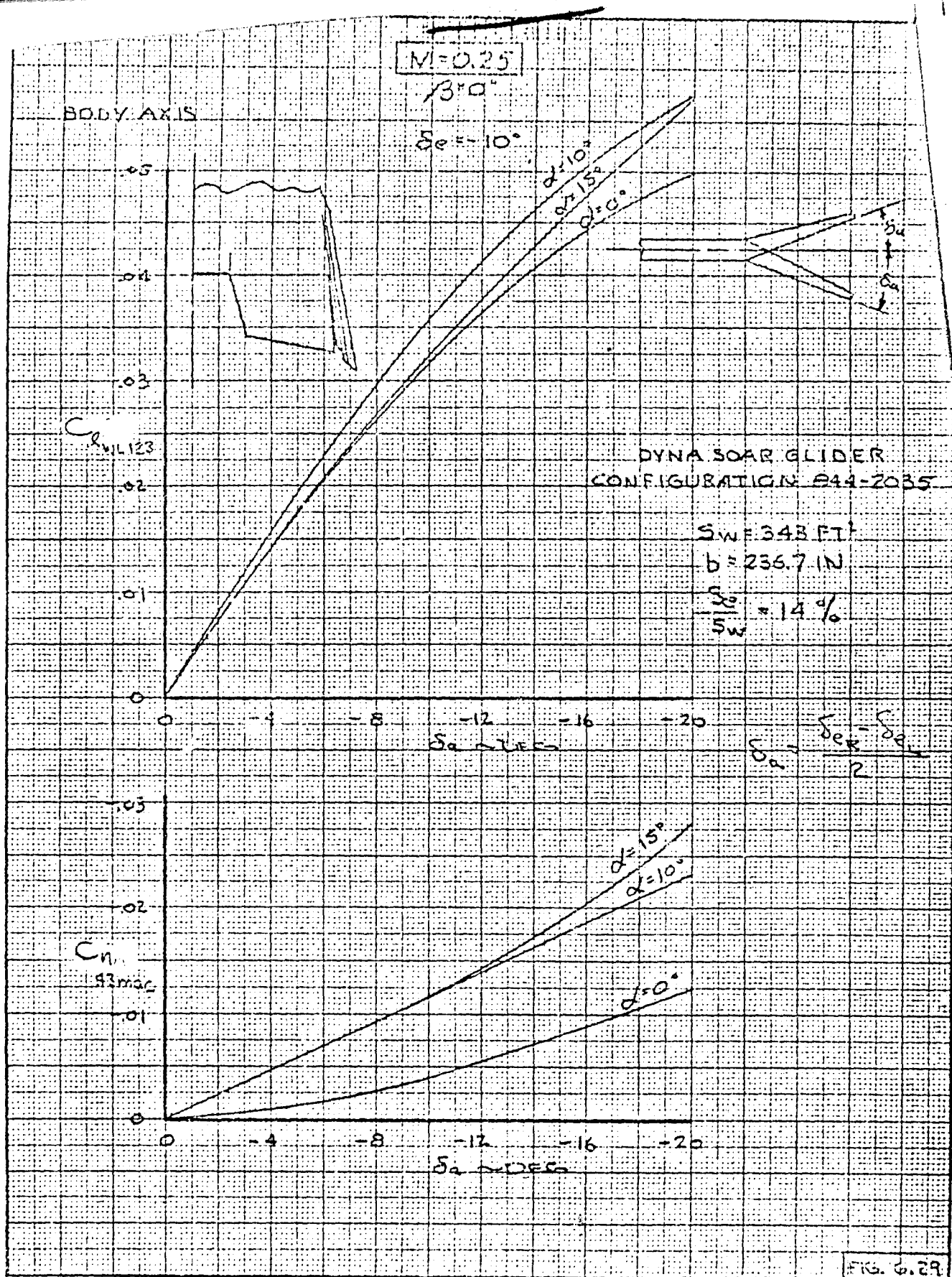
BOEING AIRPLANE COMPANY

FIG. 16.28

944 -
2035

D2-8174

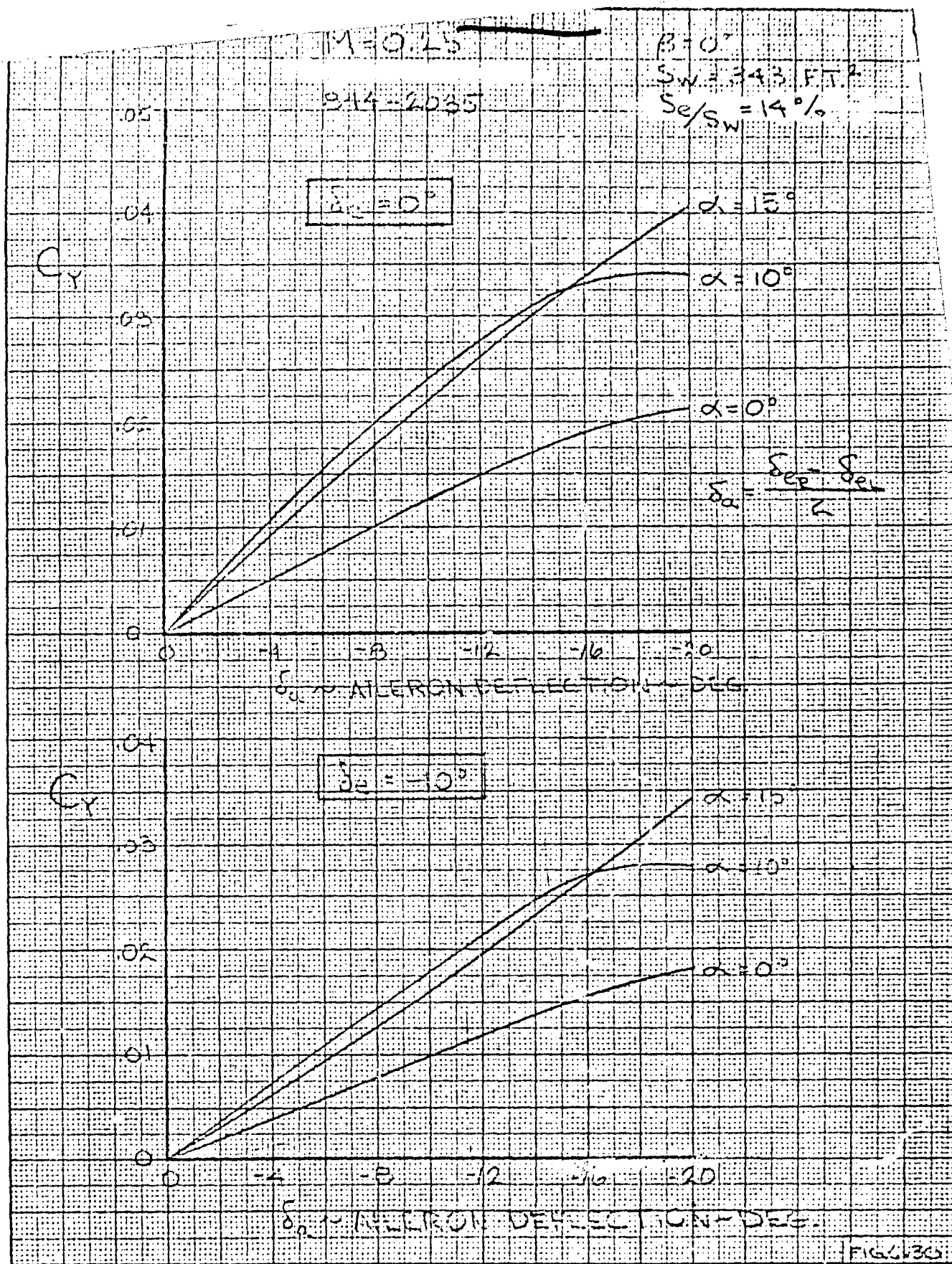
6.32



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APP				

AILERON EFFECTIVENESS
 LANDING SPEED
 $\delta_e = -10^\circ$ **143**
 BOEING AIRPLANE COMPANY

FIG. 6.29
 B44 -
 2035
 D2-2174
 6.33



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SIDE FORCE DUE TO
AILERON-LANDING SPEED

BOEING AIRPLANE COMPANY

144

844-
2035
D2-8174
PAGE
6.34

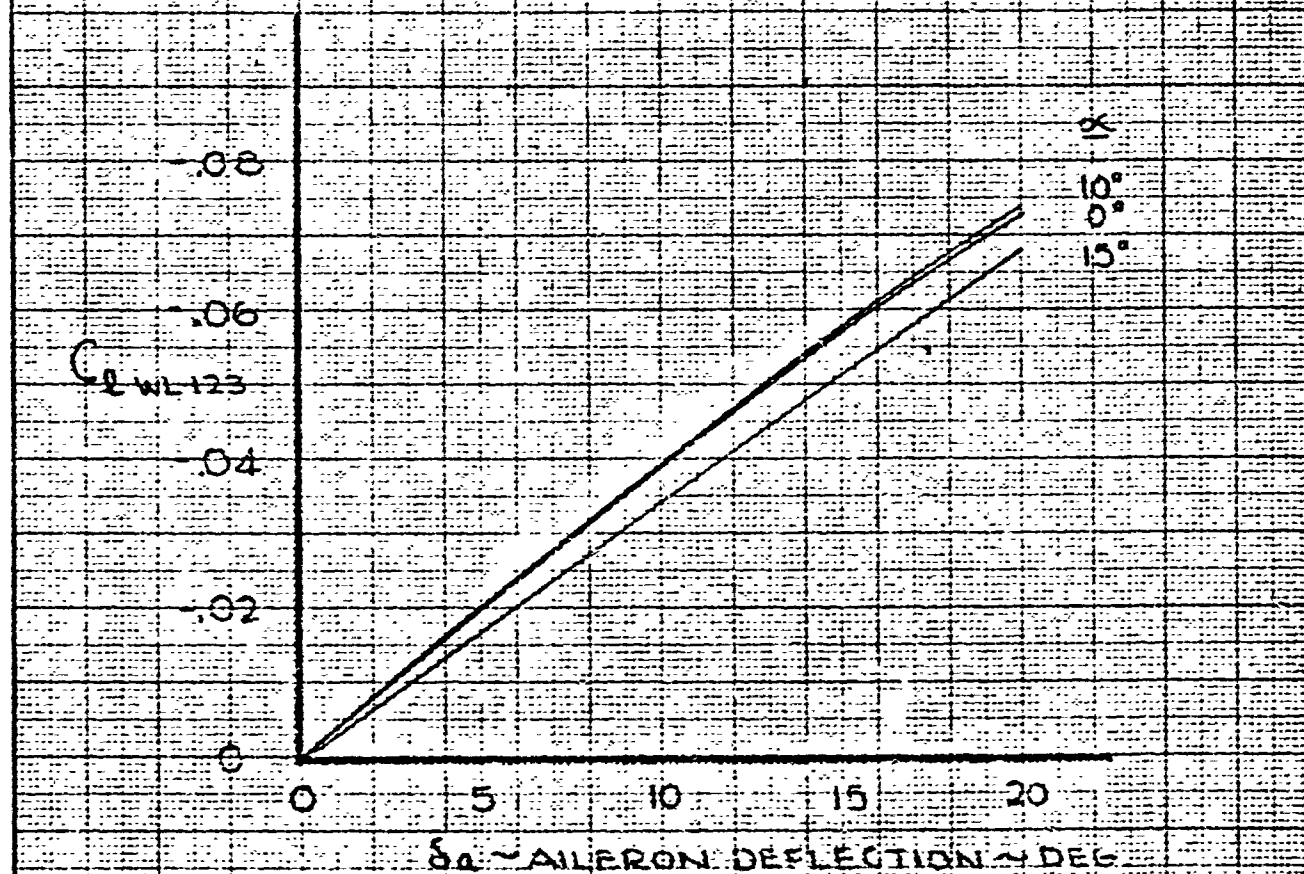
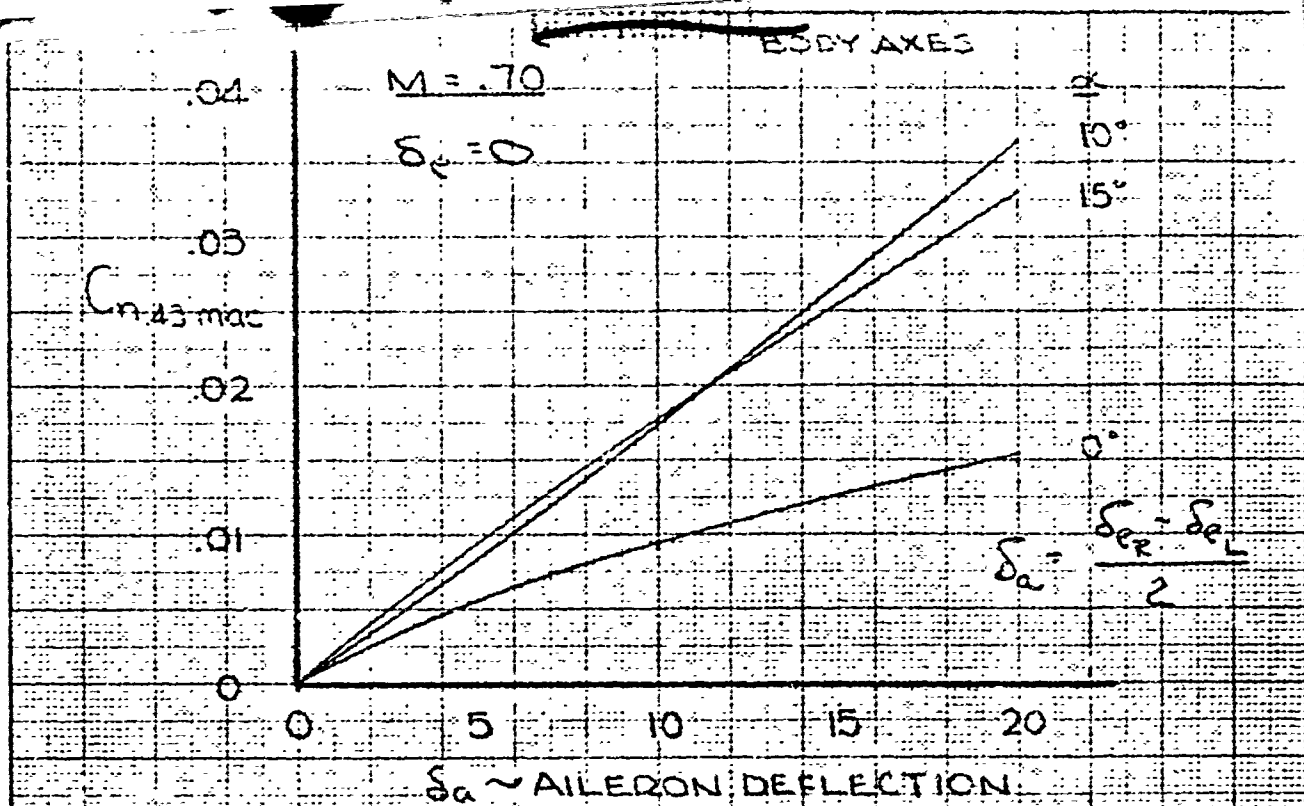


