QCX
Avro
CF105
P-FFM-57

(12)

UNCLASSIFIED

12

CF-105 ANALYZED P/F.F.M./57

FREE FLIGHT STABILITY
MODEL RESULTS

Copy [redacted].F.M. Group

(12)

A V ROE CANADA LIMITED
MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

AIRCRAFT:

REPORT NO. P/F.F.M./57

FILE NO.

NO. OF SHEETS

TITLE:

Classification cancelled / changed to ~~Unclassified~~
By authority of AVRO Arrow Declassif. Board
Date 28 Jul 87
Signature B Aubrey, Co-Chairperson
Unit / Rank / Appointment DSIS 3

CF-105

FREE FLIGHT STABILITY MODEL RESULTS

PREPARED BY M.V. Jenkins M.V.J. DATE July 1957

CHECKED BY D. Ewart D.E. DATE " "

SUPERVISED BY S. Kwiatkowski DATE " "

APPROVED BY J Chamberlin DATE " "

ISSUE NO.	REVISION NO.	REVISED BY	APPROVED BY	DATE	REMARKS

FORM 1316A

AVRO AIRCRAFT LIMITED
MALTON ONTARIO
TECHNICAL DEPARTMENT

AIRCRAFT:

REPORT NO	P/F.F.M./57
SHEET NO	

PREPARED BY	DATE
M.V. Jenkins	July'57
CHECKED BY	DATE
D. Ewart	July'57

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INDEX

FORM 1319A

NOTATION

α	Incidence in degrees.
β	Angle of sideslip in degrees.
δ	Elevator deflection in degrees.
R.N.	Reynolds Number
M	Mach Number
q_o	Free stream dynamic pressure in pounds per square feet.
V	Free stream velocity in ft/sec.
b	Span in feet.
$\bar{c}$	Mean aerodynamic chord in feet.
S	Wing area in square feet.

Using the universally accepted system of body axes:

Y	Aerodynamic force in Y direction in pounds.
C_Y	Y/q_oS
Z	Aerodynamic force in Z direction in pounds.
C_Z	Z/q_oS
L	Aerodynamic force in pounds perpendicular to flight path.
C_L	L_o/q_oS.
L_1	Rolling moment in pounds - feet about X axis.
Cl	L_1/q_oSb
M_1	Pitching moment in pounds-feet about Y axis.
C_m	$M_1/q_oS\bar{c}$
N_1	Yawing moment in pounds - feet about Z axis.
C_n	N_1/q_oSb

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PREPARED BY	M.V. Jenkins
DATE	July'57
CHECKED BY	D. Ewart
DATE	July'57

C_D	D/q_oS
$C_{D_{MIN}}$	C_D charged to aircraft at zero lift.
C_{Y_β}	dC_Y / $d\beta$
C_{n_β}	dC_n / $d\beta$
C_{l_β}	dCl / $d\beta$
C_{l_p}	$dCl.2V$ / dpb
C_{n_r}	$dCn.2V$ / drb
C_{n_p}	$dCn.2V$ / dpb

INTRODUCTION

This report contains a comparison of derivatives determined from C.F. 105 free flight models and those evaluated from C.F. 105 wind tunnel teste or theoretically derived.

Drag curves corrected to be more representative of the C.F.105 are included.

The F.F.M. results as given in this report cannot be coneidered completely representative of the C.F. 105, for one or more of the following reasons:

1. Geometrical differences - mainly the oversize fin.
2. Elastic effects.
3. Limited control movement.
4. Intake conditions.

Final assessment of the utilisation of the resulte for direct application to the C.F. 105 is nearing completion and will be reported in P/Aero Data/96 and P/Aero Data/97. A list of the models together with their salient features is included at the end of this section.

The incidence and sideslip with which the derivatives may be associated is indicated. Sideslip for F.F.M.'s #10 and #11 may be assumed negligible.

Reynolds Number associated with Mach Number is given for F.F.M.'s #10 and #11. However the trajectory and trajectory velocity is similar for F.F.M.'s #6, #7, #8, #9, and hence the R.N. for F.F.M. #10 and #11 may be considered representative. F.F.M. #5 may be coneidered to have the same order of R.N.

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REPORT NO. P/F.F.M./57
SHEET NO. IIb

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		CHECKED BY	DATE
		D. Ewart	July'57

CF 105, 1/8 SCALE FREE FLIGHT MODELS #5 - #11

F.F.M. #5 — 1st drag model c.g. at .25 MAC 8% notch, no extenstions
50° conical radome
J - 67 intakes and duct.
J - 75 rear fuselage
Fixed control surfaces.

F.F.M. #6 — 2nd Drag model.
c.g. at .25 MAC
Drooped L.E., 5% notch, 10% extension (outboard of notch).
30° conical radome.
J - 75 intakes duct and rear fuselage.
Pressure rakes in duct. Partial area - ruling of fuselage.
Fixed control surfaces.

F.F.M. #7 — 3rd Drag model.
c.g. .25 MAC
Droops, 5% notch, 10% extension (outboard of notch).
30° radome.
J - 75 intakes duct & rear fuselage.
Pressure rakes in ducts.
Special area ruling and fixed control surfaces

F.F.M. #8 & #9 — Lateral Stability Models.
c.g. .25 MAC.
Droops, 5% notch, 10% extensions (outboard of notch).
Final J - 75 intakes
(F.F.M. #9 had boundary layer ejectors)
30° conical radome
Partial area ruling
Fixed control surfaces.
Yaw impulse mechanism fitted.
Models ballasted to "raise" principal axis to a more representative position.

FORM 1319A

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REPORT NO	P/F.F.M./57
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		D. Ewart	July'57

F.F.M. #10 & 11:

F.F.M. #10 :- c.g. .20 MAC.
Droops, notches, extensions.
30° nose.
Final J - 75 intakes duct & rear fuselage
Moveable elevators (hydraulic operation)
Ballasted to adjust principal axis.

F.F.M. #11 :- as #10 but c.g. .27 MAC.

F.F.M.'s #6 to #9 had static pressure probe in front of α - β vane: on #10 & #11 this was removed and reasonably good, α readings obtained, as were obtained on #5.

The geometry of the fin which was attached to all F.F.M.'s is given on sheet 1.