FIG 6.31

EA4-2035

02-8174

PAGE 6.35

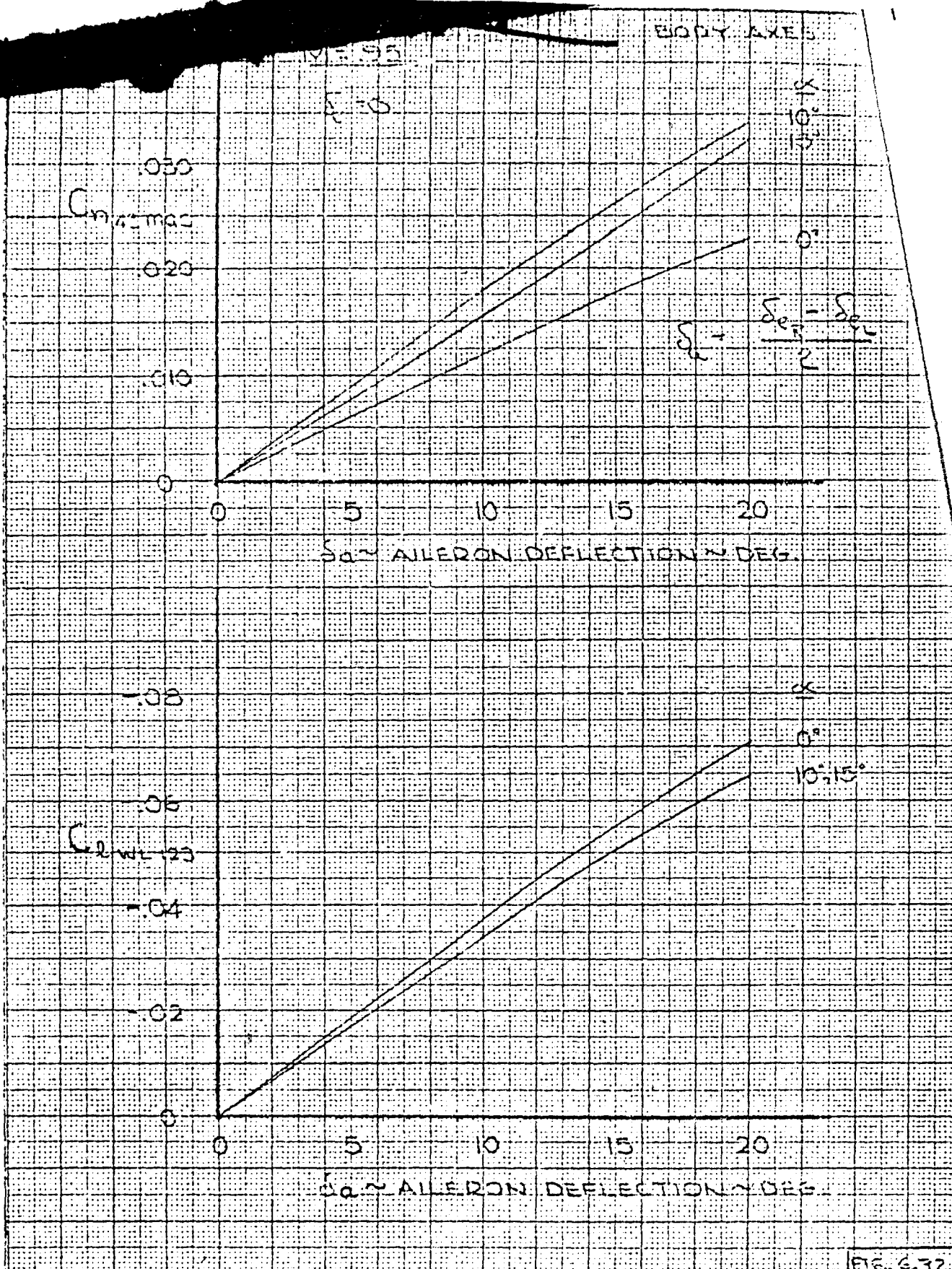
BOEING AIRPLANE COMPANY

AILERON CHARACTERISTICS
M = .70 145

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AILERON CHARACTERISTICS

$M = .95$: **146**

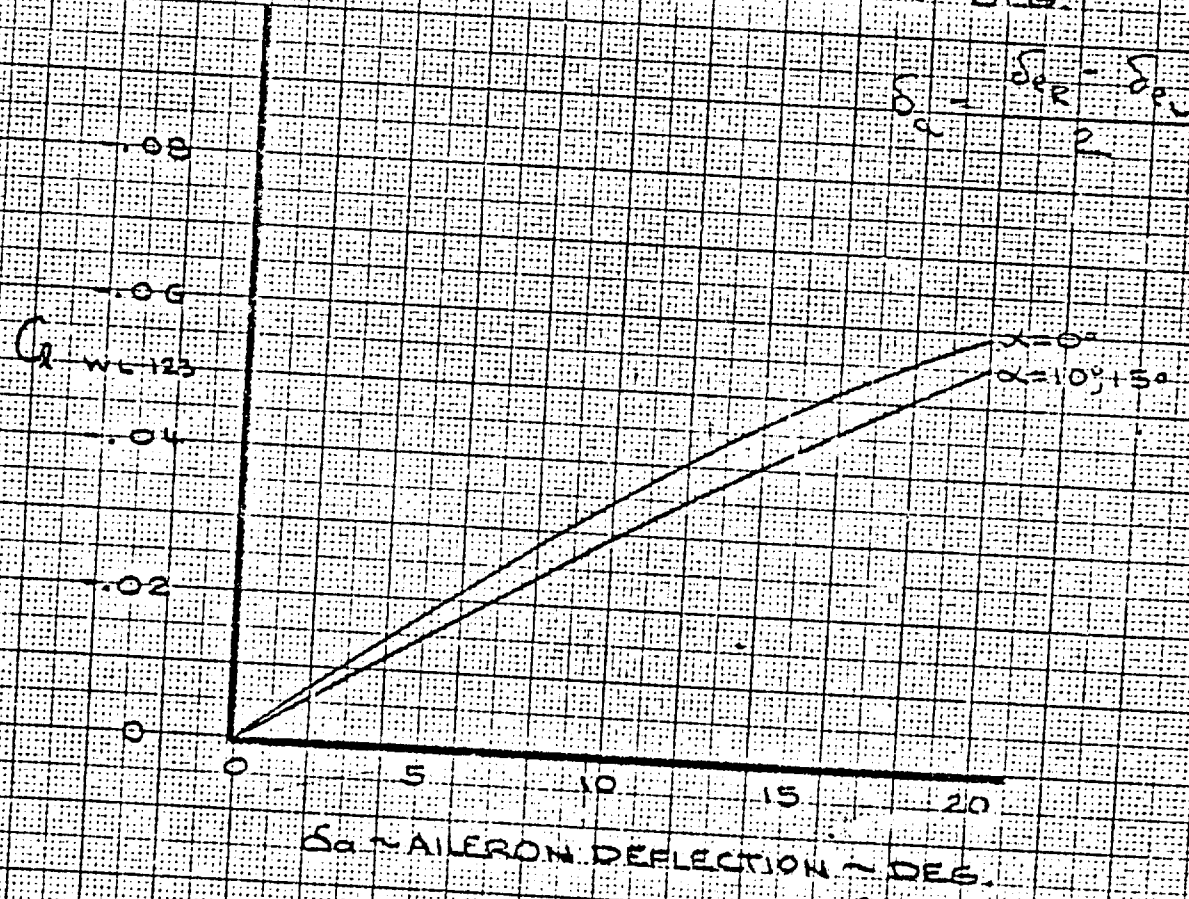
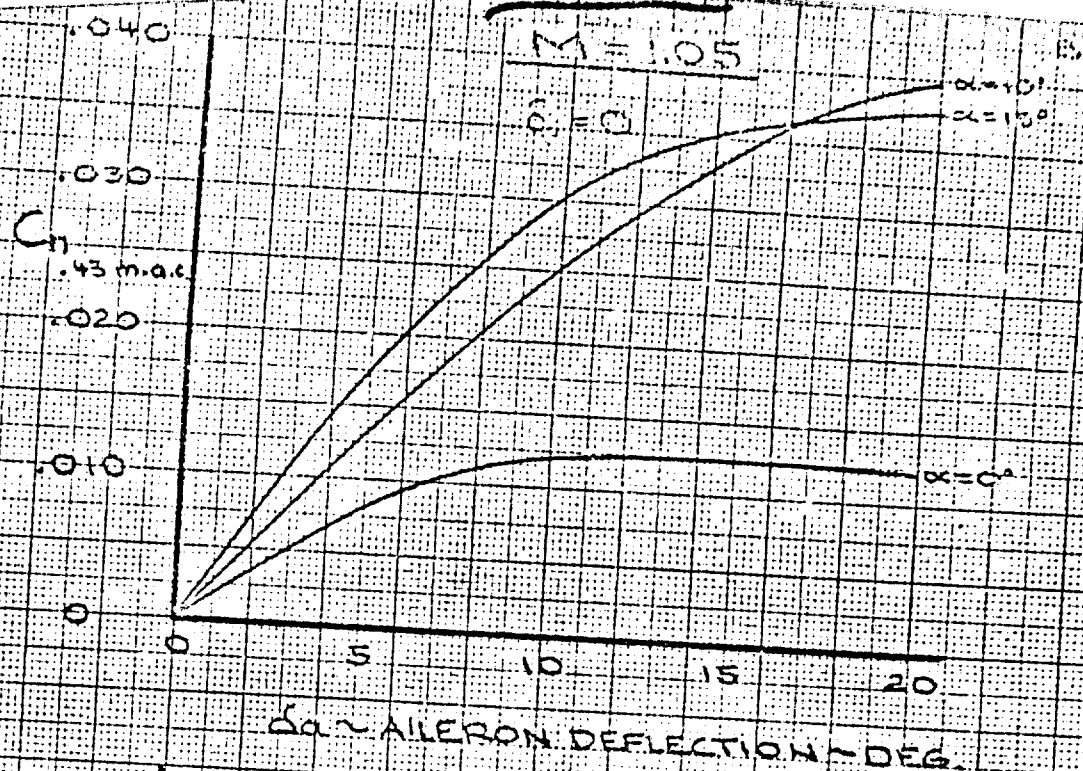
BOEING AIRPLANE COMPANY

FIG. 6.32

844-
2035

DZ-8174

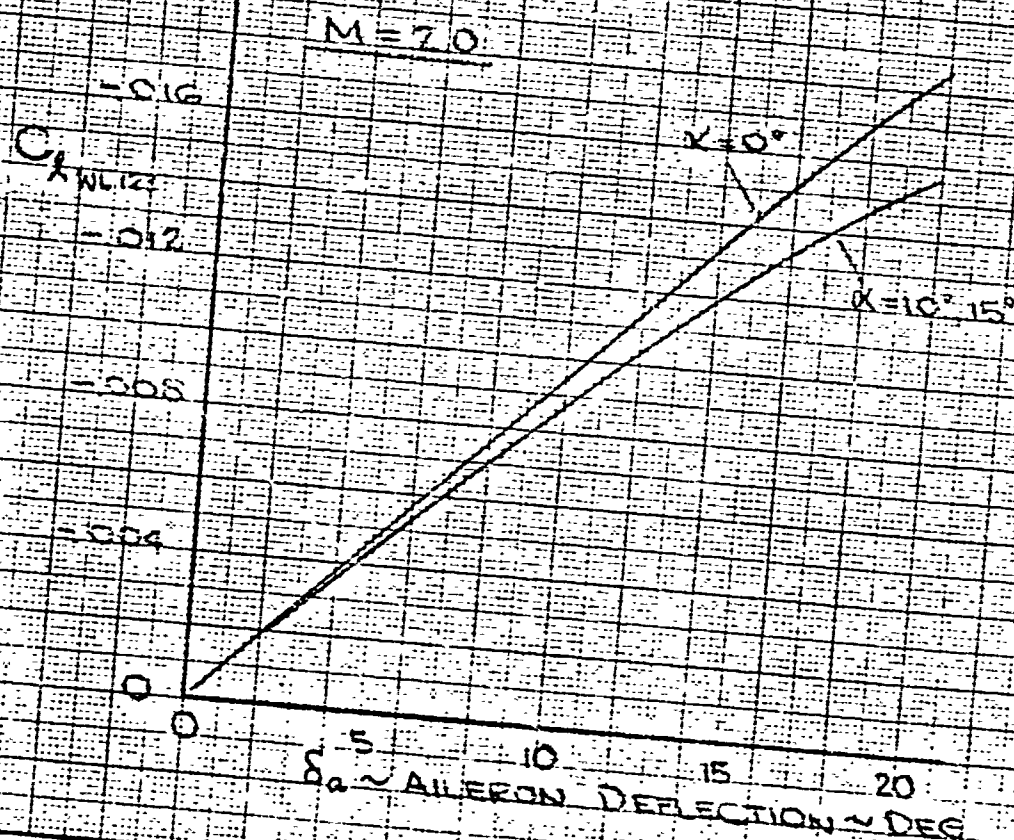
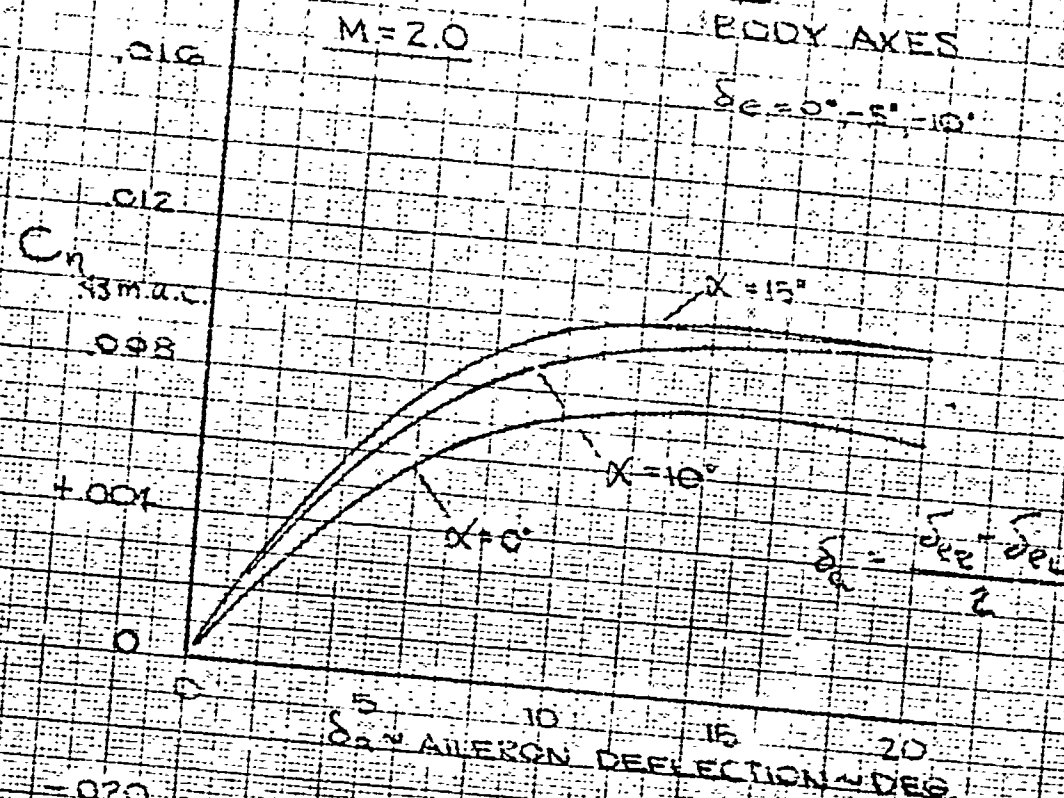
PAGE



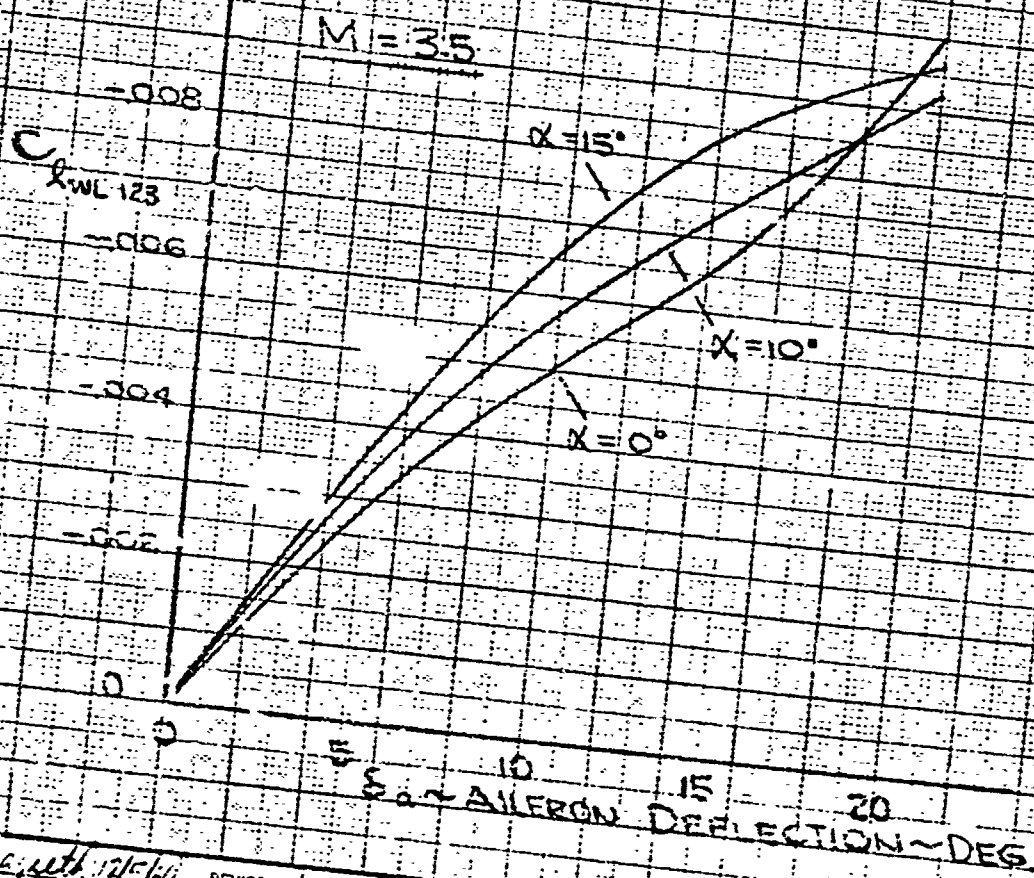
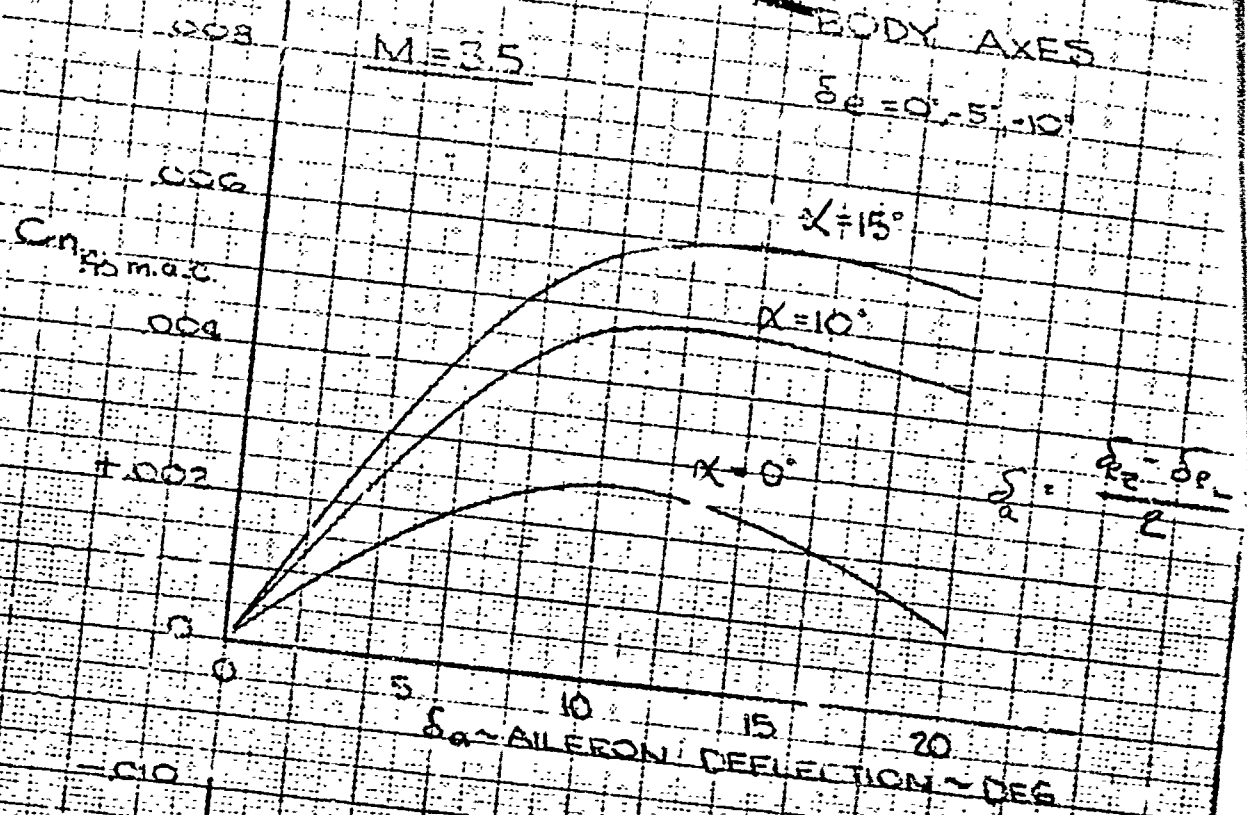
CALC	JEB/RTB	12/8/60	REVISED	DATE	AILERON CHARACTERISTICS M = 1.05 147 BOEING AIRPLANE COMPANY	FIG 6.33
CHECK						844 - 2035
APR						D2-8174
APR						PAGE 6.37

WAS NOT AFFECTED

K&E A. BARNE 1961



CALC	4/24/60	12-1-60	REVISED	DATE	AILERON CHARACTERISTICS $M=2.0$ 148 BOEING AIRPLANE COMPANY SEATTLE 24 WASHINGTON	FIG. 634
CHECK						B44-
APR						2035
APR						DZ-B174
						PAGE
						6.38