FORM 1103A

BRIEF DISCUSSION ON THE COMPARISONS

Reference Sheet No.

4 Cz_{α}

F.F.M. values confirm W/T values of $C_{L_{\alpha}}$

5 Cm_o

F.F.M. Cm_o has two sources of derivation:

1. The coupling of trim conditions with constant speed static margin.

2. Subtraction of the W/T value of Cm for the trimmed C_L and of the F.F.M., from the W/T value of Cm_o.

Derivation (1) is based on linear assumptions; however the F.F.M. trimmed values of C_L are low and hence the evaluated Cm_o is acceptable.

In both methods of derivation, the results of F.F.M. #6, #8, #9, #11 producing a narrow band of scatter have been averaged.

Mean F.F.M. Cm_o is considered more reliable than the wind tunnel values.

6 α_o

The recorded incidence of F.F.M. #10 was the more accurate of the two longitudinal stability models. The values of α_o are in fair agreement with thoee of the wind tunnel; however the latter are considered more reliable.

7 Cm_{α}

F.F.M. values confirm W/T values except at $M \simeq 0.95$

BRIEF DISCUSSION ON THE COMPARISONS (Continued)

Reference Sheet No.

8 $Cm_{\dot{\alpha}} + Cm_q$

Since α and q are almost in phase experimental solution in this form only is possible.

The F.F.M. values are considered more reliable than the previous theoretical estimates.

9 Cm_δ

F.F.M. values confirm W/T values except at $M \triangleq 0.95$

10 C_{H_0}

F.F.M. values are higher than the W/T values: The latter are considered more reliable.

11 C_{H_δ}

F.F.M. values determined over an elevator setting range of $+2.4^\circ$ to $+5.8^\circ$ are substantially more negative than those determined from the CF 105 W/T tests covering a large elevator setting range.

With due consideration to the values of C_{H_δ} from a variety of test conditions on similar configurations, it is considered that the biased mean C_{H_δ} curve shown on sheet 11.2 must closely approximate to a rigid value applicable to the maximum elevator range on the full scale aircraft.

C_{H_α}

Recourse to oscillatory data is necessary for the determination of C_{H_α} to be independent of C_{H_δ}; however then it is impossible to assess the magnitude and phasing of the pitching and normal acceleration inertia effects to the necessary degree of accuracy required for reliable determination of C_{H_α}.

BRIEF DISCUSSION ON THE COMPARISONS (Continued)

Reference
Sheet No.

C_{L_δ}

It is considered that the angle of incidence has not been established to the very high degree of accuracy required for the reliable determination of C_{L_δ}.

12 Drag corrections applied to the Drag Free Flight Models' results to make them more representative of the C.F. 105

1. Base drag correction is required becauee the edges of the model duct exit are blunter.
2. Momentum drag correction ie required since Avro charges momentum drag against engine thrust.
3. Induced drag correction.
4. Allowance is made for the difference between model and aircraft in exit flow from the nozzle.
5. Spillage drag correction is required since Avro charges spillage drag against the engine thrust.
6. On the model there wae an additional and out of ecale pitot tube.
7. The models contained an out of scale pressure rake located in the duct exit.
8. The fixed elevator setting of the models requires a trim drag correction.
9. Fin difference.
10. Correction for $\alpha - \beta$ vane installation, where fitted.
11. Fuselage contour differences where applicable.

Brief Discussion on the Comparisons (Continued)

LATERAL DERIVATIVES FROM FREE FLIGHT TESTS NO'S 8 AND 9

13 C_{y_β} - The F.F.M. ¢ W./T. estimates of this derivative, check well, except in the high subsonic speed range.

14 C_{n_β} - The check of F.F.M. ¢ W./T. estimates for this derivative is good throughout the Mach Number range covered.

15 C_{l_β} - Although the numerical check of the F.F.M. and W./T. estimates is not very good, both methods show the same trend of the derivative with Mach Number, and except for $.95 < M < 1.2$ the numerical check is quite fair.

16 C_{l_p} - The F.F.M. estimate is considerably higher than the calculated values except for the lowest Mach Number of the F.F.M. range. There is a considerable amount of scatter between the two F.F.M. tests but the peak values, and generally higher order, of the derivative from the F.F.M.'s seem well substantiated.

17
18 C_{n_r} ¢ C_{n_p} - It will be noticed that no comparison of these derivatives with calculated values is shown. The reasons for this are two-fold.

(i) From the F.F.M. analysis the algebraic sum of $p\,C_{n_p}$ ¢ $r\,C_{n_r}$ is obtained and not the derivatives separately.

(ii) The theoretical method of estimating C_{n_p} is very unreliable and so comparison of ($p\,C_{n_p}$ ¢ $r\,C_{n_r}$) will be reserved until a better theoretical method of estimating C_{n_p} has been devised.

α - The variation of angle of attack throughout the Mach Number range for F.F.M. No's 8 and 9 is shown on Sheet 3.1.