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APR			

AILERON CHARACTERISTICS

$M = 3.5$ 149

BOEING AIRPLANE COMPANY

FIG. 6.35

B44-2035

D2-B174

PAGE 6.39

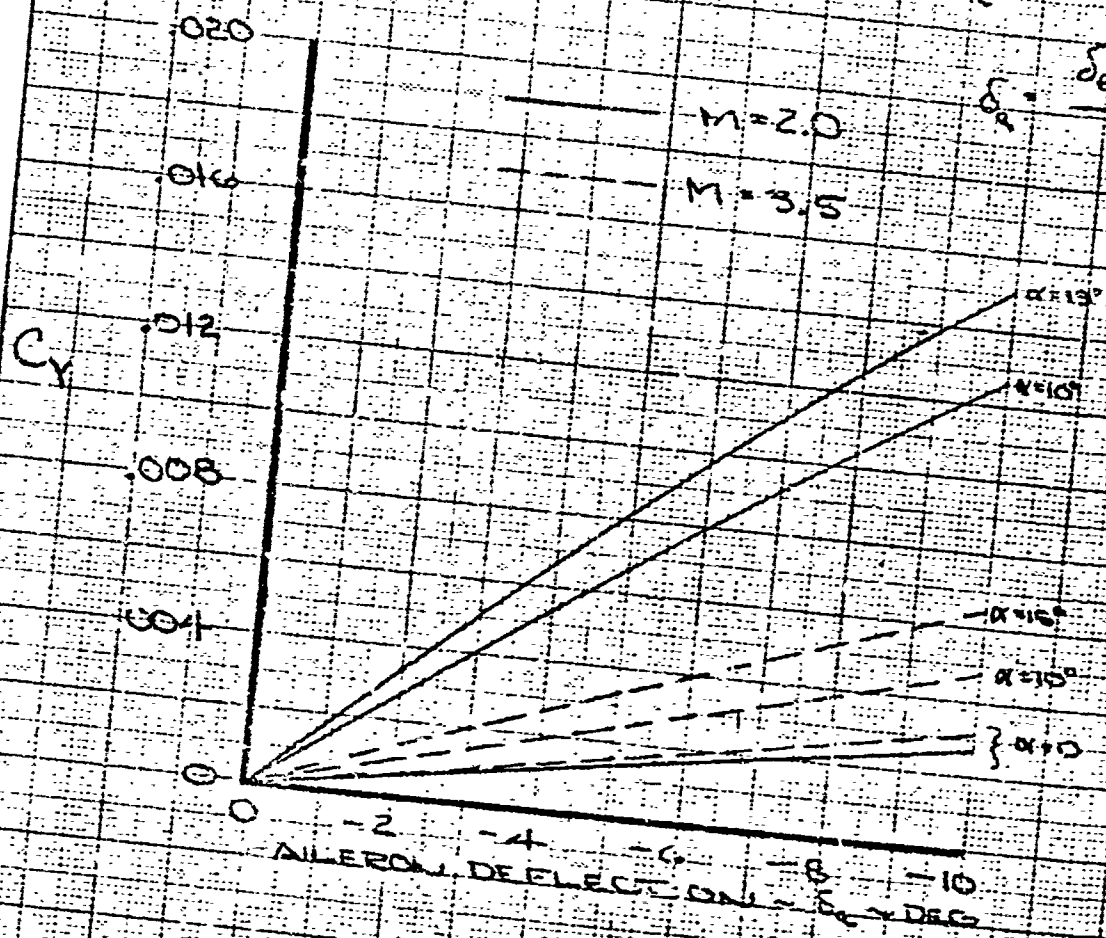
E44-2035

$S_w = 34.3 \text{ FT}^2$

$S_e/S_w = 14\%$

$\delta_e = 0$

$\delta = \frac{\delta_{e2} - \delta_{e1}}{2}$



CH/EFB 12-20

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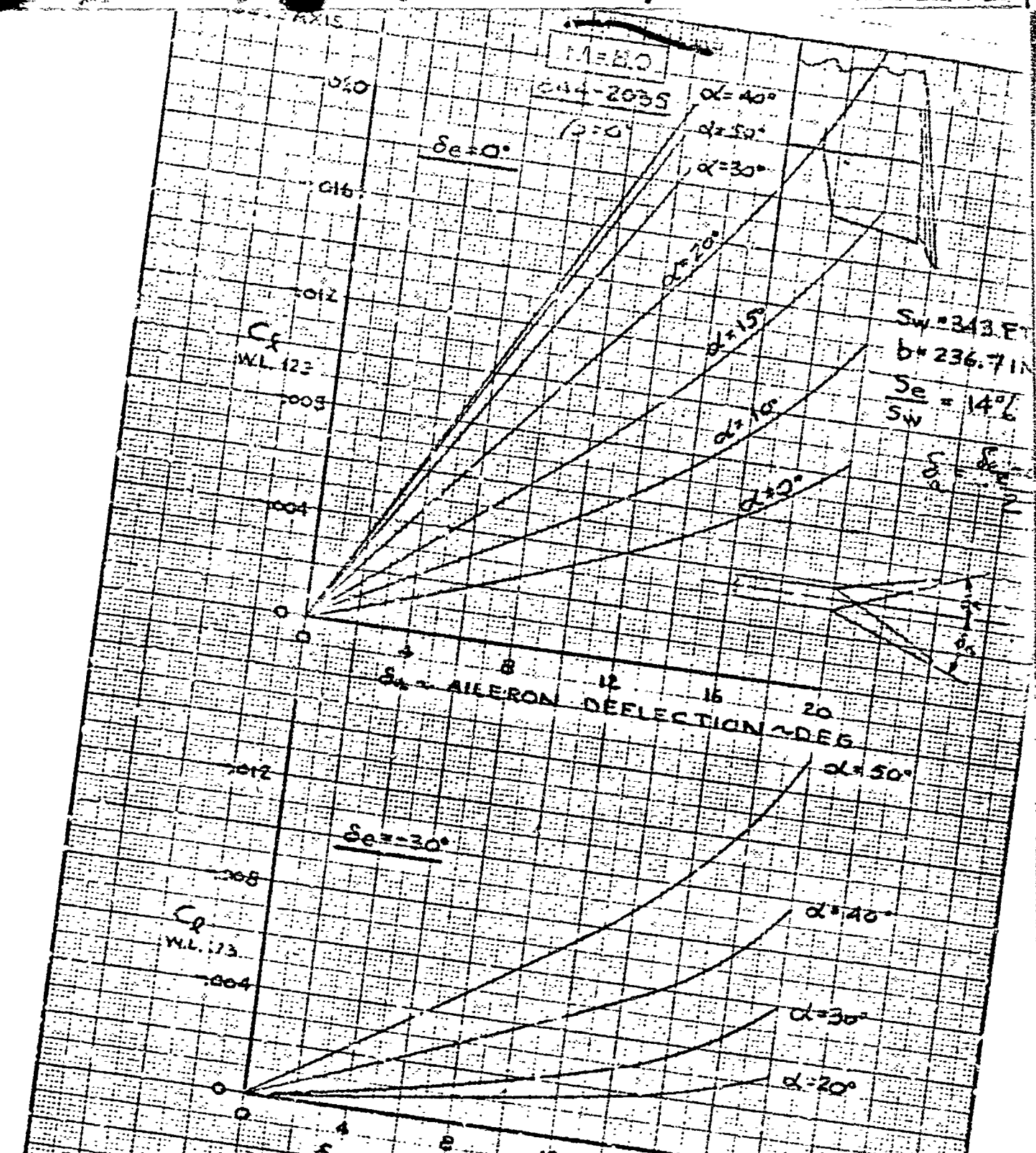
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DATE

SIDE FORCE DUE TO
AILERON DEFLECTION
M=2.0 AND 3.5
BOEING AIRPLANE COMPANY

FIG. 6.36
E44-
2035
D2-8174
PAGE
6.40



$S_w = 343.87$
 $b = 236.71$
 $\frac{S_e}{S_w} = 14\%$
 $\delta_e = \delta_a$

NOTE: THESE CURVES ARE BASED ON M=8.1 TEST DATA AND
 PARTIALLY SUBSTANTIATED BY M=9.5 TEST DATA

CALC	EJH	W/8/0	REVISED	DATE
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ROLLING MOMENT
 DUE TO AILERON **151**
 HYPERSONIC SPEED
 BOEING AIRPLANE COMPANY

FIG 4.37
 E44-2035
 D2-C174
 6.41

BODY AXIS

M = 6.1

844-2025

$\beta = 0^\circ$

$\delta_e = 0^\circ$

0.12

0.08

0.04

0.02

0

4

8

12

16

20

δ_e - AILERON DEFLECTION - DEG

δ_e - AILERON DEFLECTION - DEG

0

4

8

12

16

20

$\delta_e = -30^\circ$

$\delta_e = 30^\circ$
 $\delta_e = 20^\circ$
 $\delta_e = 10^\circ$
 $\delta_e = 0^\circ$
 $\delta_e = -10^\circ$
 $\delta_e = -20^\circ$
 $\delta_e = -30^\circ$

C_L

0.08

0.04

$S_w = 343 \text{ FT}^2$

$b = 236.7 \text{ IN}$

$\frac{S_e}{S_w} = 14\%$

NOTE: THESE CURVES ARE
 BASED ON M=6.1
 TEST DATA AND
 PARTIALLY
 SUBSTANTIATED BY
 M=9.5 TEST DATA.

CALC ECH 12/0/0 REVISED DATE

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APR

YAWING MOMENT
 DUE TO AILERON
 HYPERSONIC SPEED

152

BOEING AIRPLANE COMPANY

152

844-

2025

12-8174

152

152

60029

BODY AXIS

M = 3.0

844-2035

$\beta = 0^\circ$

$\delta_e = 0^\circ$

C_y

$S_w = 343 \text{ FT}^2$

$\frac{\delta_e}{S_w} = 14\%$

$\delta_e = \frac{\delta_{e_1} + \delta_{e_2}}{2}$

δ_a - AILERON DEFLECTION - DEG

$\delta_e = -30^\circ$

C_y

δ_a - AILERON DEFLECTION - DEG

NOTE: THESE CURVES ARE BASED ON M=3.1 TEST DATA AND PARTIALLY SUBSTANTIATED BY M=9.5 TEST DATA.

FIG. 6.39

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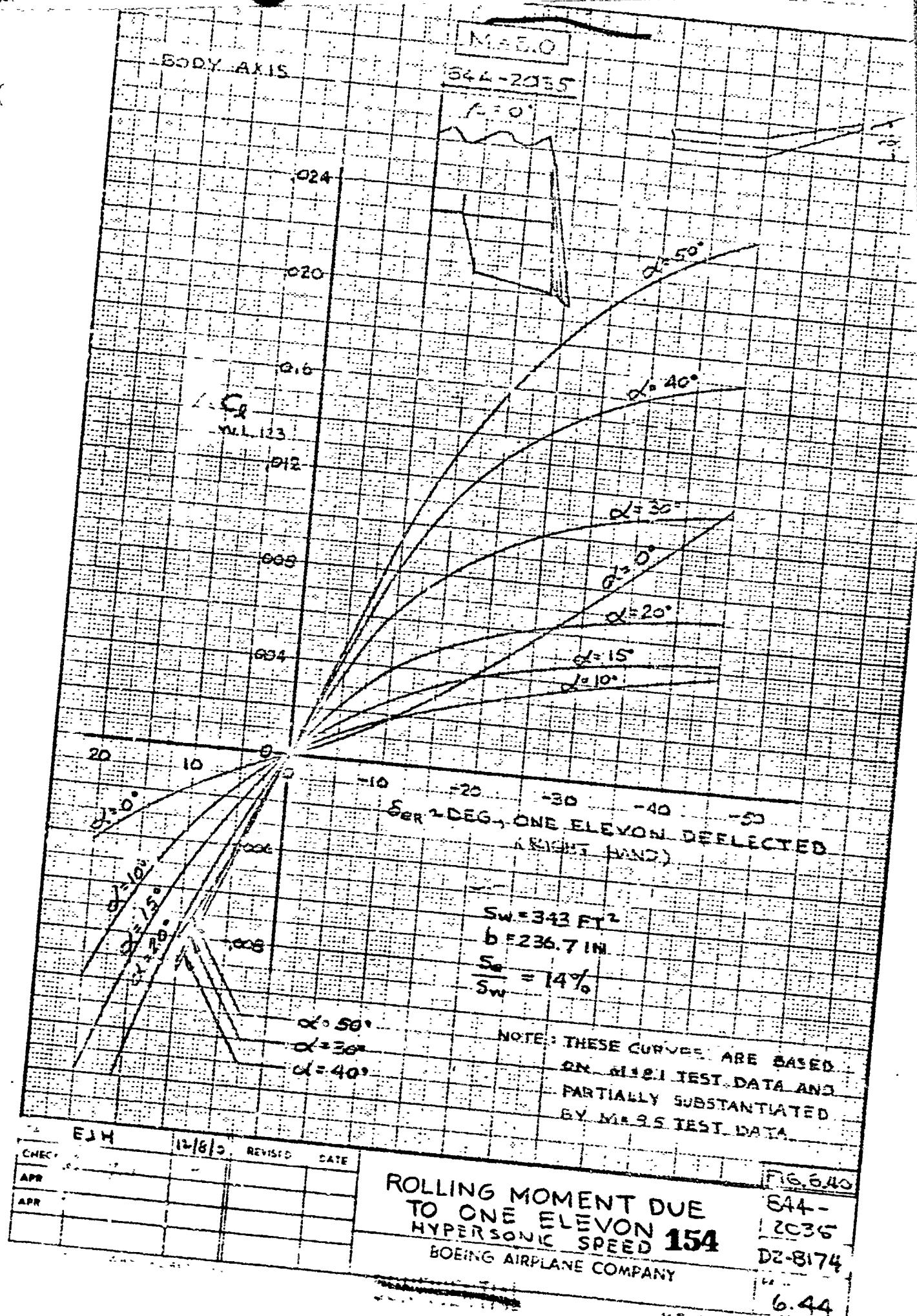
SIDE FORCE DUE TO
AILERON
HYPERSONIC SPEED **153**

BOEING AIRPLANE COMPANY

844-2035

DE-8174

PAGE 6.43

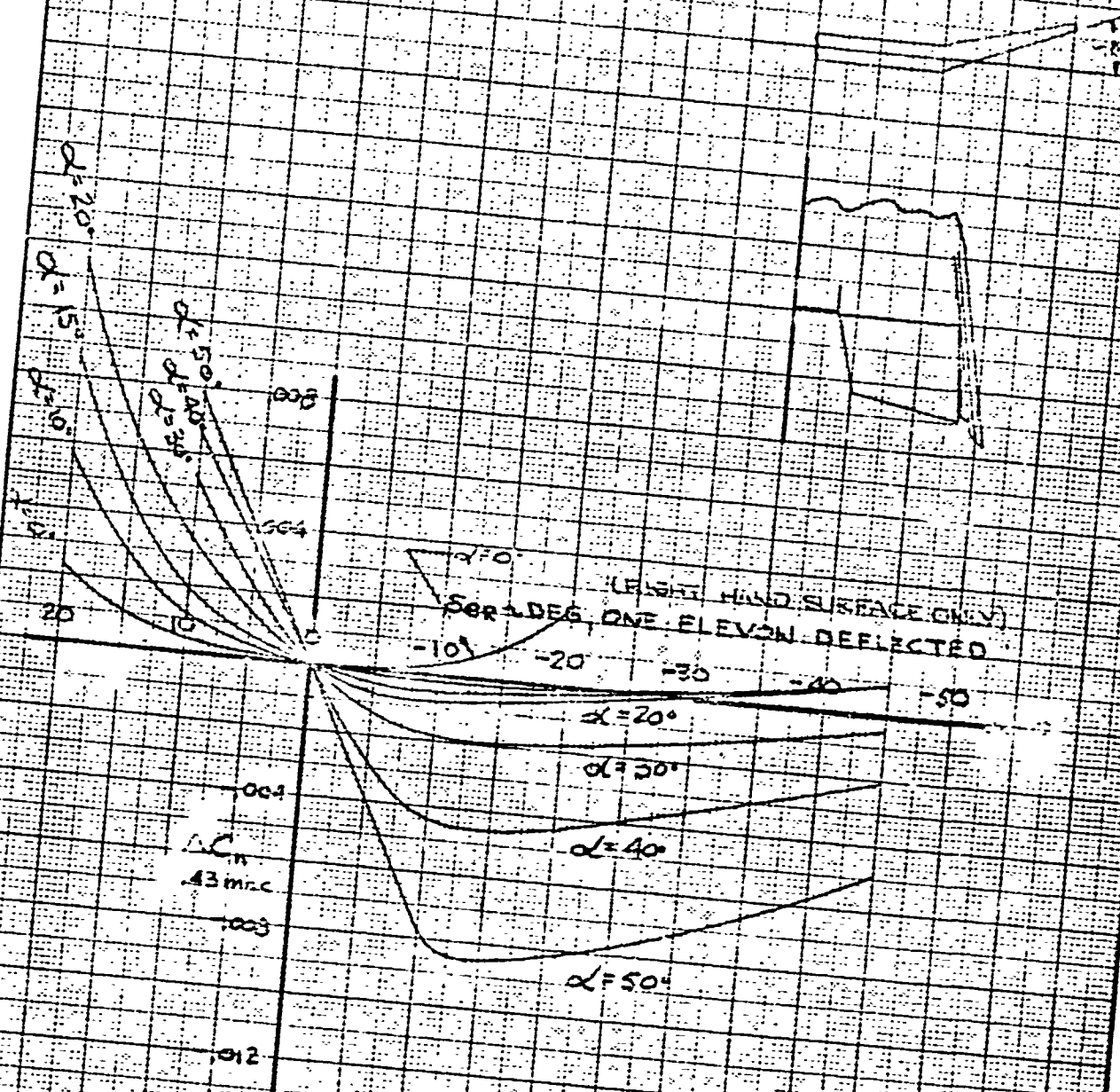


BODY AXIS

$M=8.0$

844-2035

$\beta=0^\circ$



$S_w = 343 \text{ FT}^2$

$b = 236.7 \text{ IN}$

$\frac{S_e}{S_w} = 14\%$

NOTE: THESE CURVES ARE BASED ON $M=8.1$ TEST DATA AND PARTIALLY SUBSTANTIATED BY $M=8.5$ TEST DATA.

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YAWING MOMENT DUE
TO ONE ELEVON
HYPERSONIC SPEED **155**
BOEING AIRPLANE COMPANY

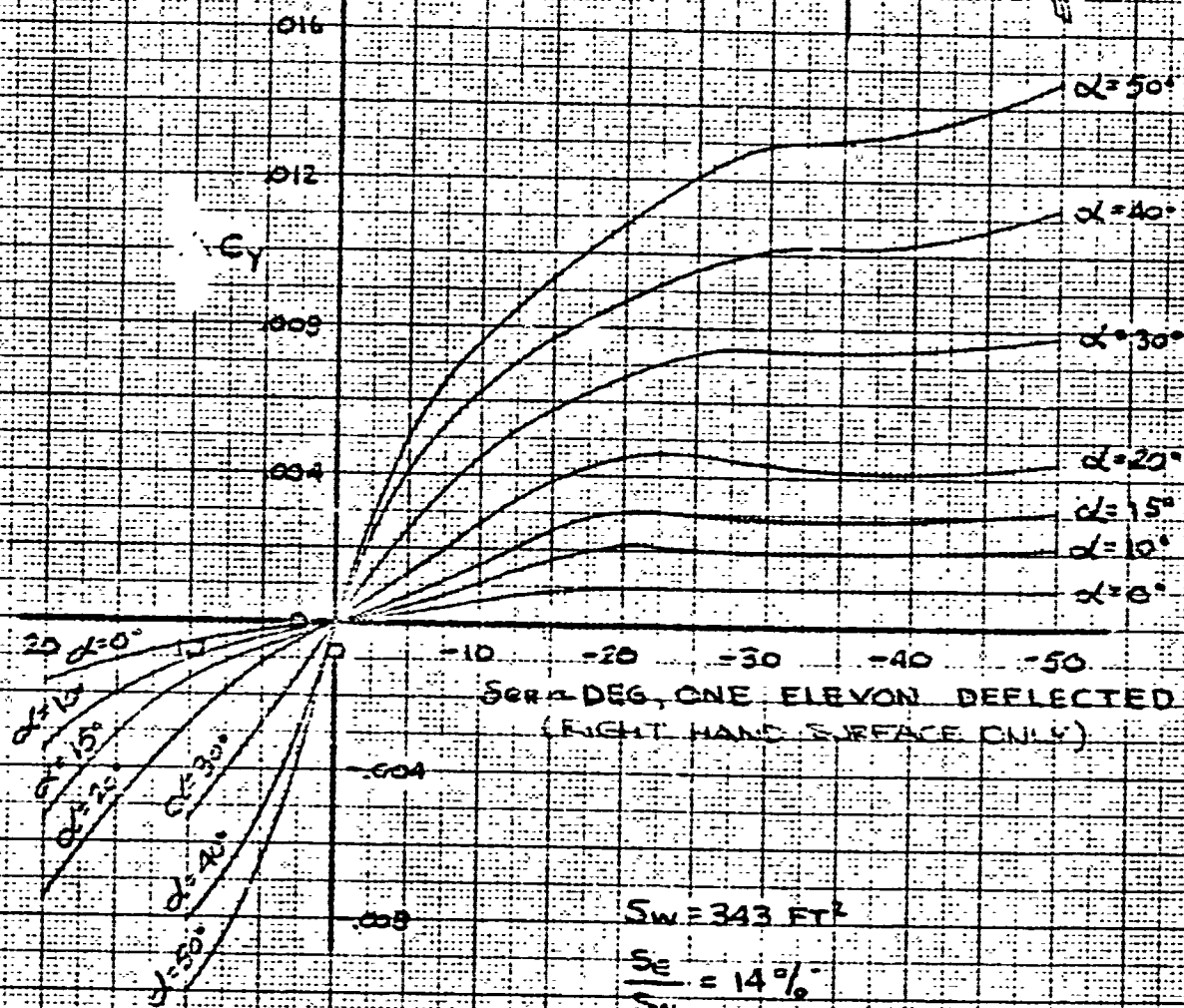
FIG. 6.41
844-
2035-
DZ-8174
6.45

BODY AXIS

M=8.0

844-2035

$\beta=0^\circ$



NOTE: THESE CURVES ARE BASED ON M=8.1 TEST DATA AND PARTIALLY SUBSTANTIATED BY M=9.5 TEST DATA.

CALC	EJH	11/18/0	REVISED	DATE
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SIDE FORCE DUE TO
ONE ELEVON
HYPERSONIC SPEED 156
BOEING AIRPLANE COMPANY

FIG. 6.42

844-2035

D2-8174

PAGE 6.46

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6.3

RUDDER CHARACTERISTICS AND EFFECTIVENESS

Rudder effectiveness data for the 844-2035 configuration are presented in Figures 6.43 through 6.51. Summary curves of $C_{n\delta_r}$, $C_{Y\delta_r}$, and $C_{l\delta_r}$ versus Mach number are presented on Figures 6.43, 6.44, and 6.45; more detailed data are presented on Figures 6.46 through 6.51. The data presented are based on wind tunnel data on similar configurations adjusted to the dimensions of the 844-2035.

Landing speed rudder effectiveness is based on preliminary data from BTWT 619. Transonic and supersonic effectiveness were obtained from wind tunnel tests of a model 814-1047 at $M = .905$, 2.0 and 3.5. The hypersonic characteristics are presented for $M = 8$, based on a model similar to 814-1050 at AEDC-B (test BAC 8). These characteristics are currently considered to apply for higher hypersonic speeds. The effect of altitude (i.e., Reynolds number) is assumed to be negligible.

C

157

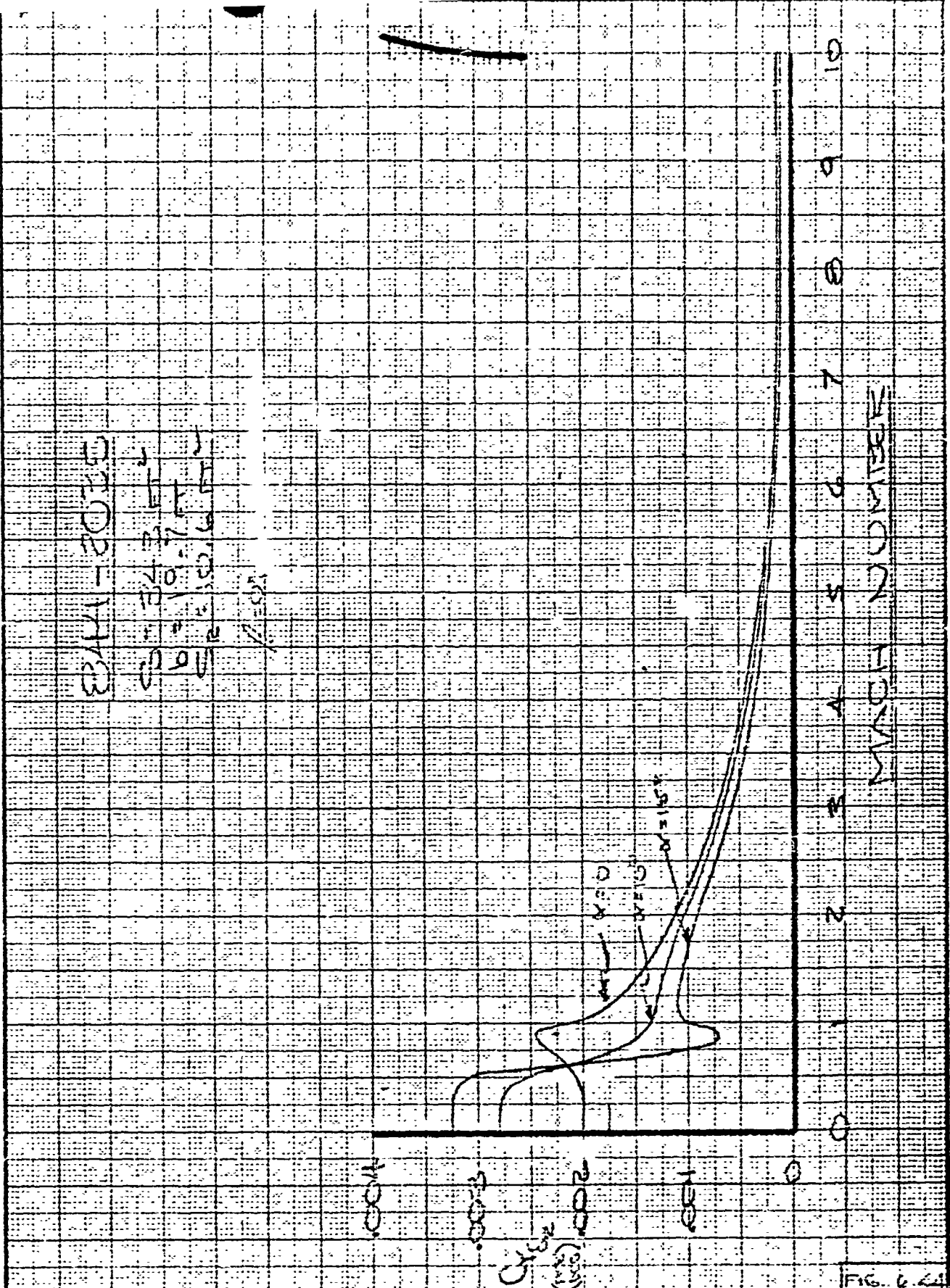
BAC 1546 LR3

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~~CONFIDENTIAL~~

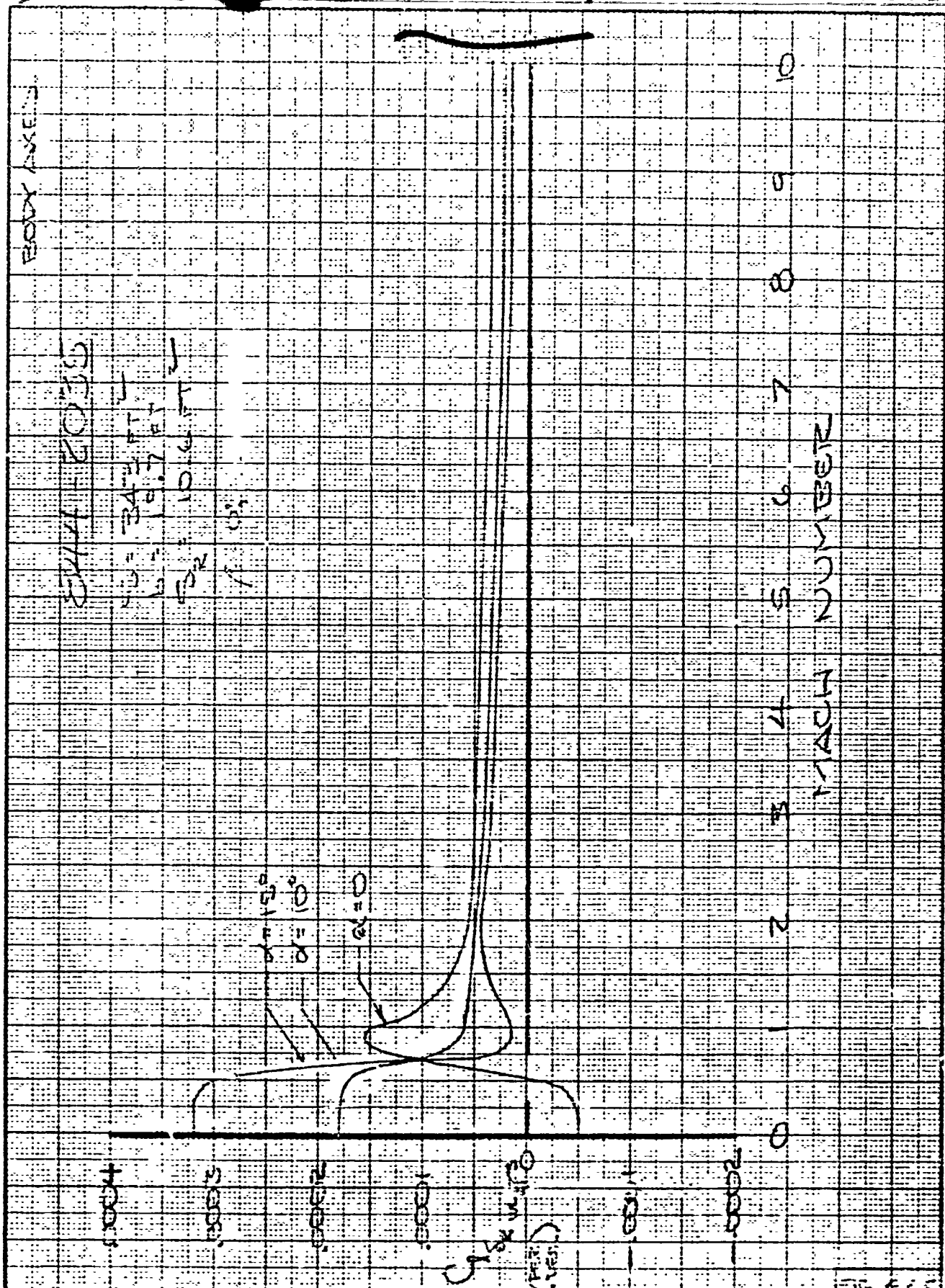
NO D2-B174

PAGE 6.47

K-E 44-38861-100 60824



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CALC	1278	12-0	REVISED	DATE	ROLLING MOMENT DUE TO RUDDER BOEING AIRPLANE COMPANY 160	EAT-2035
CHECK			1278	12-10		12-8174
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APR						6.50

BODY AXIS

$M=0.25$

DYNA SOAR GLIDER
MODEL NO. E44-2035

$\beta=0^\circ$
 $\beta=15^\circ$

$\alpha=15^\circ$
 $\alpha=10^\circ$
 $\alpha=5^\circ$
 $\alpha=0^\circ$
 $\alpha=0^\circ$

RUDDER DEFLECTION
5 DEG

SW = 343.7 LBS
b = 236.7 IN
SR = 10.6 FT²/SIDE

ΔC_Y

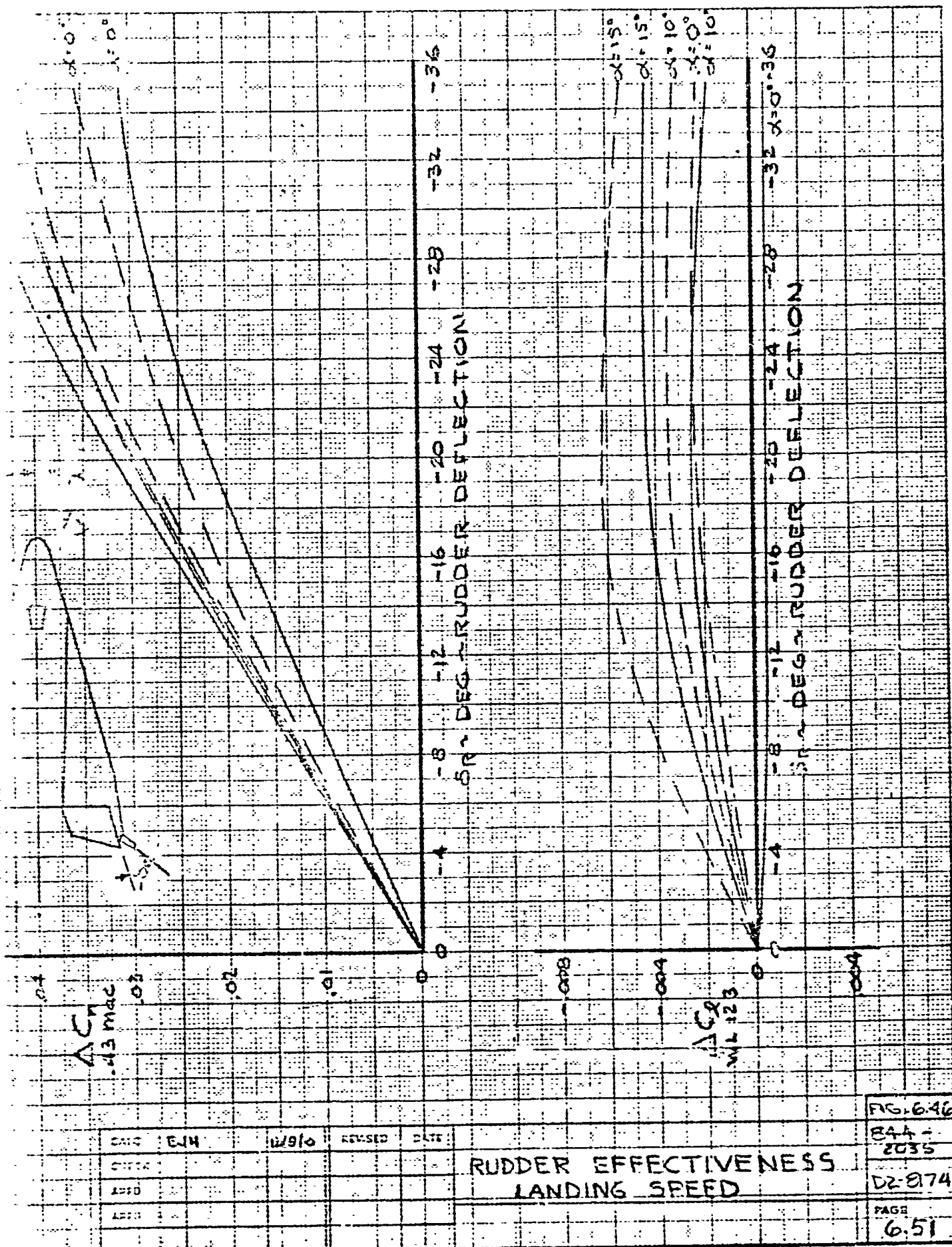
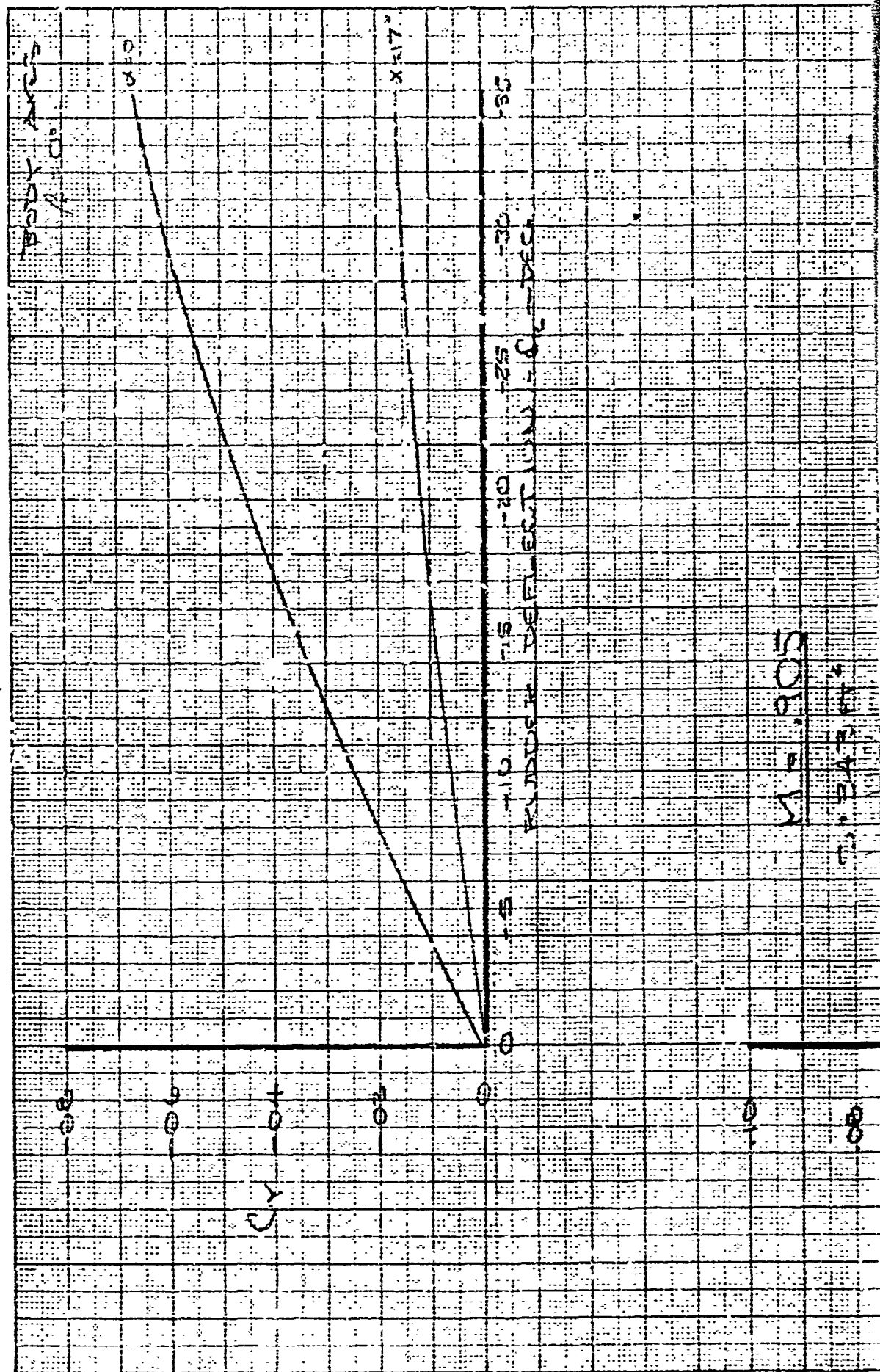
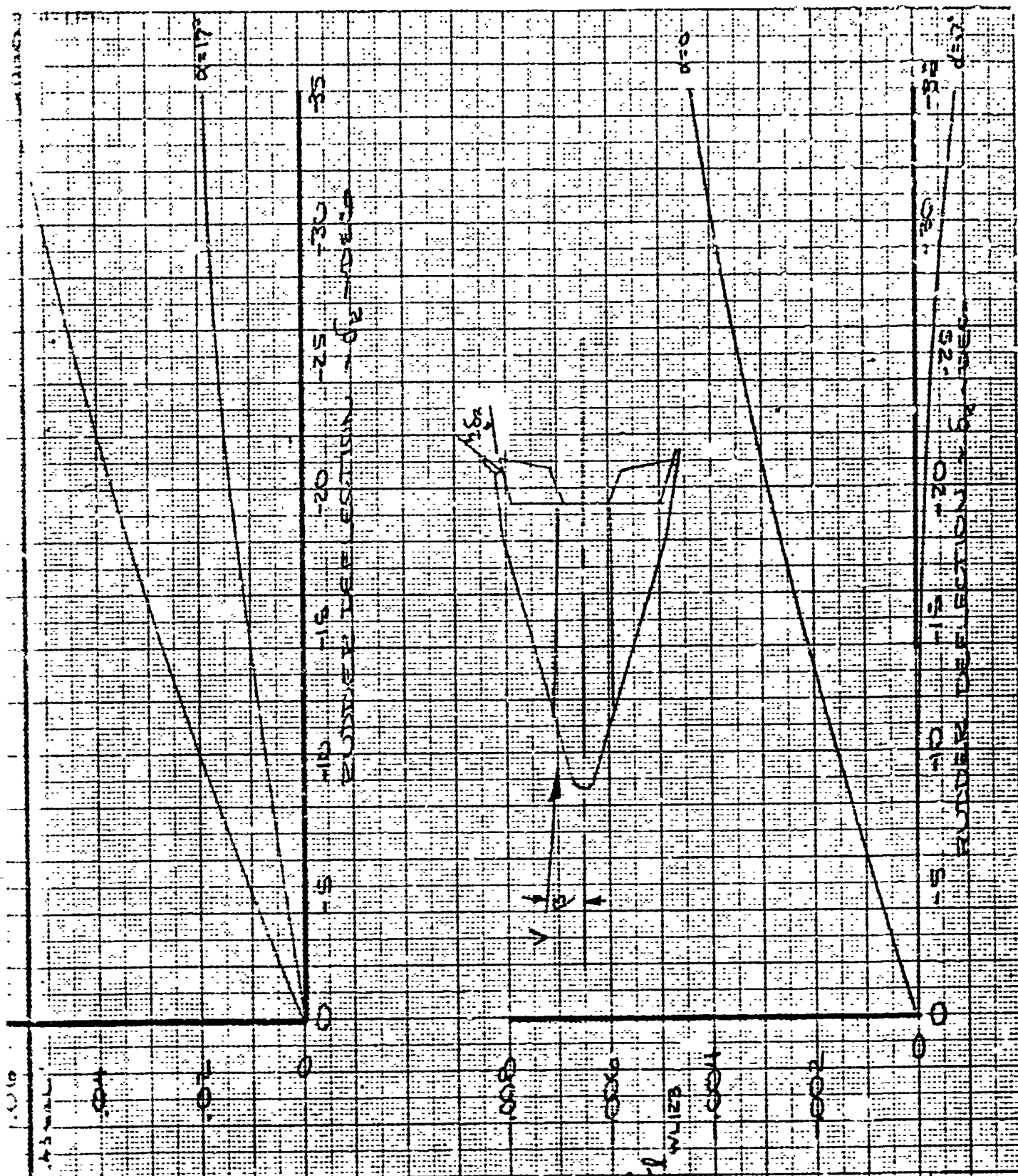