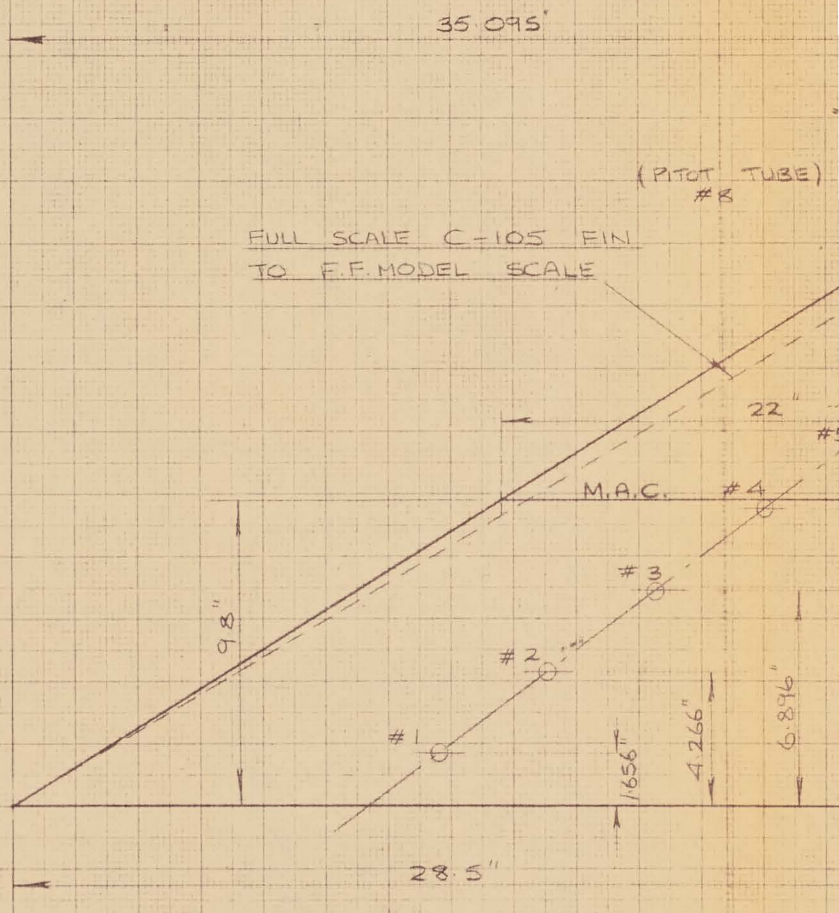
- The range of sideslip angle varies from 1.0° to 1.6° for F.F.M. No. 8, and from 0.3° to 3.5° from F.F.M. No. 9.

C - 105

FREE FLIGHT MO

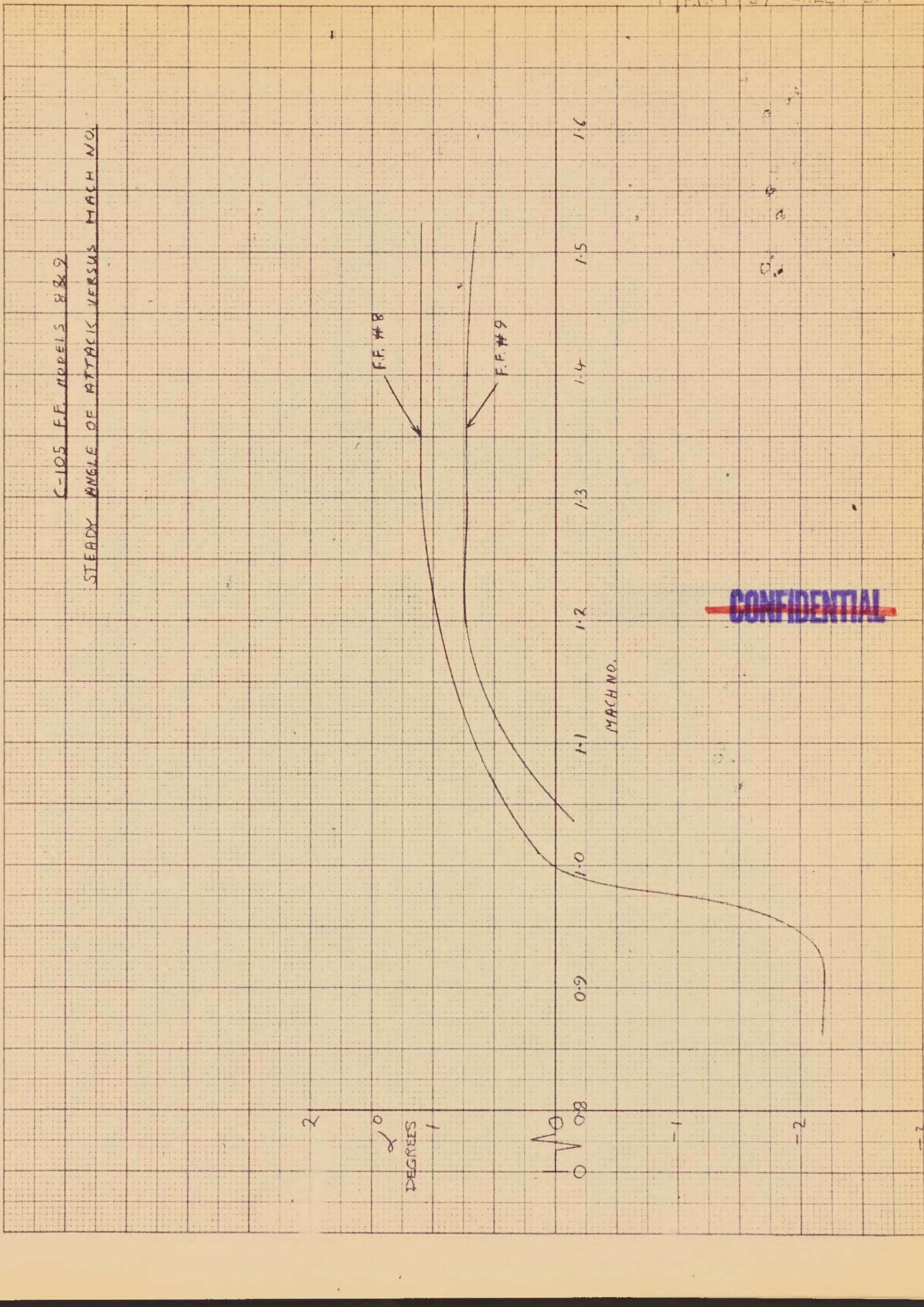
&

FIN PRESSURE POINTS



VB/7.2.57

P/FFM/57 SHEET 3.1



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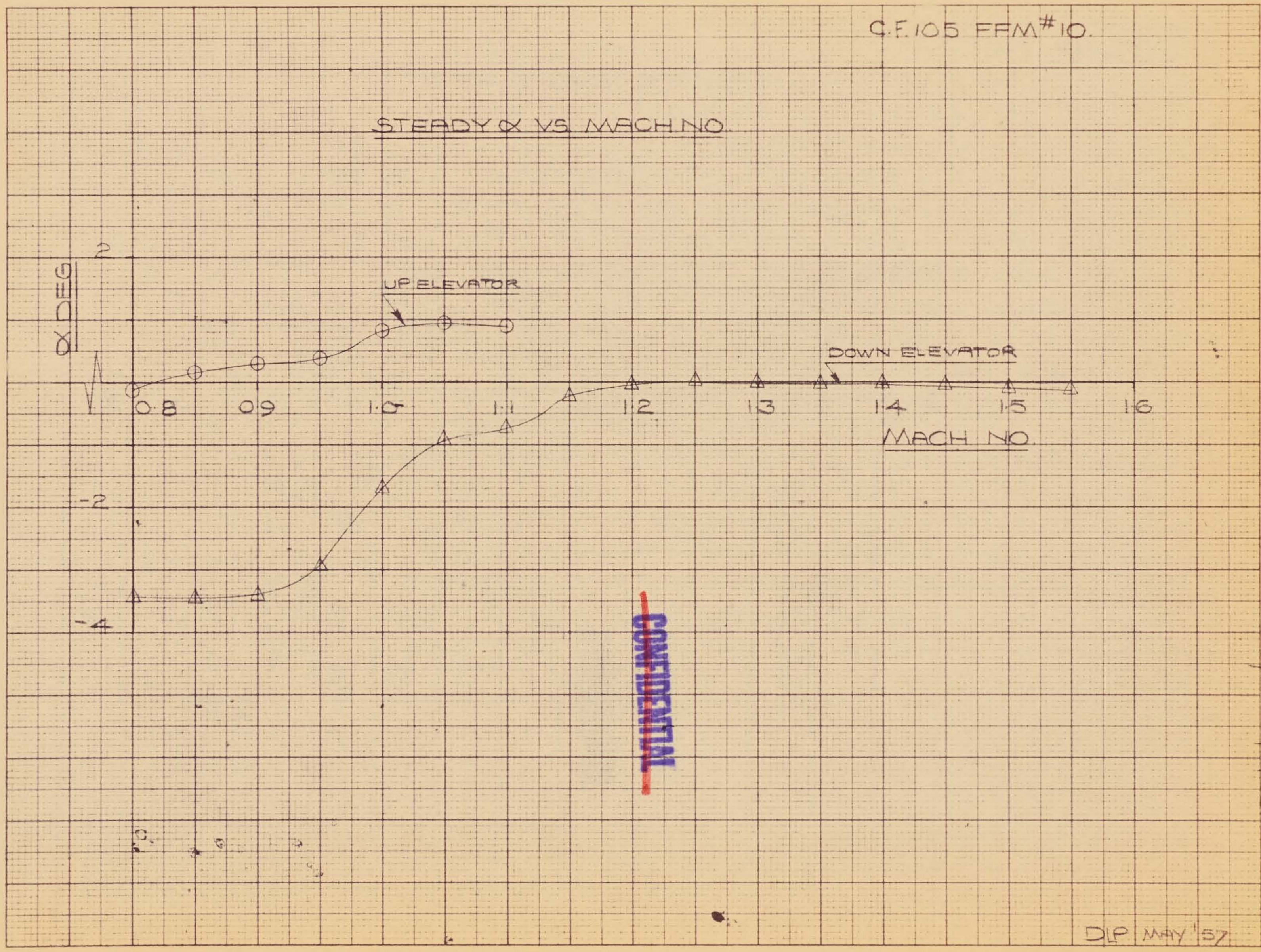
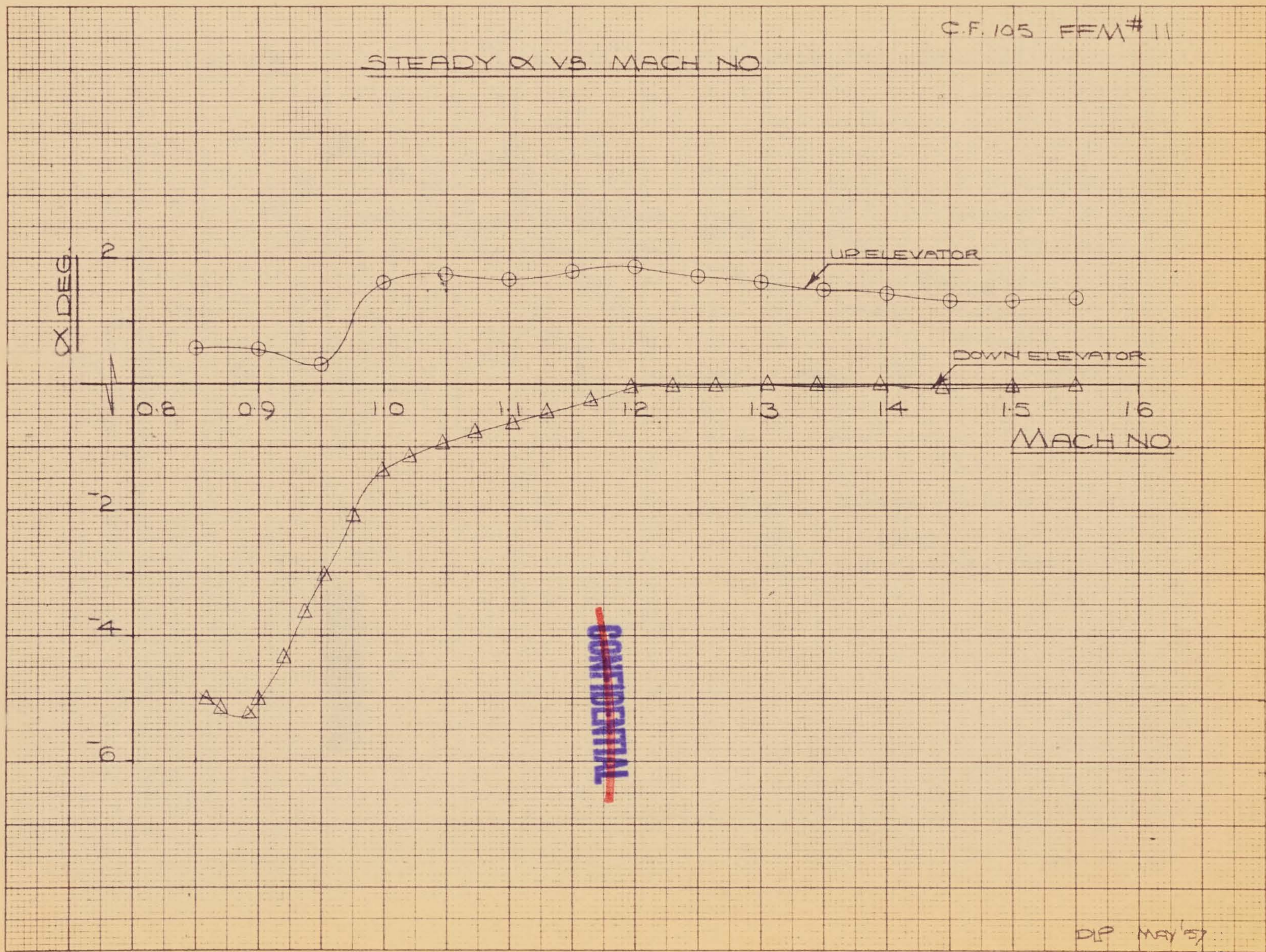
G9-12
10 X 10 TO THE ½ INCH