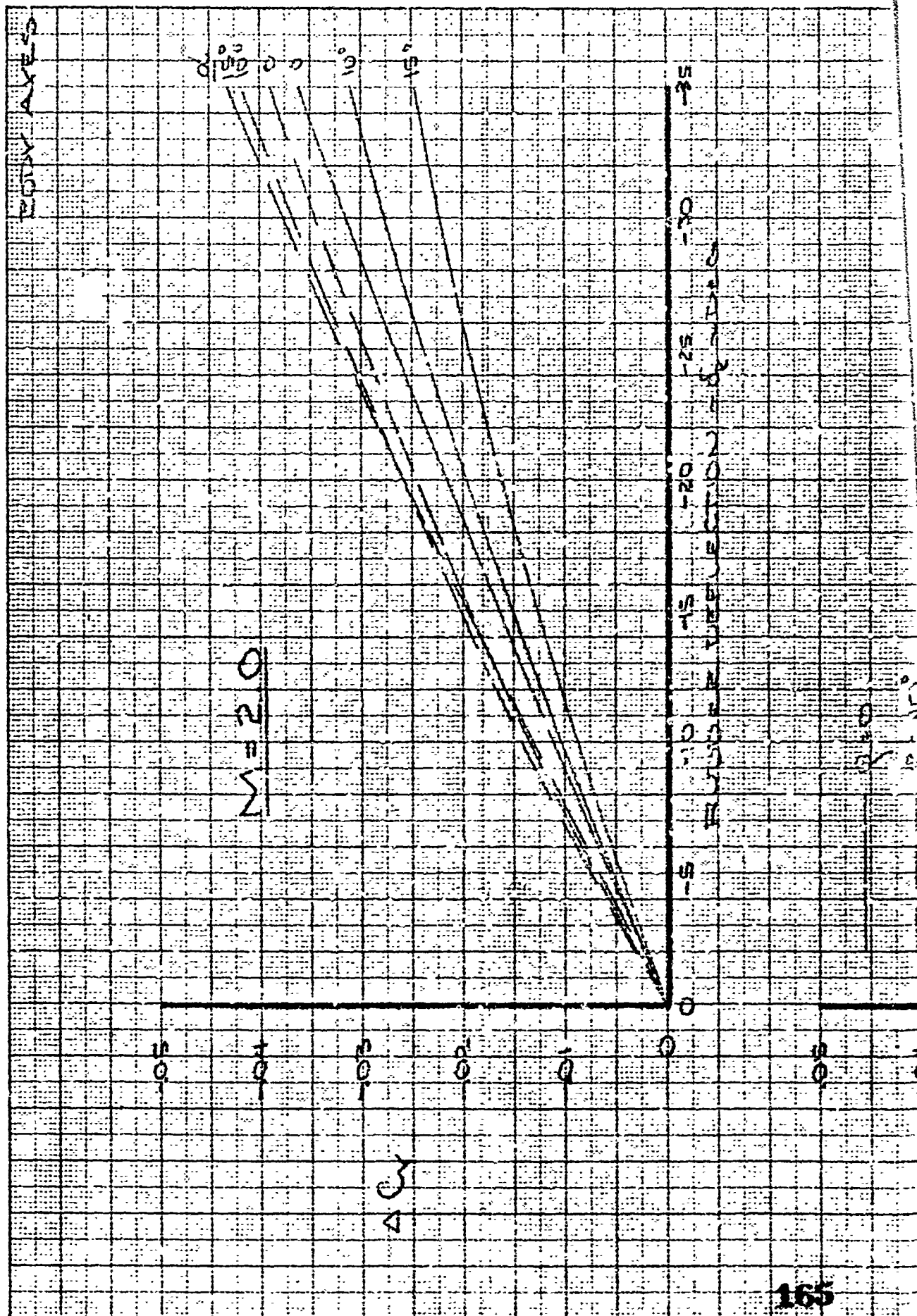
FIG. 6.46
BAA -
2035
D2-974
PAGE
6.51

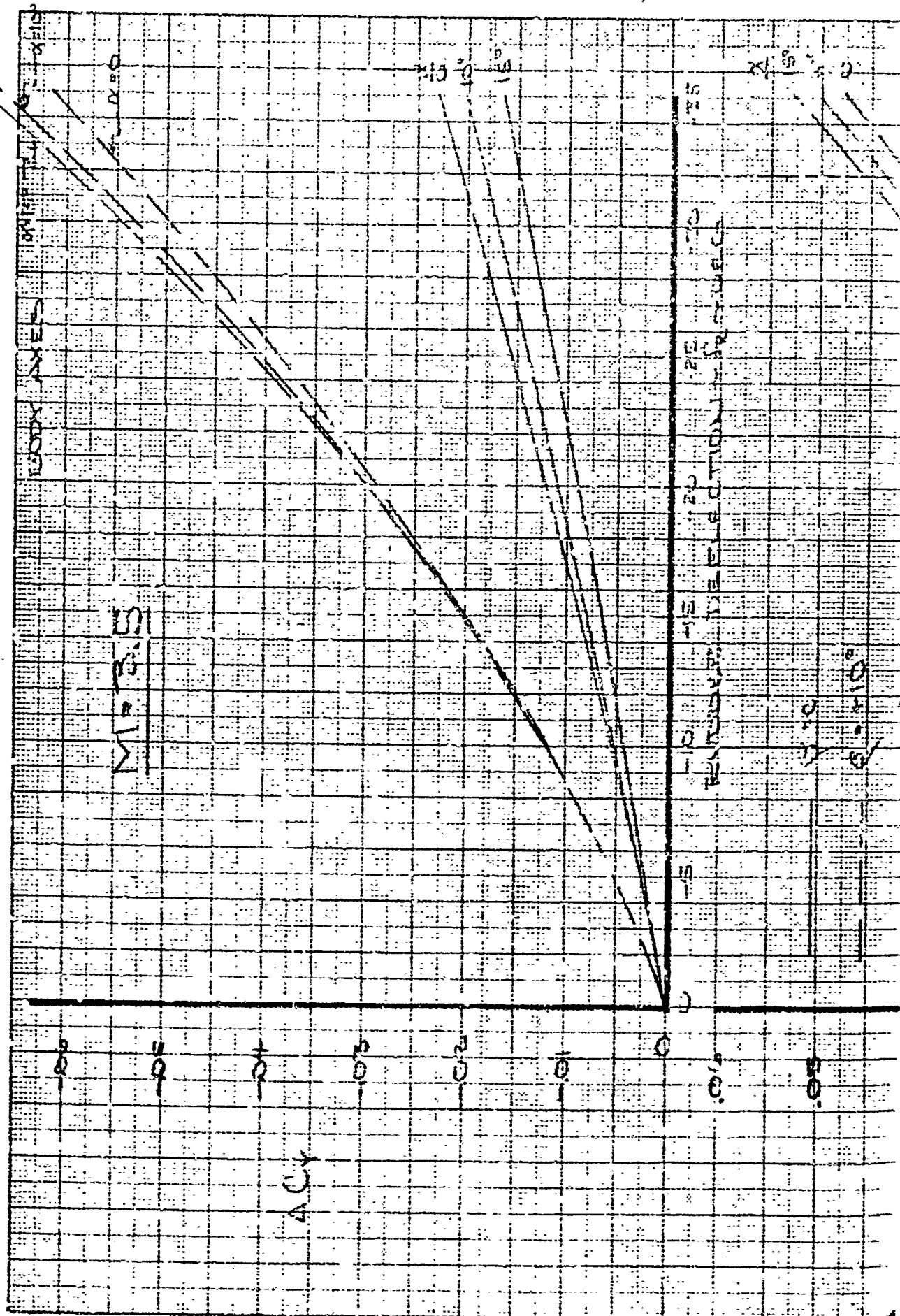


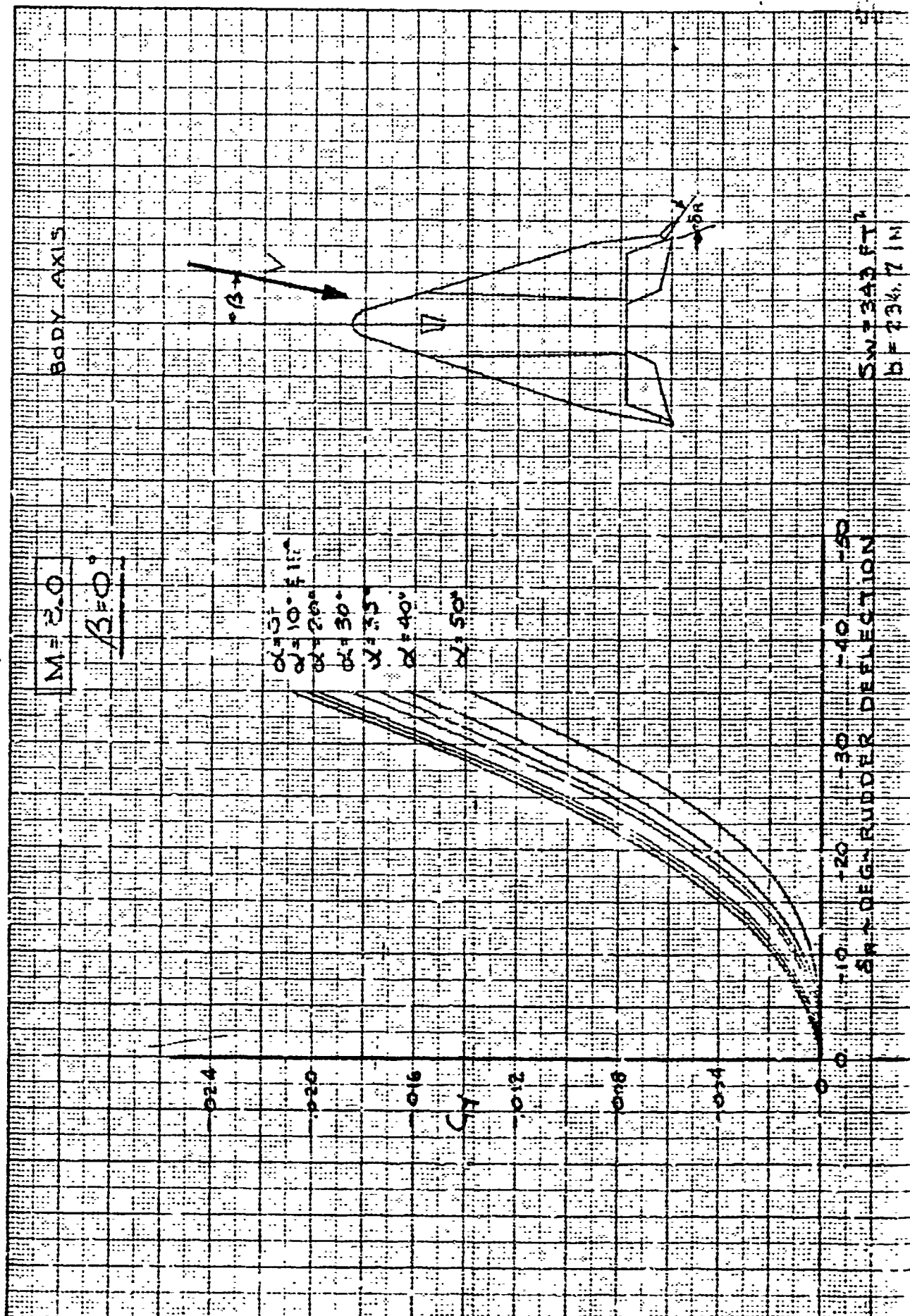


CALC	BTR	12-8-0	REVISED	DATE	FIG 6.47
CHECK					844-
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APPRO					12-8174
					PAGE
					6.52

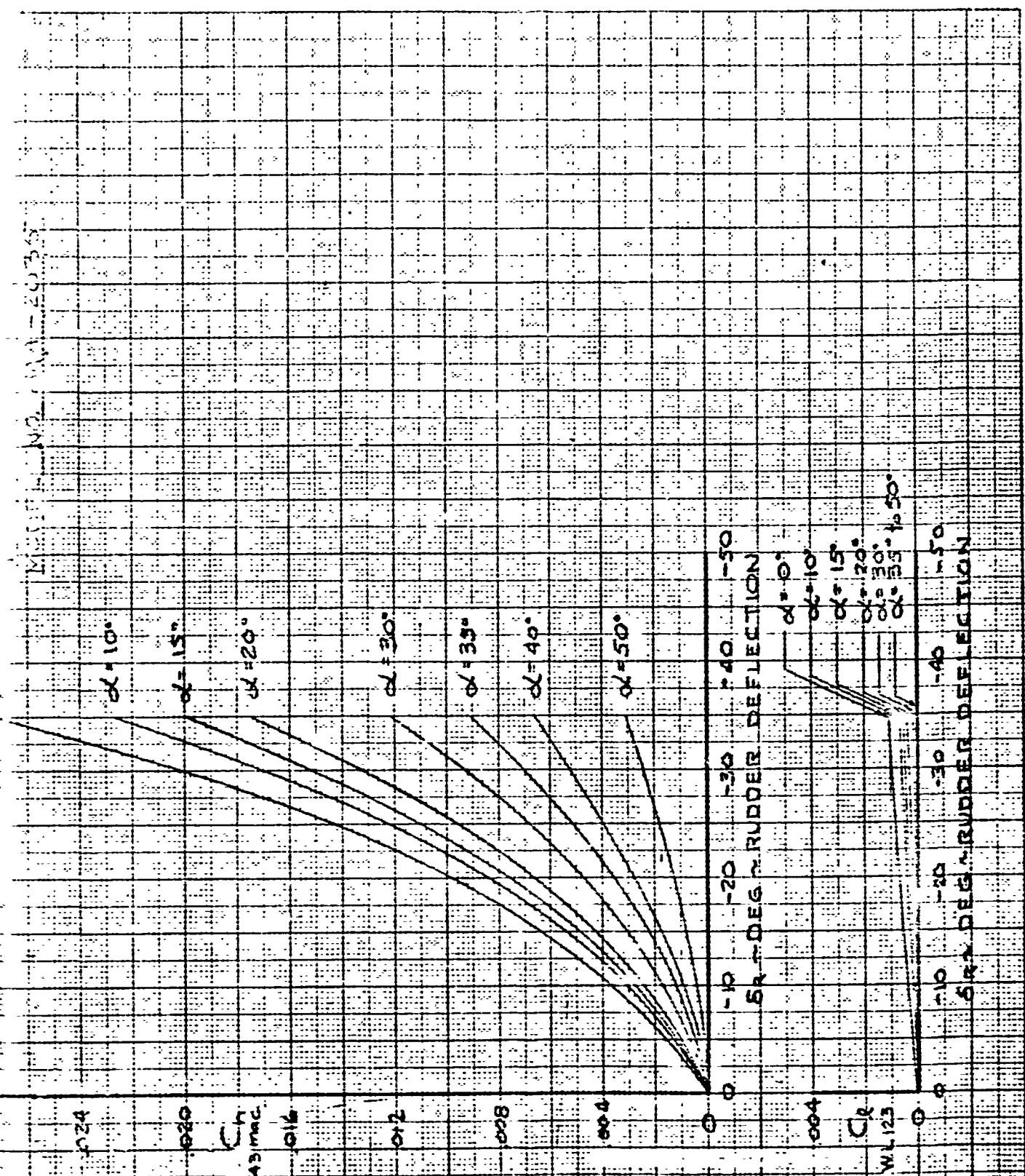
RUDDER EFFECTIVENESS
M = .905







W2-111-2035



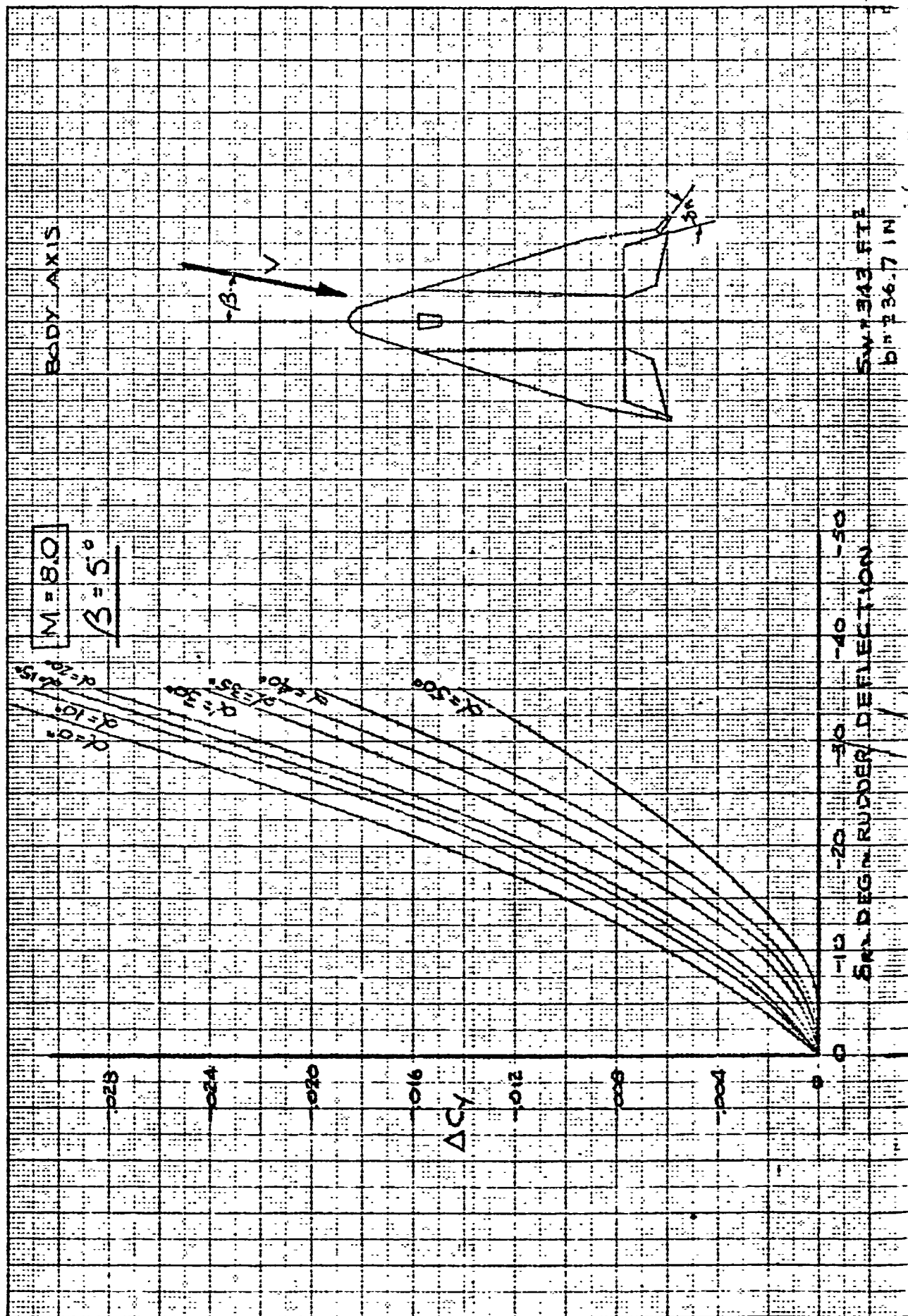
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RUDDER EFFECTIVENESS HYPERSONIC SPEED, $M \geq 5$