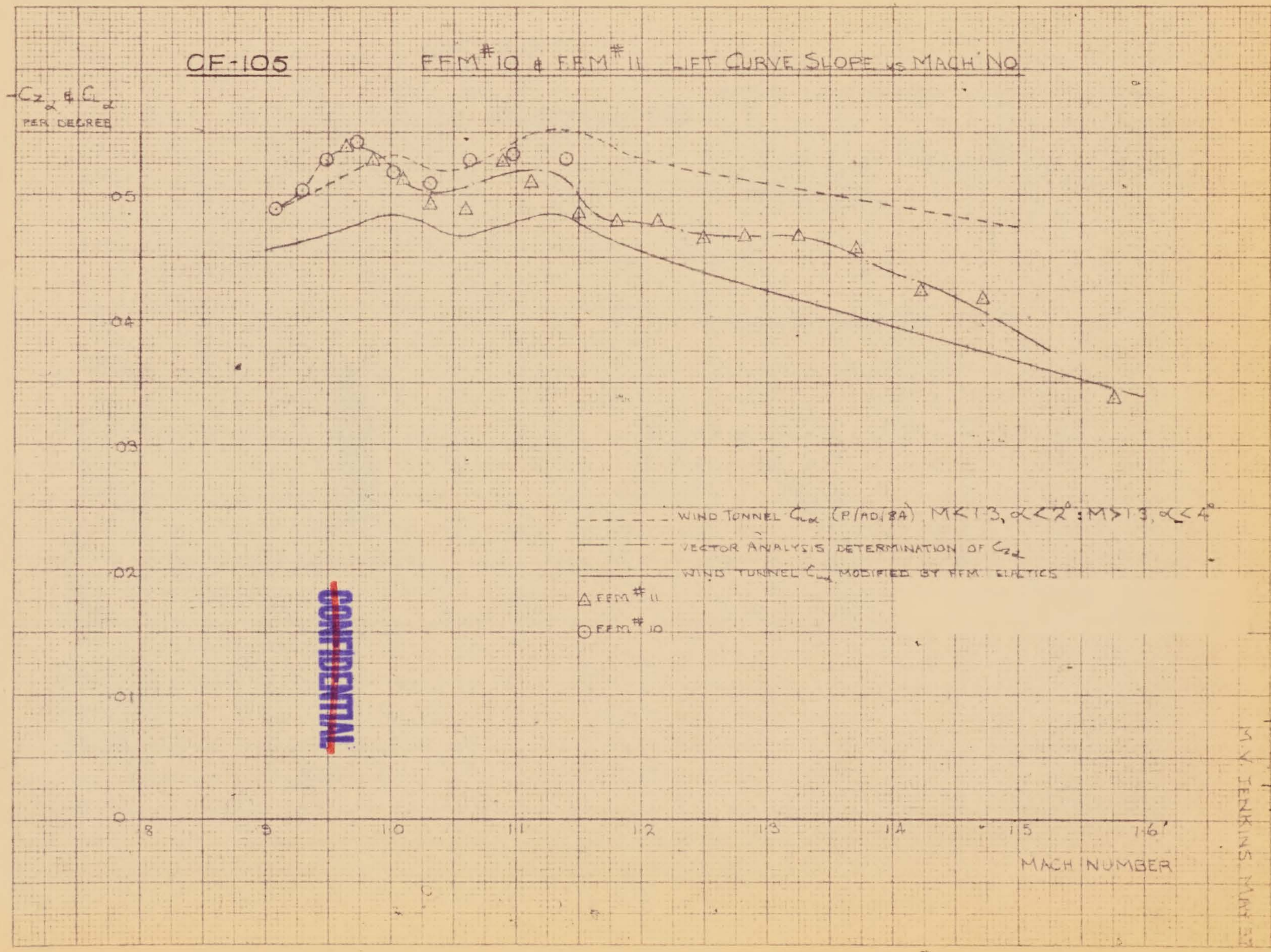
G9-12
10 X 10 TO THE ½ INCH
MADE IN CANADA



P/F.F.M/57 SHEET 3.2



P/FFM/57 SHEET 3.3


CF-105
FFM #10 & FFM #11 LIFT CURVE SLOPE vs MACH NO
$-C_{z_\alpha}$ & C_{L_α}
PER DEGREE
.05
.04
.03
.02
.01
0
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
MACH NUMBER
WIND TUNNEL C_{L_α} (P/AD/8A) M<1.3, α<2° : M>1.3, α<4°
VECTOR ANALYSIS DETERMINATION OF C_{z_α}
WIND TUNNEL C_{L_α} MODIFIED BY FFM ELASTICS
△ FFM #11
⊙ FFM #10
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SHEET 5
P/FFM/17 | 57

G9-12
10 X 10 TO THE ½ INCH

CF-105

C_{m_0} VS MACH NO

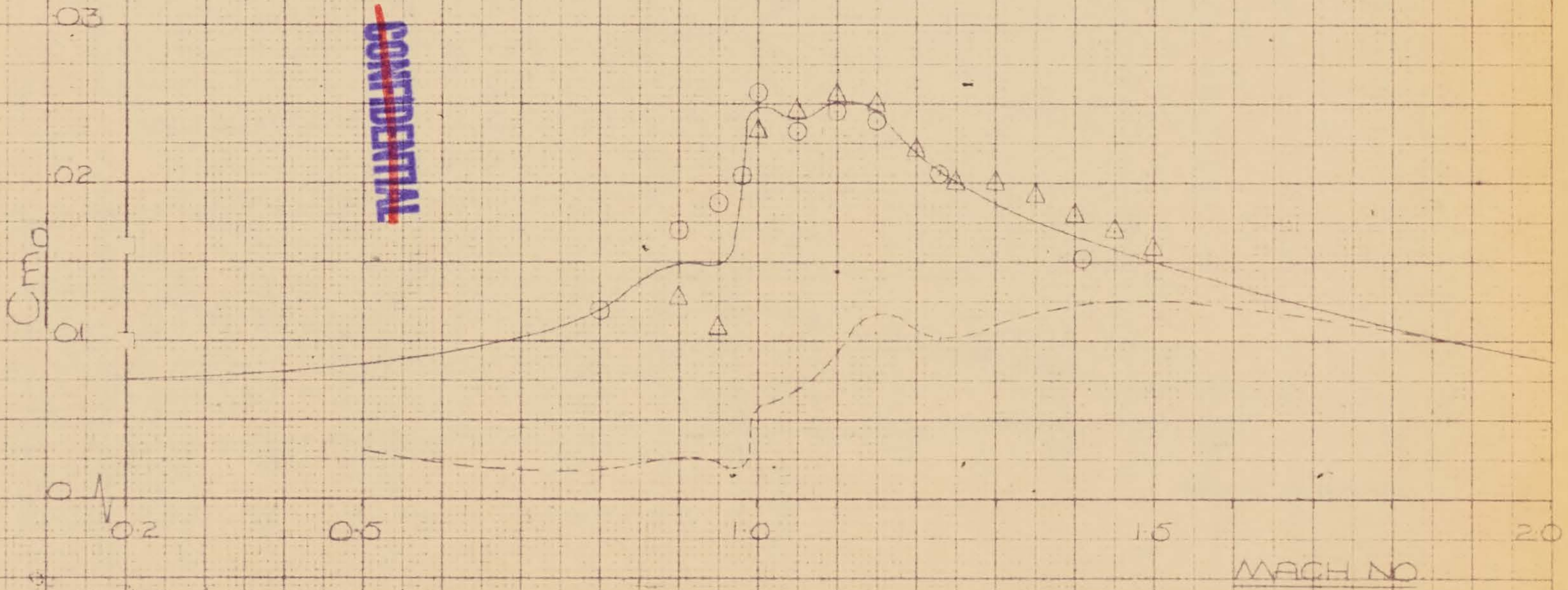
BASED ON AVERAGE RESULTS OF FFM# 6, 8 & 9 AND UP AND DOWN ELEVATOR RESULTS OF FFM# 11.

△ MEAN FFM $C_{m_0} = -\frac{C_{m_\alpha}}{C_{N_\alpha}} C_N - \delta\left[\frac{C_{m_\alpha} C_{L_\delta}}{C_{m}} - C_{m_\delta}\right]$

○ TRUE C_{m_0} W/T + MEAN (FFM C_m − C_m W/T)

– – – – TRUE C_{m_0} W/T

——— MEAN CURVE OF ○ & △



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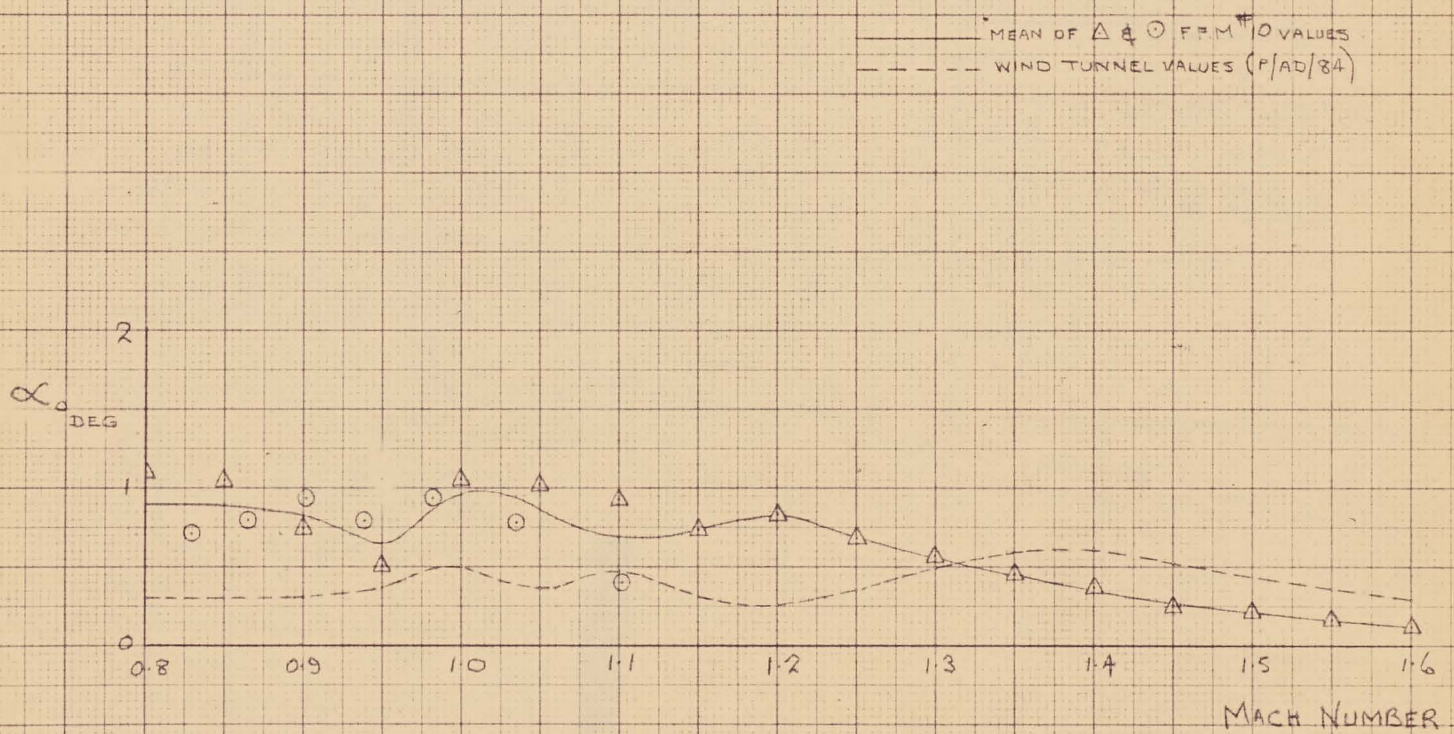
SHEET 6