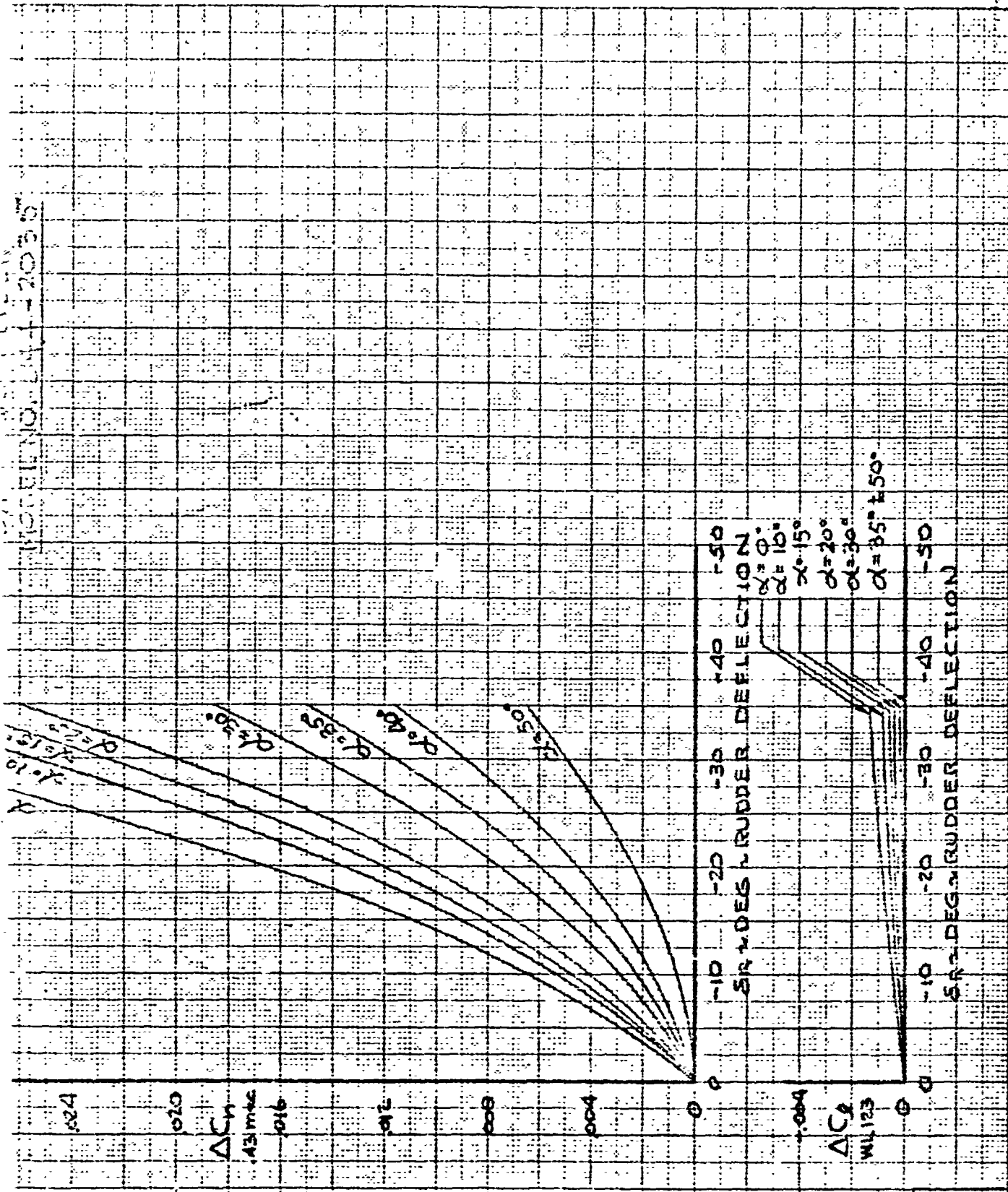
FIG. 6.50
844 -
2035
D2-8174

PAGE

6.55



SW = 343 FT²
b = 36.7 IN



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APPD				

RUDDER EFFECTIVENESS
HYPERSONIC SPEED

FIG. 6.51
844-2035
D2-8174
E.56

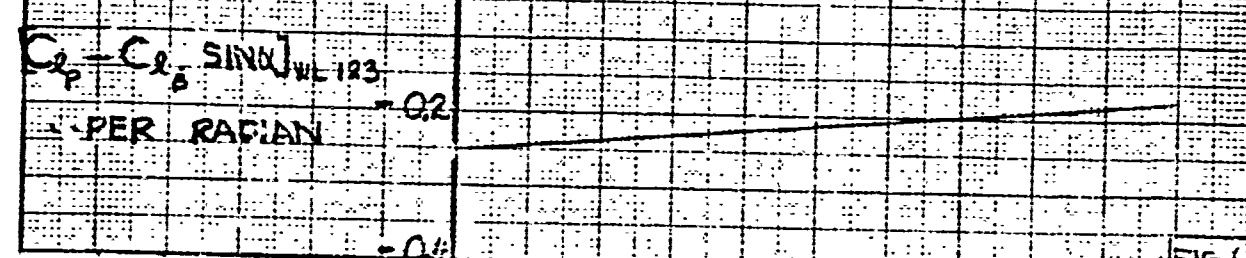
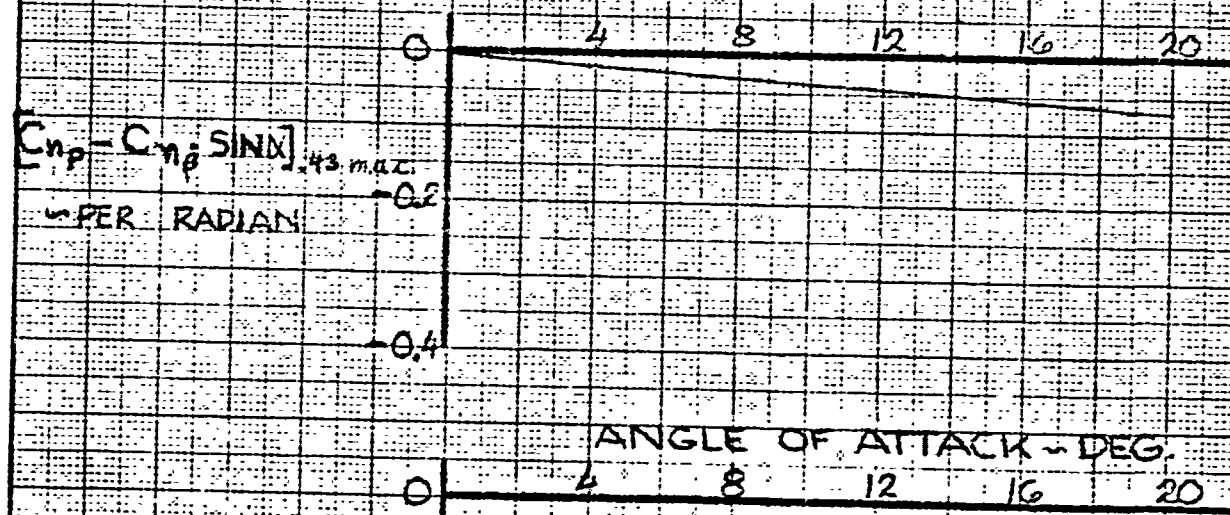
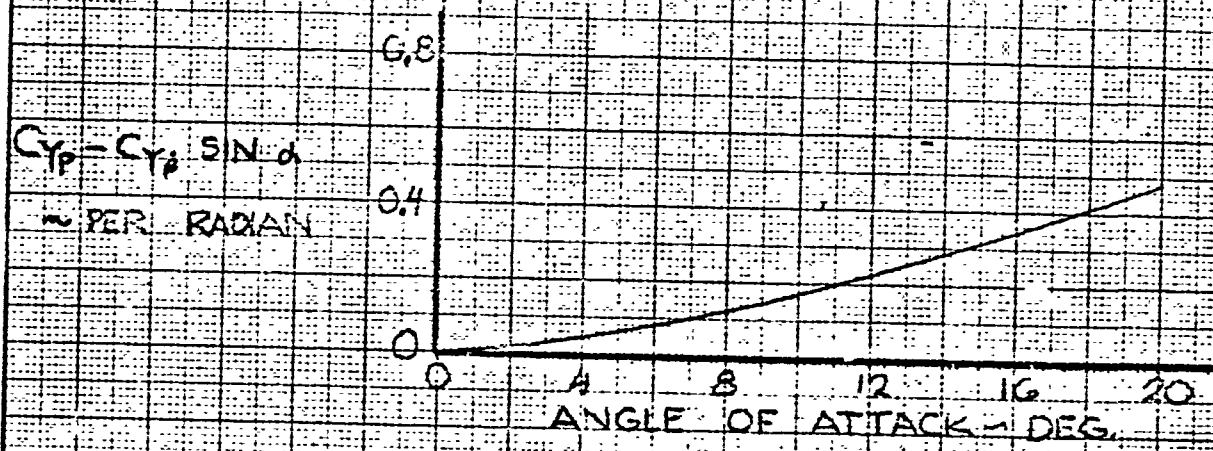
The roll and yaw rate damping derivatives are presented on Figures 6.52 and 6.53 for various angles of attack at landing speed, and on Figures 6.54 and 6.55 for various Mach numbers. The landing speed derivatives are presented in the form that they would be obtained from rotary-derivative wind tunnel tests. The derivatives presented versus Mach number include a theoretical estimate of the contribution due to rate-of-change-of-sideslip. This estimate is included in order to permit use of these rotary derivatives for root-solutions and simulator studies where rate-of-change-of-sideslip may not be desired. Further study may alter this estimate significantly.

The landing speed rotary derivatives are based upon preliminary Langley Research Center rotary derivative test data on a model of configuration 814-2002, a model of the NASA Space Ferry (similar to the Dyna Soar glider), and the Bell-Martin Phase I Dyna Soar glider (Reference b). The data have been correlated by theoretical computations which are based on steady rolling or steady yawing (Reference c).

The rotary derivatives versus Mach number, Figures 6.54 and 6.55, were obtained from Figures 6.52 and 6.53 for landing speed, and the variation with Mach number was obtained from theoretical formulae and rotary derivative tests of the X-15 airplane (Reference d).

DATA SOURCE

THEORETICAL PREDICTIONS FROM
 NACA LTN 2409 CORRELATED WITH FREE
 TO DAMP OSCILLATION TESTS OF THE
 ① BELL-MARTIN VEHICLE (C119-ER-1044)
 ② NASA SPACE FERRY (PRELIMINARY DATA)
 ③ BAC MODEL 2002 ()

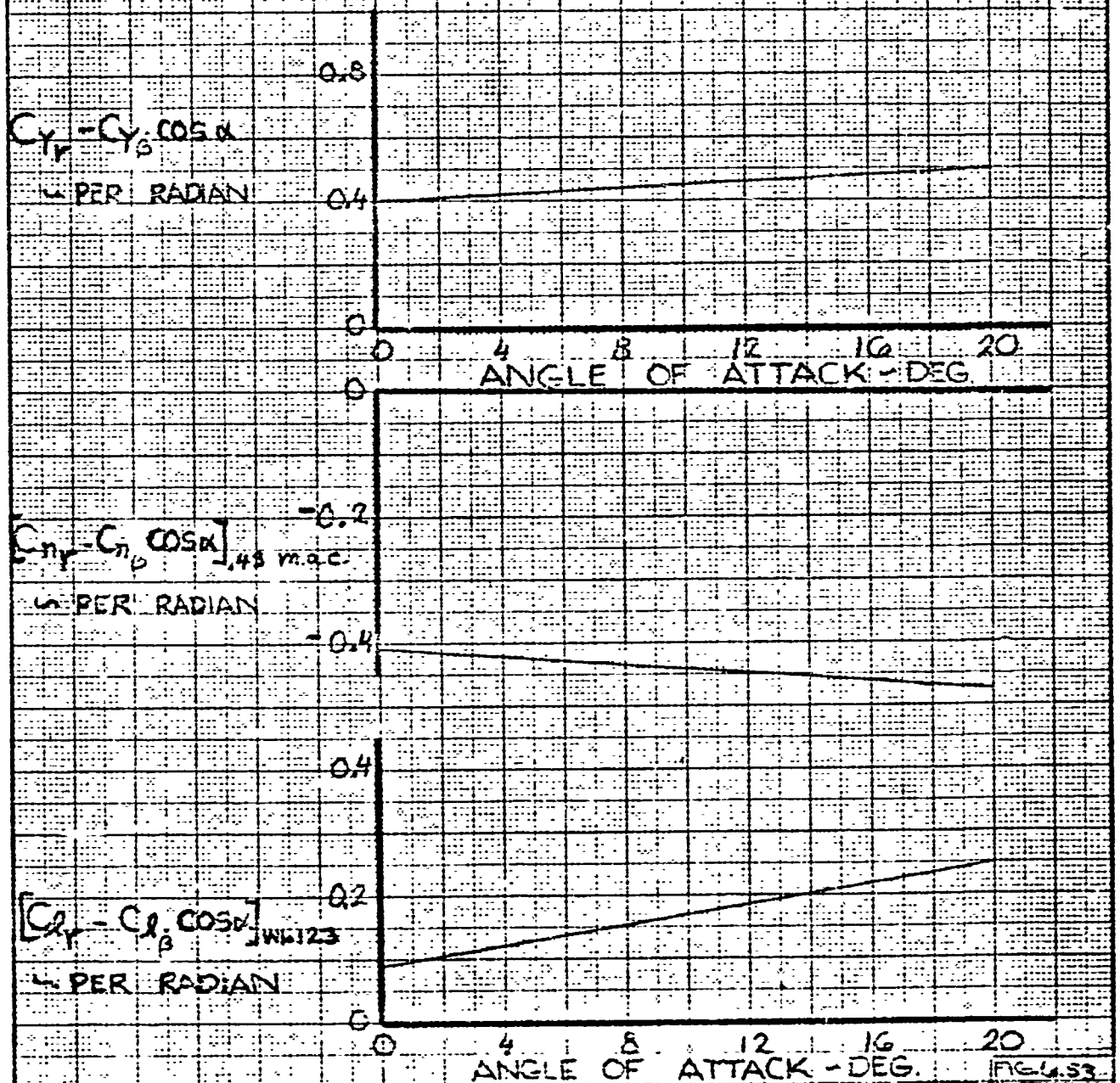


CALC	$\sqrt{m^2}$	12-7-60	REVISED	DATE	EFFECT OF ANGLE OF ATTACK ON ROLLING DERIVATIVES ~ LANDING SPEED BOEING AIRPLANE COMPANY	FIG. 6.52
CHECK	<i>[Signature]</i>					844-2035
APR						D2-674
APR						PAGE 6.58

3-20-60

DATA SOURCE:

THEORETICAL PREDICTIONS FROM:
 NACA LTN 2409 CORRELATED WITH FREE
 TO DAMP OSCILLATION TESTS OF THE
 ① BELL-MARTIN VEHICLE (C119-ER-1044)
 ② NASA SPACE FERRY (PRELIMINARY DATA)
 ③ BAC MODEL 202 (" ")



CALC	DM	12-5-60	REVISED	DATE	EFFECT OF ANGLE OF ATTACK ON YAWING DERIVATIVES ~ LANDING SPEED	844-2035 D2-6174
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BOEING AIRPLANE COMPANY					175	PAGE 6.59

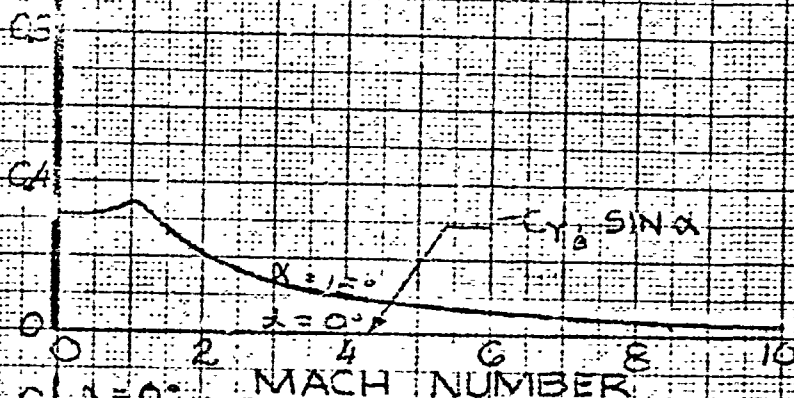
BODY AXES

DATA SOURCE:

SUPPLEMENTARY DATA FROM FIGS. 6.58 & 6.59
 SUPERSONIC PREDICTIONS AND
 TEST DATA FROM NASA
 TM-X-1287 (X-15 AIRPLANE)

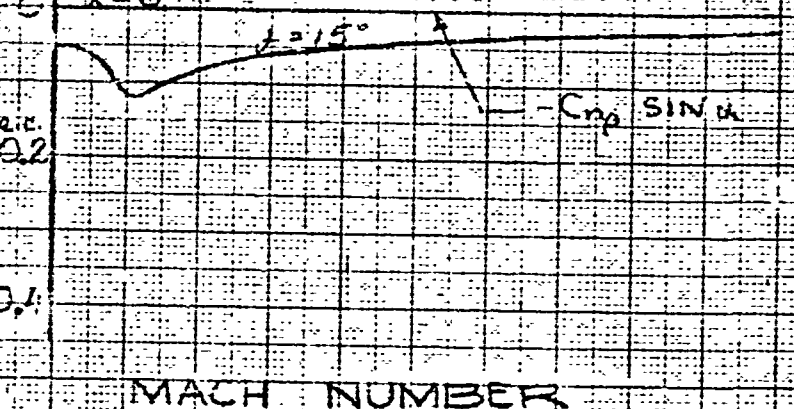
$$C_{YF} - C_{YB} \sin \alpha$$

~ PER RADIAN



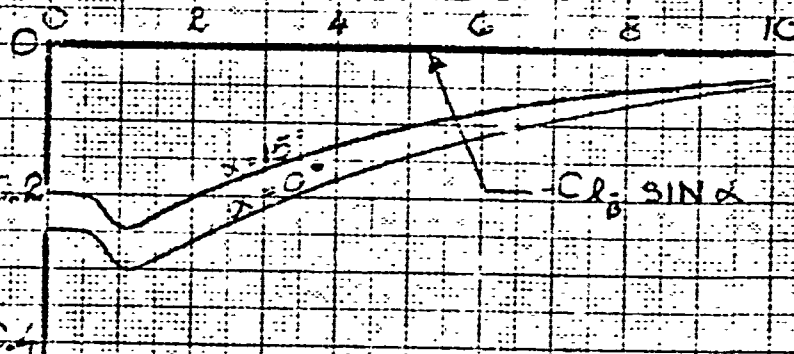
$$[C_{np} - C_{n\dot{\beta}} \sin \alpha]$$

~ PER RADIAN



$$[C_{lp} - C_{l\dot{\beta}} \sin \alpha]$$

~ PER RADIAN



CALC	PM	12-8-60	REVISED	DATE
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EFFECT OF MACH NUMBER
 ON ROLLING DERIVATIVES

BOEING AIRPLANE COMPANY 176

FIG. 6.54

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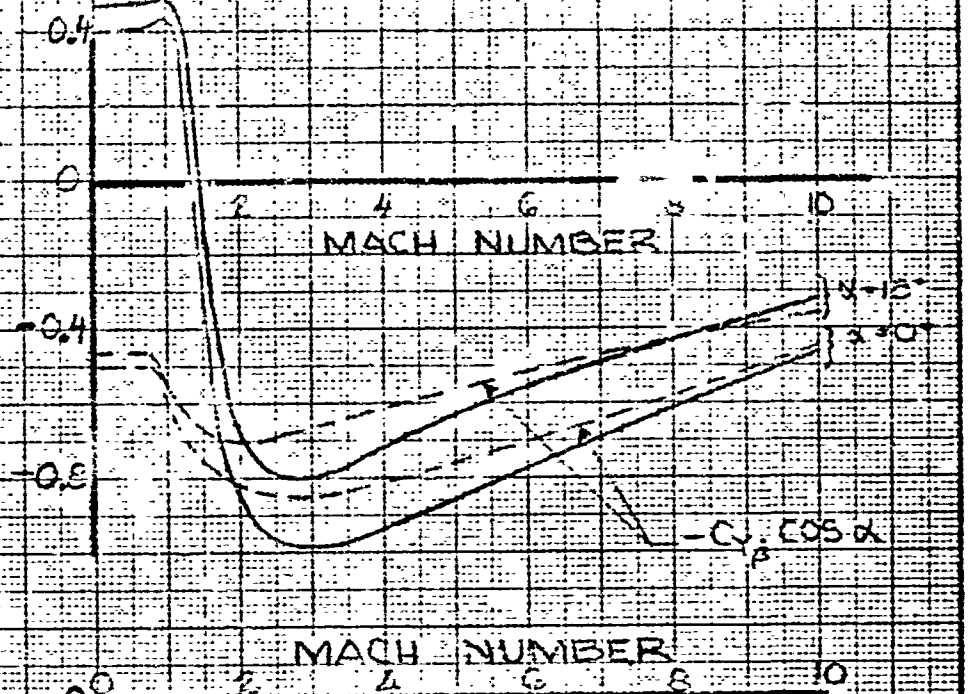
PAGE 6.60

BODY

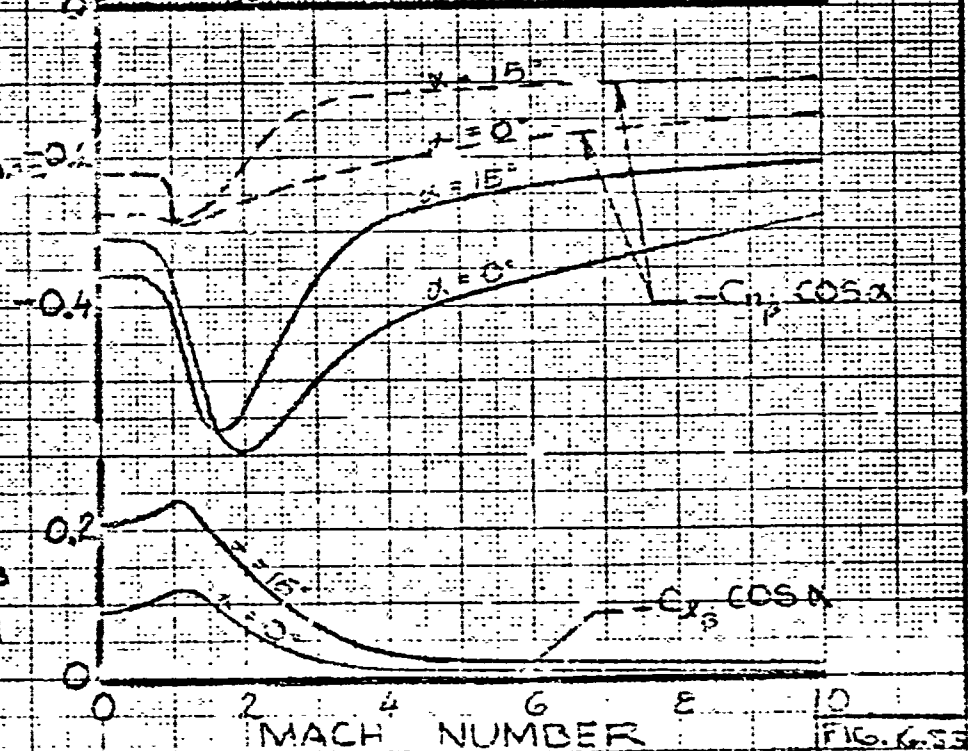
DATA SOURCE:

SUBSONIC DATA FROM FIGS. 6-53 & 6-59
SUPERSONIC PREDICTIONS AND
TEST DATA FROM NASA
TMX-287 (X-15 AIRPLANE)

$C_{Y_r} = C_{Y_b} \cos \alpha$
- PER RADIAN



$[C_{Y_r} - C_{Y_b} \cos \alpha]_{\alpha=0} = 0$
- PER RADIAN



$[C_{L_r} - C_{L_b} \cos \alpha]_{\alpha=0} = 0$
- PER RADIAN

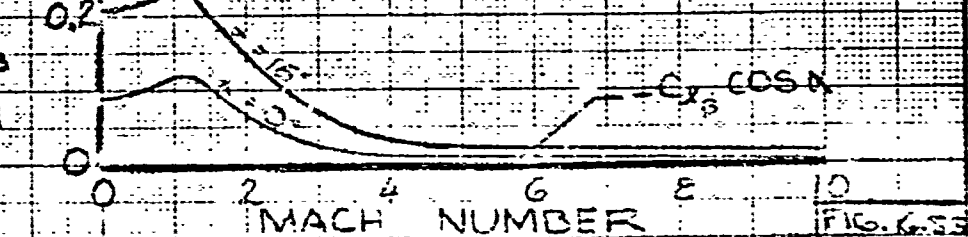


FIG. 6-53

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BOEING AIRPLANE COMPANY

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7.0

GLIDER WITH TRANSITION SECTION

The addition of the third stage rocket and transition section to the glider moves the center of gravity rearward and changes the glider pitch and yaw characteristics. These effects are reflected in the longitudinal and lateral-directional stability data shown in Figures 7.1 through 7.13. Wind Tunnel data available for pitch characteristics were used from $M=7$ to $M=35$; at lower and higher speeds, theoretical estimations were necessary. The lateral directional data were estimated. The reference centers of gravity for the moments were those for the instant of ignition of the third stage rocket and at burn out after 19 seconds of rocket burning. The c.g. moves forward 8.8% m.a.c. during third stage powered flight. Present plans include modifying the transition shape and length from that shown to reduce the zero lift pitching moment and to increase the glider static stability at transonic speeds. The effect of change of shape to reduce the zero lift pitching moment has been estimated and included in the data shown. The effect of length to increase stability has not been included.

7.1

LONGITUDINAL STABILITY AND CONTROL

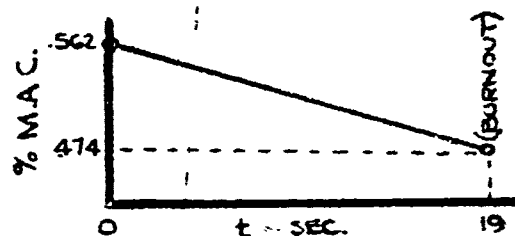
The addition of the transition section to the glider creates positive zero-lift pitching moment and reduces the vehicle normal force. This effect is most prevalent at subsonic and transonic speeds, diminishing at supersonic speeds. The increments of normal force and pitching moment for various angles of attack and Mach numbers with no elevon deflection were determined from wind tunnel tests of an early configuration and modified to reflect the current configuration. Data were available for a range of speeds from $M = .7$ to $M = 3.5$. These increments were added to the glider-alone data.

The data reflect the 66 inch transition length tested rather than the 55 inch length shown in Reference A. The transition length will be established from aerodynamic and performance requirements. The 55 inch length represents a logical separation plane from structural design considerations since the pressure bulkhead for the heat blast diagram is located in that region. However, sufficient static stability may not be available from the 55 inch transition section.

Two center of gravity locations are shown on the plots in Figures 7.1 through 7.8. These are: (1) the initial center of gravity at the instant of separation from the second stage and (2) the center of gravity at rocket burnout.

Lines of constant elevon deflection and constant angle of attack are shown only for the initial center of gravity location at .562 m.a.c. Other fore and aft center of gravity locations can be represented on these plots by a rotation of the vertical (C_m) axis. This rotation is shown for the center of gravity at rocket burnout of .474 m.a.c. The vertical center of gravity location is assumed fixed when the C_m axis is rotated to represent a different fore and aft center of gravity location.

The following method can be used to determine the amount of rotation of the C_m axis required to represent other center of gravity locations. (1) Assume center of gravity travel linear with burn time (t).



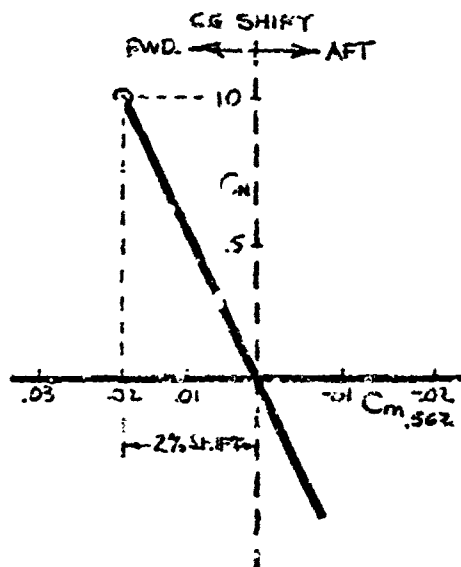
Then determine the center of gravity location in present m.a.c. for the time (t) desired as shown in the sketch above.

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(2) Shift the C_N axis to reflect the center of gravity location for the time (t).

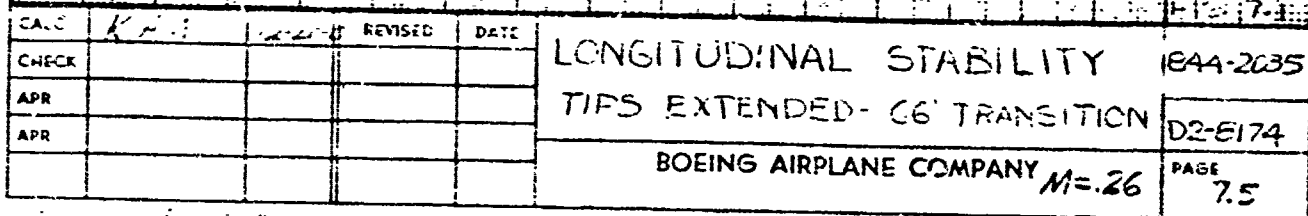
Example: Shift the center of gravity 2 percent m.a.c. forward.

- (1) locate on the C_N vs C_m plot the point at $C_N = 1.0$ and $C_m = .02$.
- (2) Draw a line through the point and the origin as shown in the sketch below.



Static directional stability characteristics are presented in Figures 7.9 and 7.10 for the effects of angle of attack, folding wing tip extensions, and center of gravity location. Theoretical estimations for the effects of the transition section were added to the glider-alone stability derivatives. The data represent the glider plus transition section aerodynamic characteristics reasonably well for $\pm 5^\circ$ sideslip. The data shows the fold down tip in the down, or extended, position to $M=3.5$. The precise speed to which the folding tips will be extended is to be determined.

The effects of rudder deflection on the glider plus transition directional characteristics are shown in Figures 7.11 through 7.13 for two angles of attack. The effectiveness differs from the glider-alone characteristics because of the center of gravity location.



NOTES:

1. $S_{\text{SW}} = 14$
 $S_{\text{T/SW}} = 1032$
 $L_{\text{MP}} = 15'$
 $MAC = 25.2\%$
 $\Delta \text{TRANS} = 5.2'$

2. C.G. TRAVEL LINEAR WITH 19 SEC BURN TIME.

3. α FOR α CONSTANT AND C.G. AT $t=0$ AT .562 MAC,
 $(C_{m_{\text{SEC}}}) + (C_{m_{\text{SEC}}-0}) (1 + 0.16t)$
 $t_{\text{BURN-OUT}} = 19.0 \text{ SEC.}$

M = .70

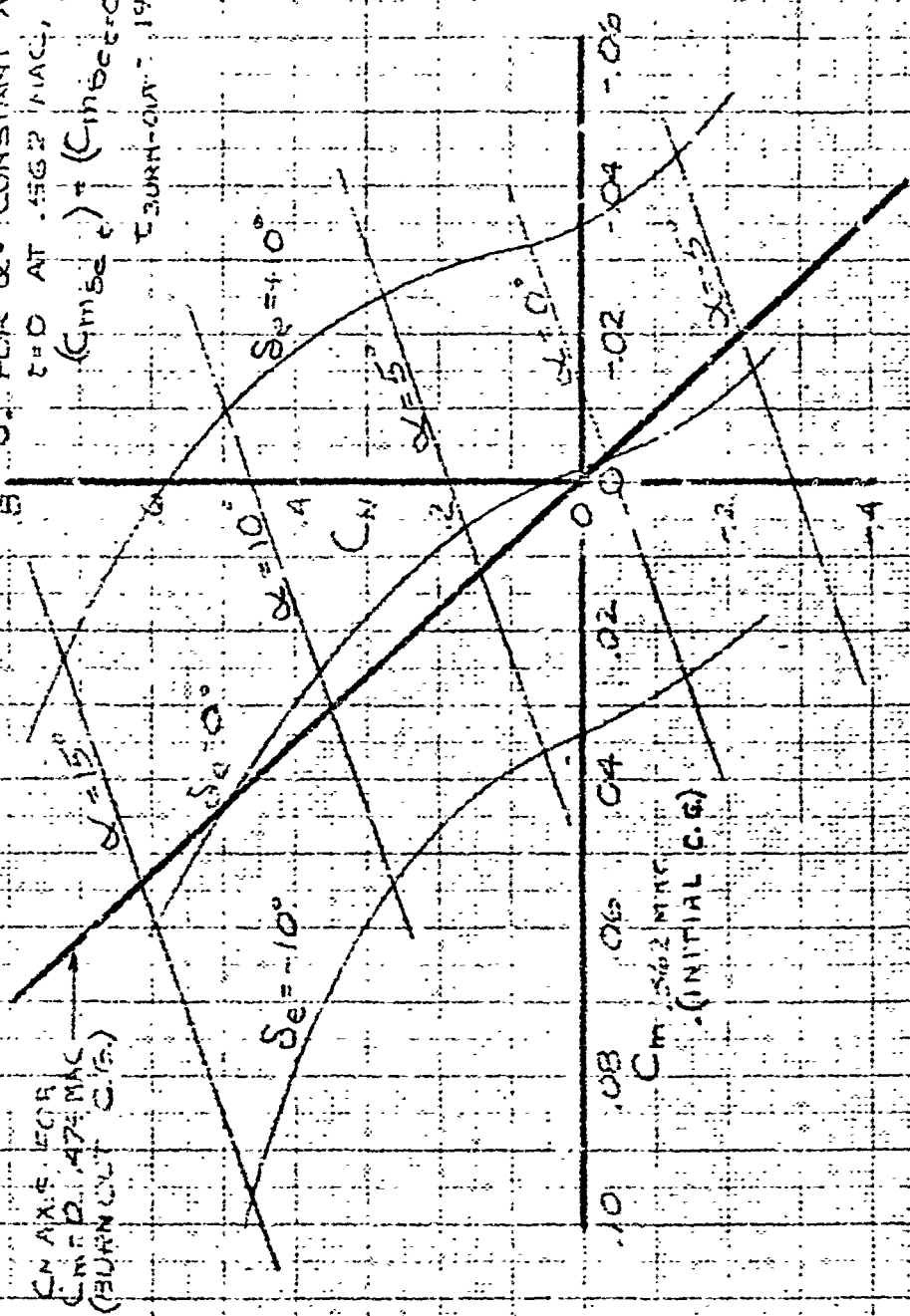


FIG 7.2

18 (99 JAW)

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LONGITUDINAL STABILITY

64-2035

TIPS EXTENDED - 66° TRANSITION

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LONGITUDINAL STABILITY

TIPS EXTENDED - 66" TRANSITION D2-6174

BOEING AIRPLANE COMPANY M=90 PAGE 7.7

FIG. 7.3
844-2035

M=90

NOTES

1. $S_e/S_w = .14$
 $S_t/S_w = .032$
 $\lambda_{TP} = +15^\circ$

66" TRANSITION
 $S_w = 342.2 \text{ SQ FT}$
 $MAC = 252.5 \text{ IN}$
 $\lambda_{TRANS} = 5.2^\circ$

C.G. TRAVEL LINEAR WITH
19 SEC. BURN TIME

CN AXIS FOR
 $C_m = 0.479 \text{ MAC}$
(BURN OUT C.G.)

$\alpha = 15^\circ$

CN

$\delta_e = +10^\circ$

$\delta_e = 0$

$\delta_e = -10^\circ$

$\alpha = 10^\circ$

$\alpha = 5^\circ$

$\alpha = 0^\circ$

-0.03

-0.02

-0.01

0

.01

.02

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.04

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$C_m = .562 \text{ MAC}$
(INITIAL C.G.)

FOR $\alpha = \text{CONSTANT AND C.G. AT}$
 $t=0 \text{ AT } .562 \text{ MAC,}$

$(C_{m_{60t}}) F (C_{m_{60t}} F = 1) (1 + 0.15 t)$

$t_{\text{BURN-OUT}} = 19 \text{ SEC.}$

$\alpha = -5^\circ$

-0.2

-0.4

NOTES:
1. $\frac{S_0}{S_0 + S_{\infty}} = 14$
2. CG TRAVEL - NEAR
WITH 195FC. BY THE
3. FOR $\alpha = 12^\circ$ (INITIAL C_0)
CG AT $\alpha = 12^\circ$ IS 1.5

CLAVE FOR
1. $M = 160$
2. $\alpha = 12^\circ$
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100. $\alpha = 12^\circ$

FIG 75

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三

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[illegible][illegible]

1000

[illegible]

Age Group	Total	Female	Male	Unknown
18-24	100	85	15	0
25-34	100	75	25	0
35-44	100	85	15	0
45-54	100	75	25	0
55-64	100	85	15	0
65+	100	75	25	0

100

[illegible]

100

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[illegible]

$\frac{d}{dt} \left(\frac{1}{2} m v^2 \right) = \frac{1}{2} m \frac{dv^2}{dt}$

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LEARNING OBJECTIVES

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BOEING AIRPLANE COMPANY

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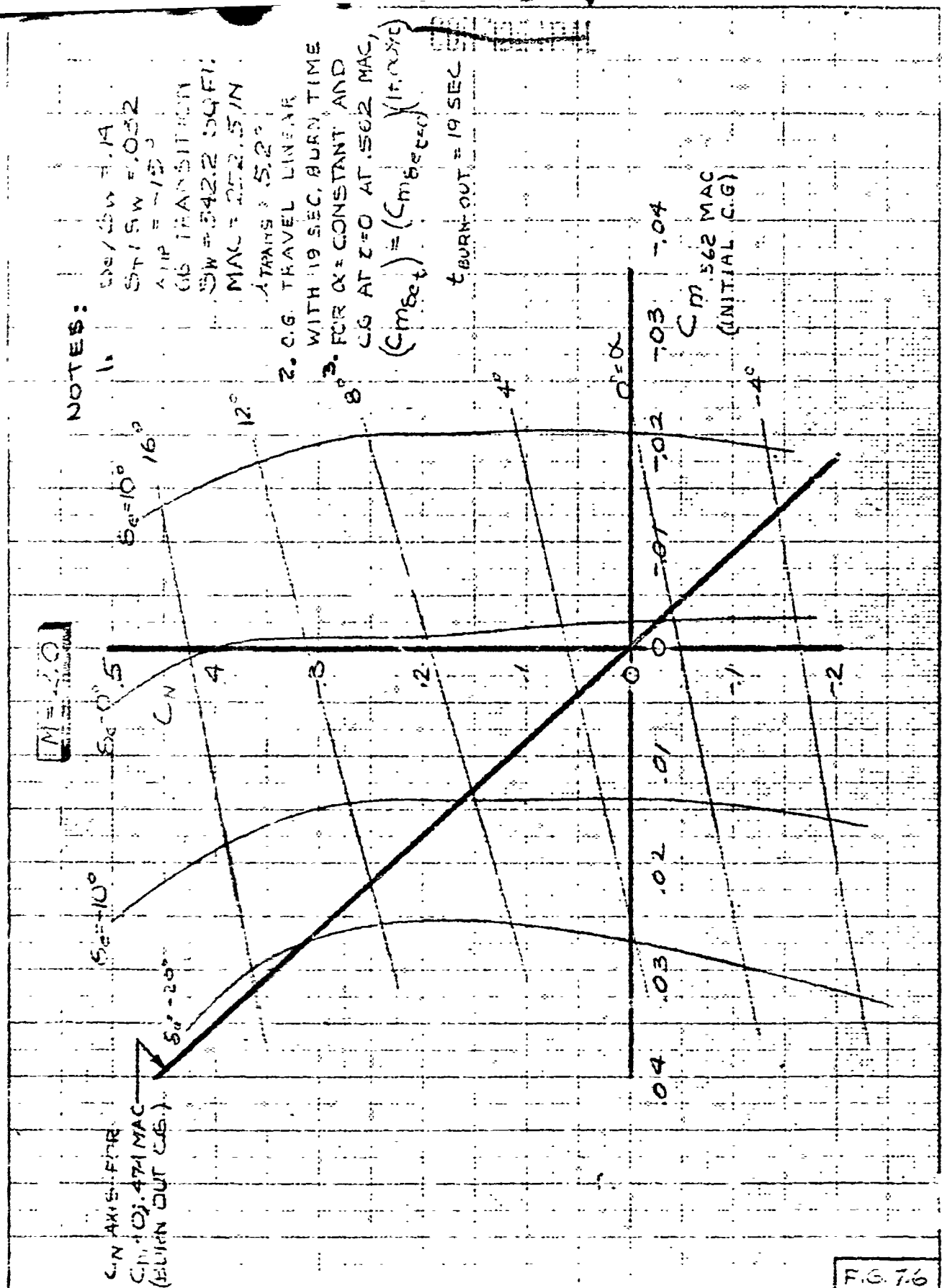
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LONGITUDINAL STABILITY

TIPS EXTENDED - 66 TRANS -

BOEING AIRPLANE COMPANY M=2.0 DATE 7.10

FIG. 7.6
844-2035



NOTES:

1. $\beta_{1/2} = 0.03$
 2. $\beta_{1/2} = 7.5$
 3. $\beta_{1/2} = 4.66$

4. $\beta_{1/2} = 1.5$
 5. $\beta_{1/2} = 1.5$
 6. $\beta_{1/2} = 1.5$

7. $\beta_{1/2} = 1.5$
 8. $\beta_{1/2} = 1.5$

9. C.G. TRAVEL LINEAR WITH IS ECUATED FOR 1. FOR A CONSTANT AND C.G. AT 1.55 AT 1.55

10. $(C_{m_{\text{static}}}) + (C_{m_{\text{dynamic}}})$

11. $C_{m_{\text{static}}} = 1.55$

12. $C_{m_{\text{static}}} = 1.55$

$M = 3.5$

CW

$\beta_{1/2} = 0$

$\beta_{1/2} = 10$

$\beta_{1/2} = 20$

$\beta_{1/2} = 30$

$\beta_{1/2} = 40$

$\beta_{1/2} = 50$

$\beta_{1/2} = 60$

$\beta_{1/2} = 70$

$\beta_{1/2} = 80$

$\beta_{1/2} = 90$

$\beta_{1/2} = 100$

$\beta_{1/2} = 110$

$\beta_{1/2} = 120$

$\beta_{1/2} = 130$

$\beta_{1/2} = 140$

$\beta_{1/2} = 150$

CW AXIS FOR $C_m = 0.974$ (AIRY OUT C.G.)