P/FFM/57

C.F. 105 F.F.M. #10

α_0 vs MACH No, $\delta = 0$



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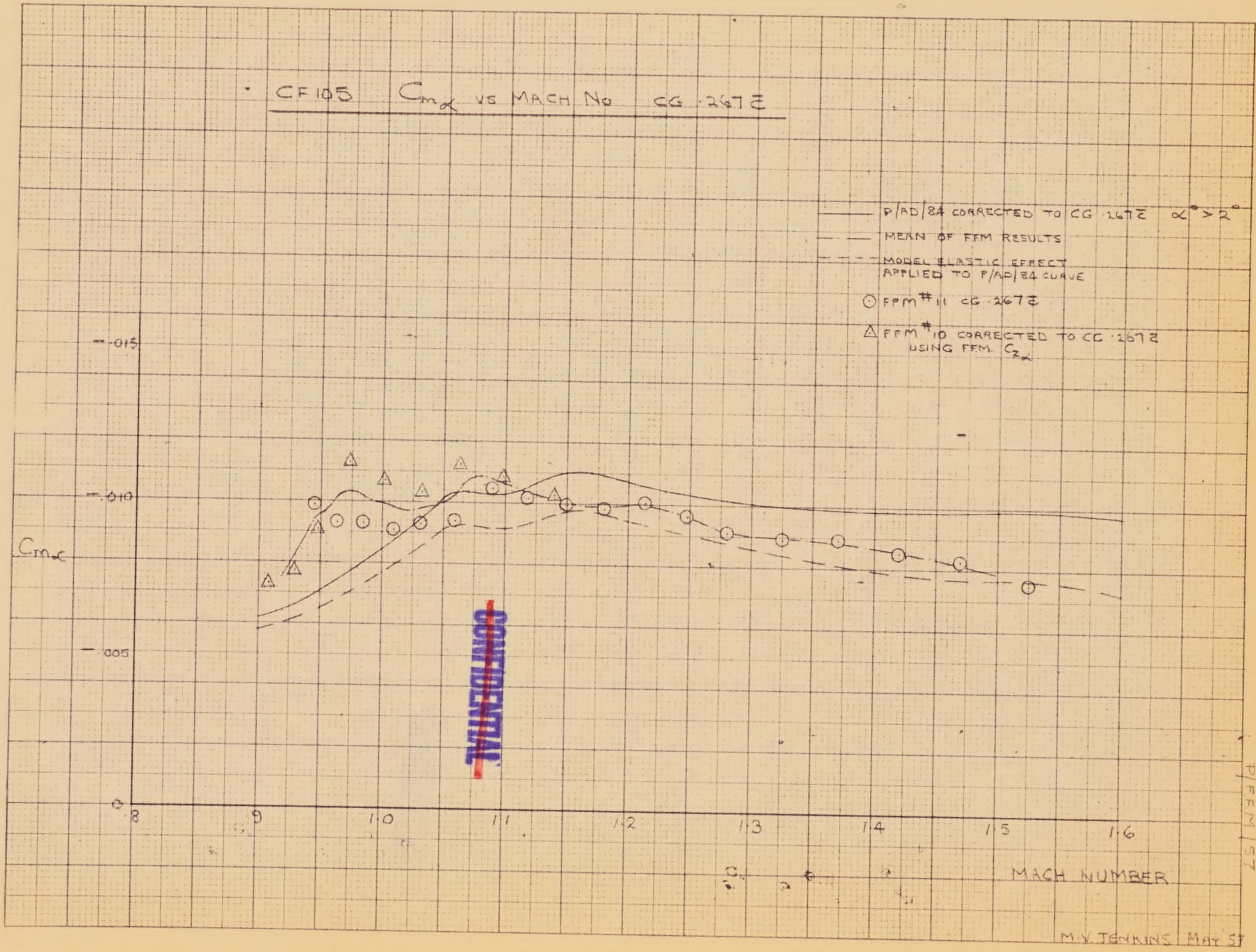
G9-12
10 X 10 TO THE ½ INCH
MADE IN CANADA