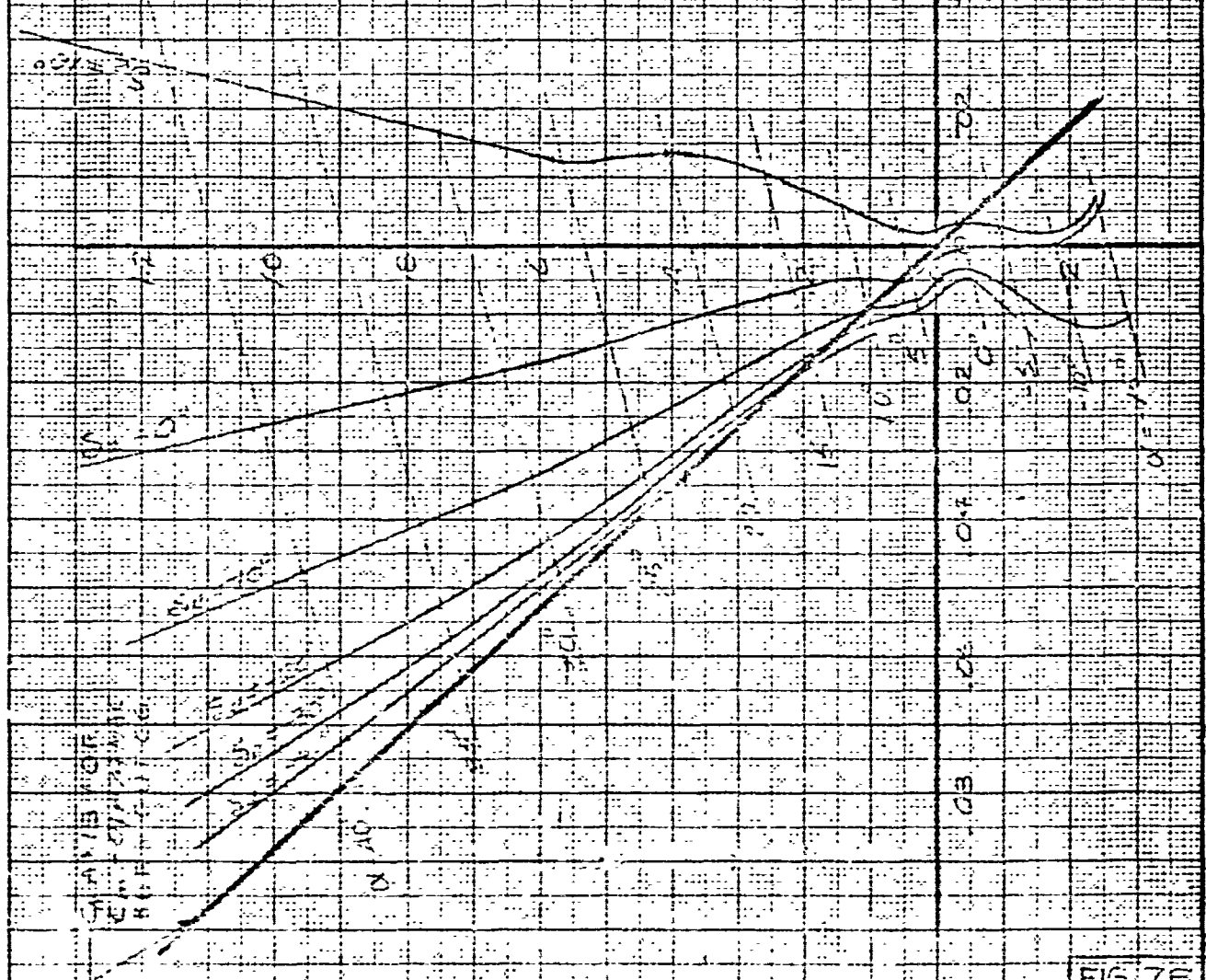
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LONGITUDINAL STABILITY
 1-IPS EXTENDED - 66" TRANSITION
 BOEING AIRPLANE COMPANY $M = 3.5$

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 PAGE 7.11

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|---|---|-----|-----------------|
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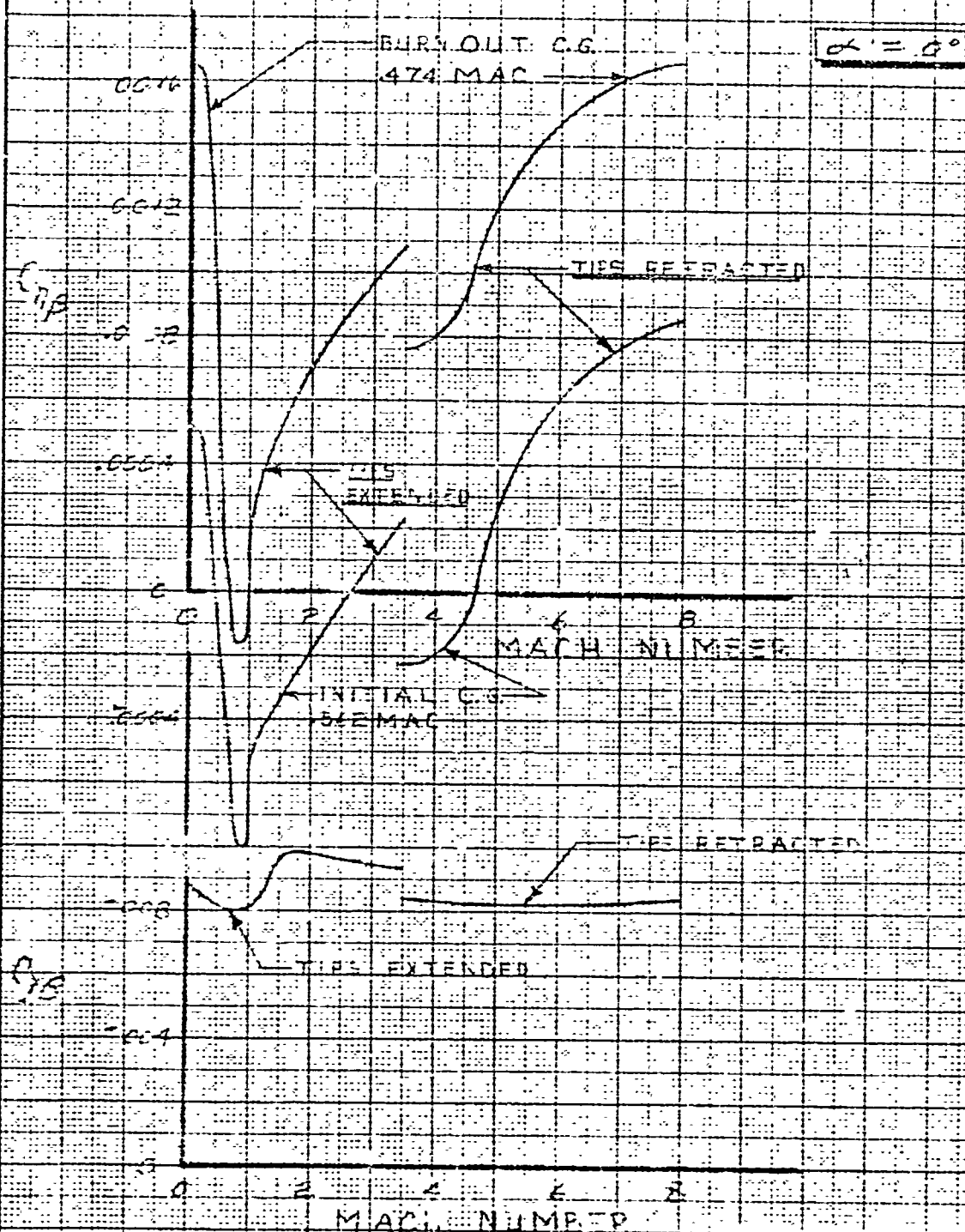


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CHECK			TIPS RETRACTED-60" TRANSITION	DZ-2174
APR			BOEING AIRPLANE COMPANY M=3.1	PAGE 7.12
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NOTES:

1. C.G. TRAVEL LINEAR WITH 19 SEC. BURN TIME
 2. $\alpha = -15^\circ$ $L_{TRANS} = 5.20$ $S_{W} = 543 \text{ FT}^2$
 $\rho = 0.002$ $L_{TRANS} = 5.20$ $b = 19.7 \text{ FT}$

BODY AXIS



CALC	FAH	12-31-0	REVISED	DATE	DIRECTIONAL STABILITY	844-2035
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					$\alpha = 0^\circ$ 190	82-5174
					BOEING AIRPLANE COMPANY	PAGE 7.13

NOTES:

1. CG TRAVEL LINEAR WITH BASED BLANKING
 2. $\alpha_{TIP} = -75^\circ$ 60" TRAVEL THIN $S_{WING} = 243 \text{ FT}^2$
 $C_{L_{TIP}} = 0.32$ $\alpha_{TIP} = 5.2^\circ$ $D = 13.7 \text{ FT}$

BODY AXIS

$\alpha = 15^\circ$

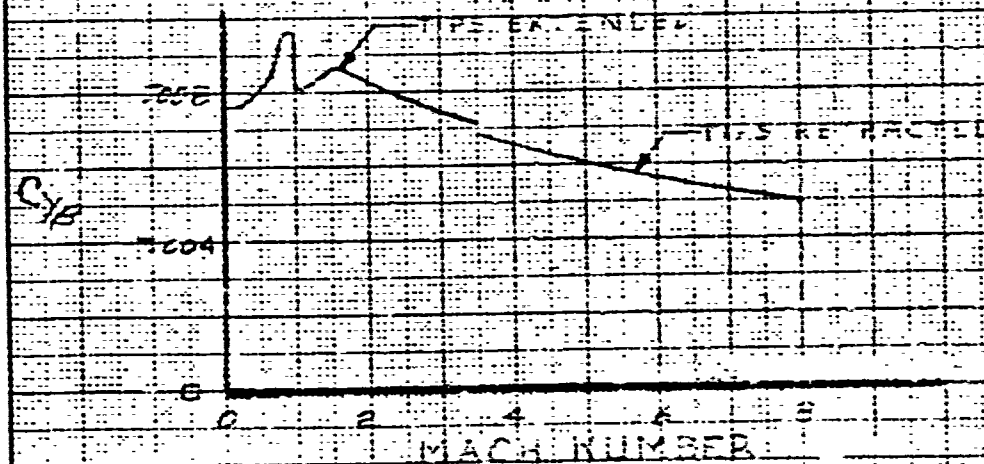
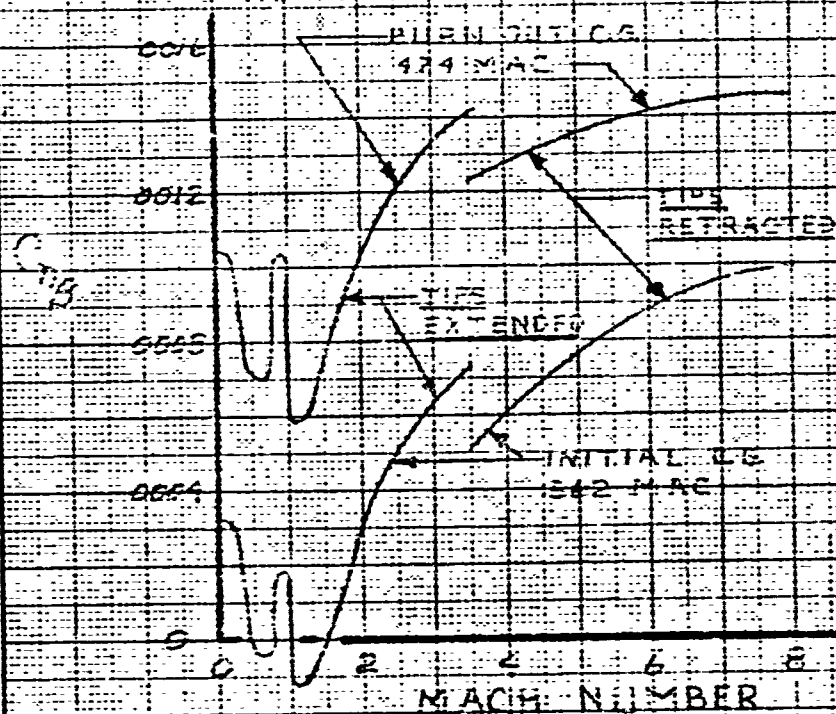


FIG 7.0

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DIRECTIONAL STABILITY

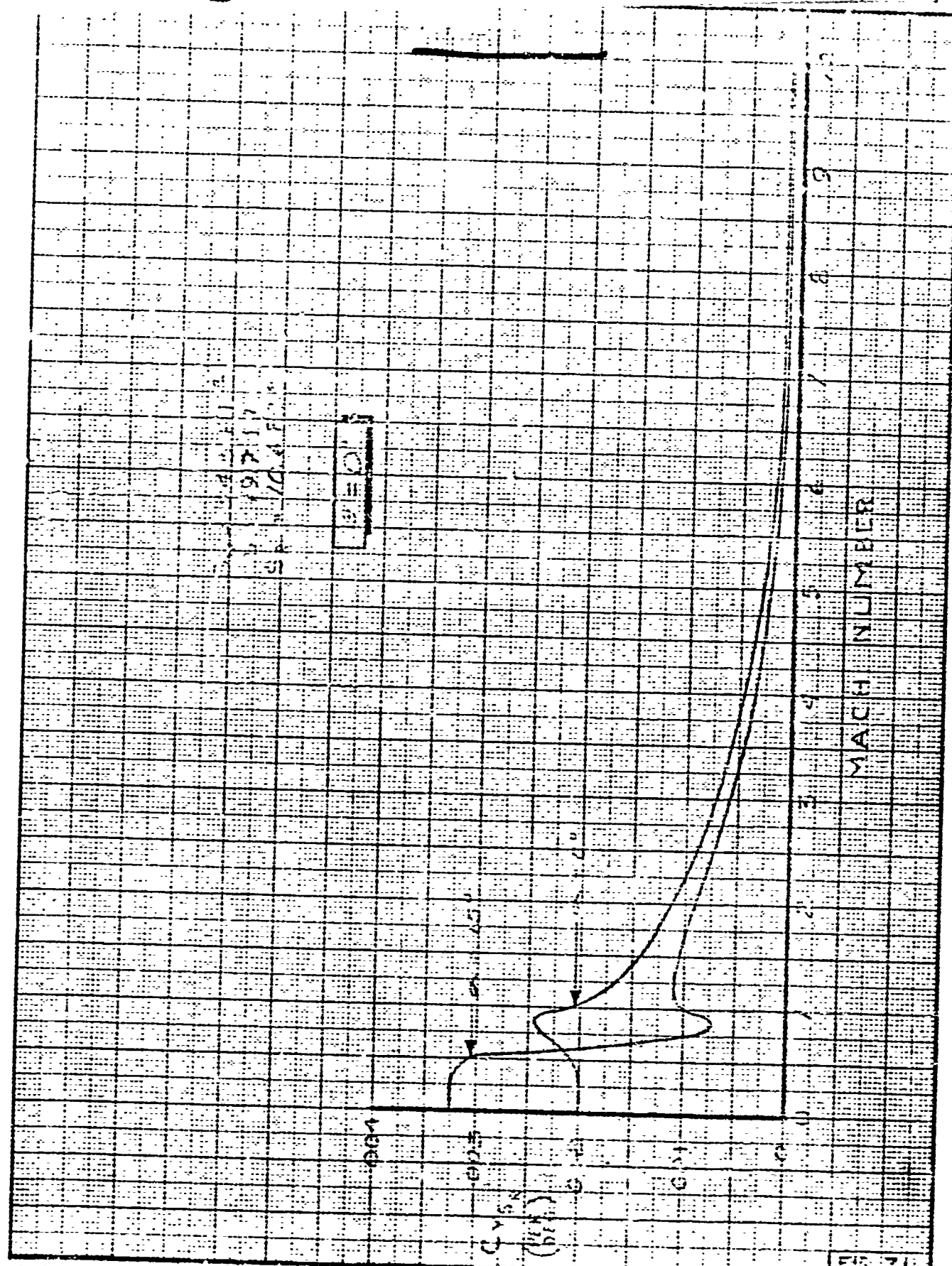
244-2035

$\alpha = 15^\circ$ 191

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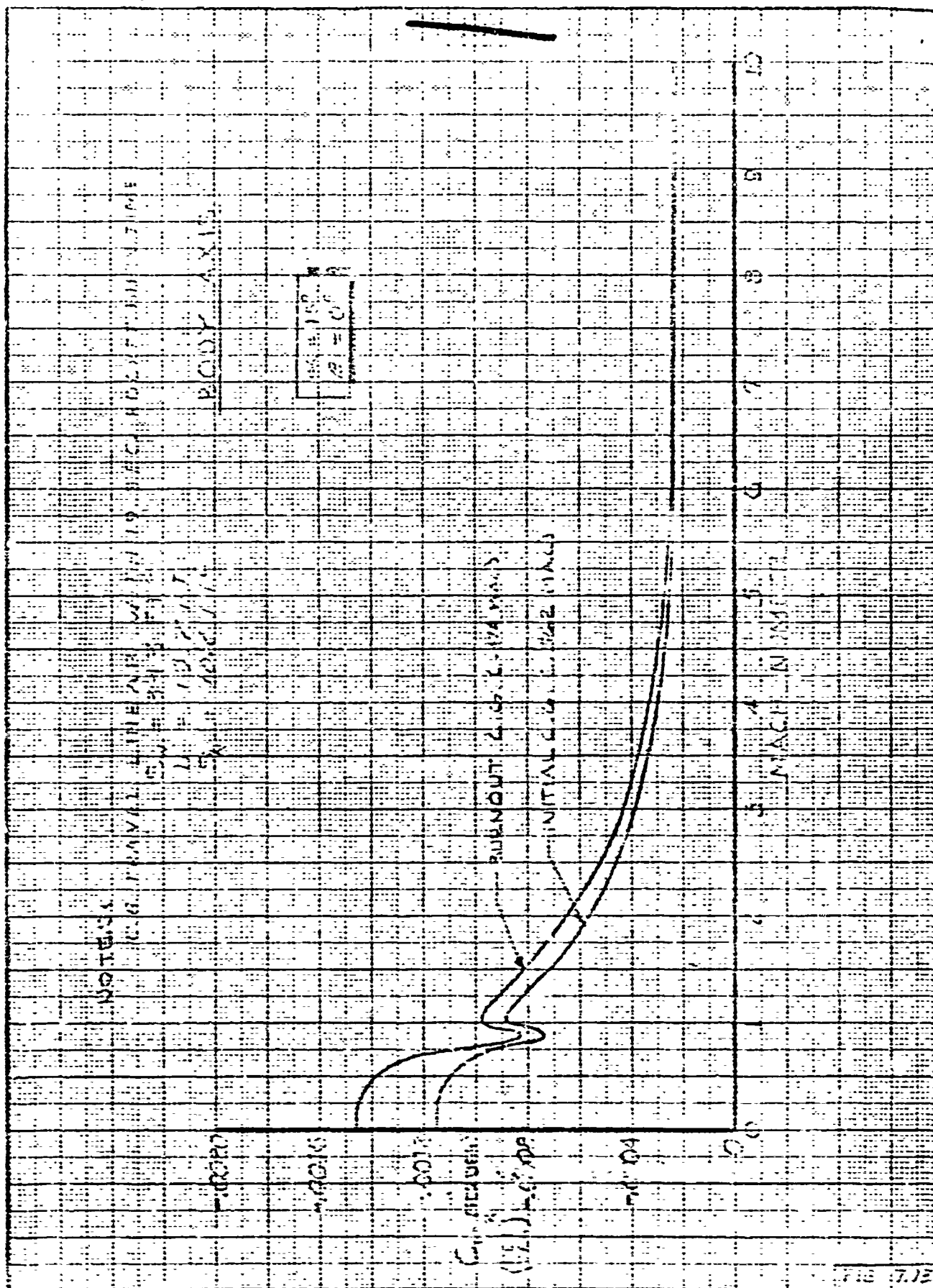
BOEING AIRPLANE COMPANY

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RUDDER EFFECTIVENESS 192 BOEING AIRPLANE COMPANY	FIG. 7.1
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RUDDER EFFECTIVENESS
 $\alpha = 15^\circ$
 BOEING AIRPLANE COMPANY
 FIG. 7.12
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