SHEET 7

P/FFM/57



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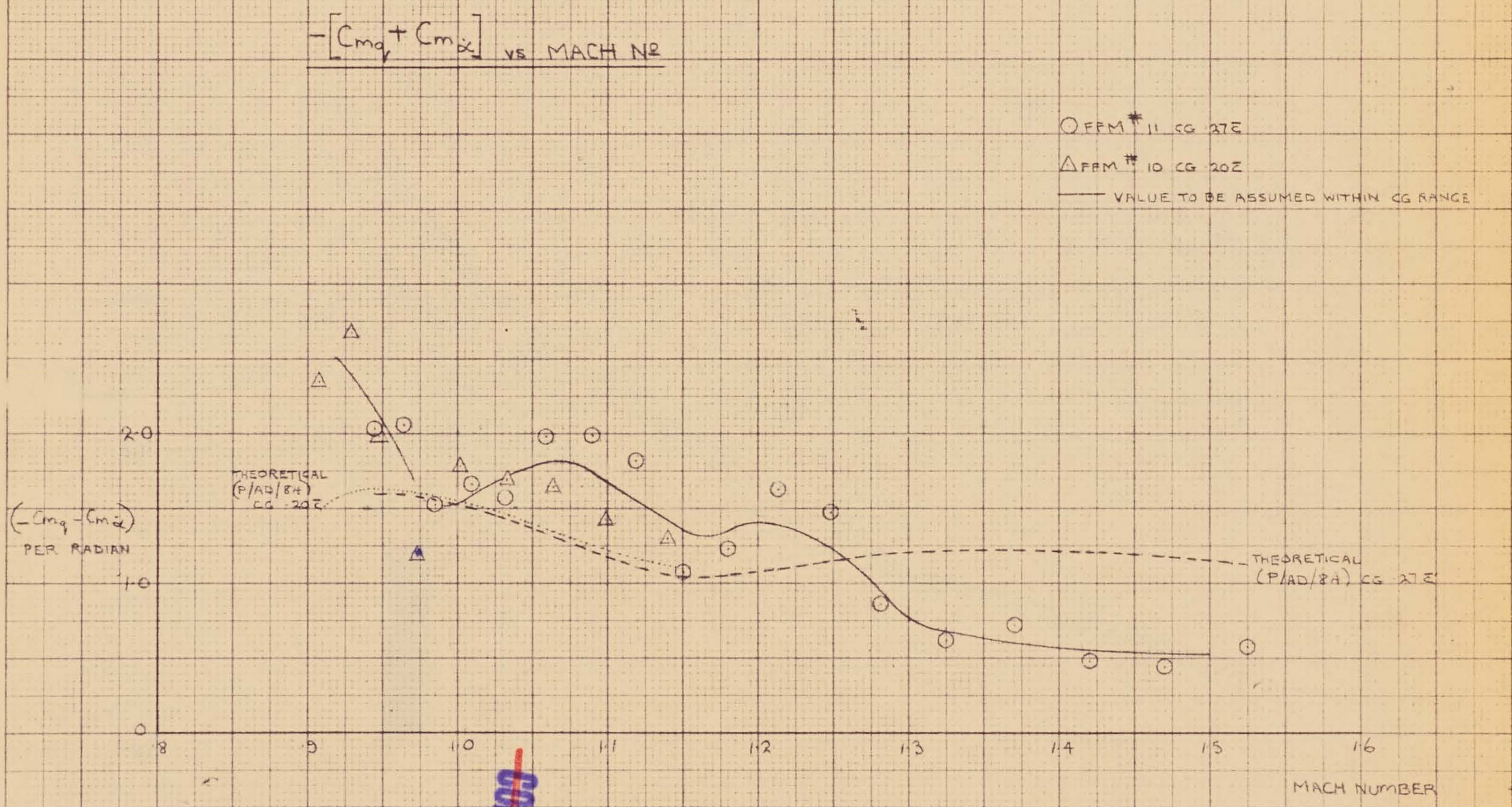

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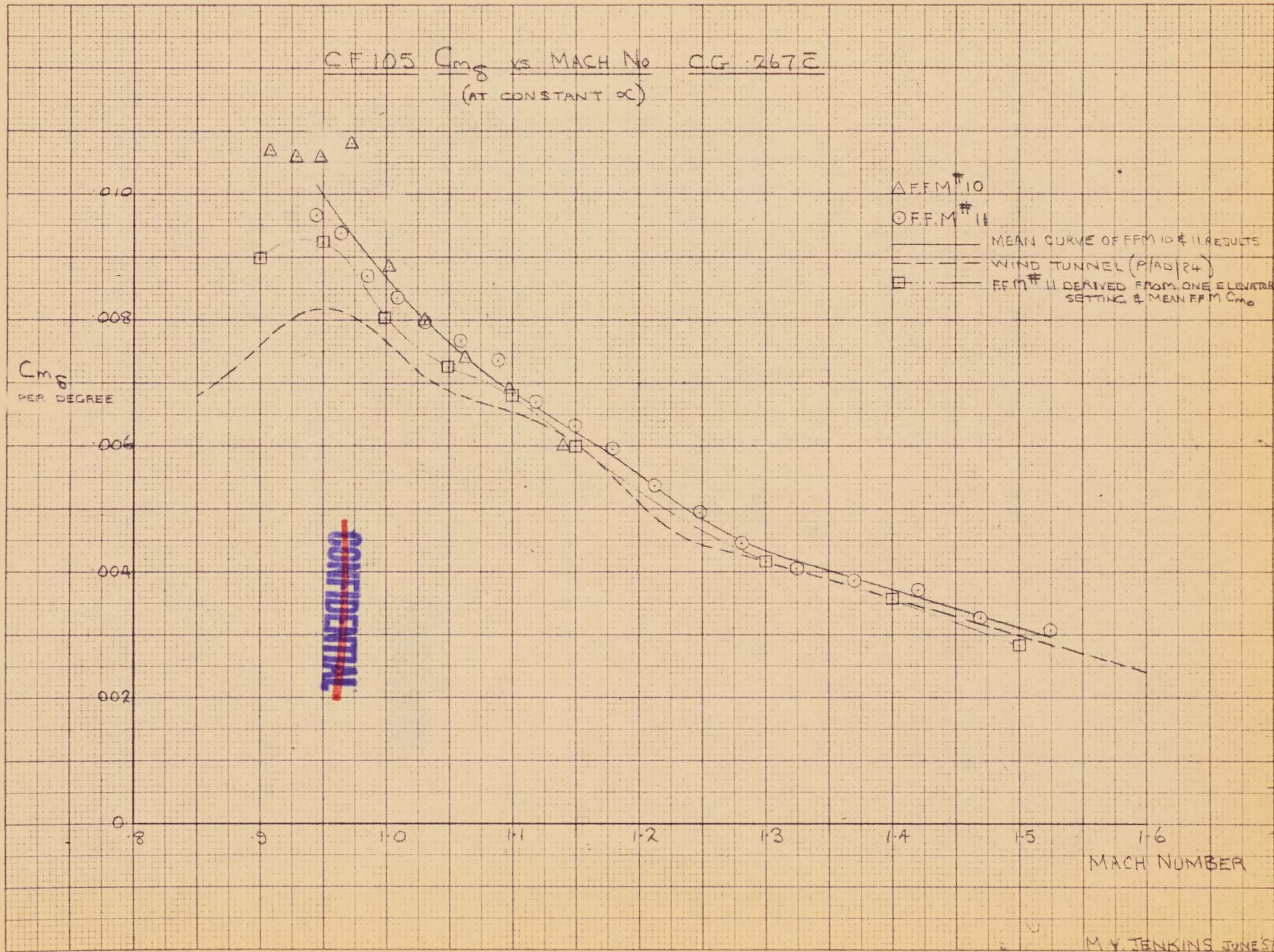
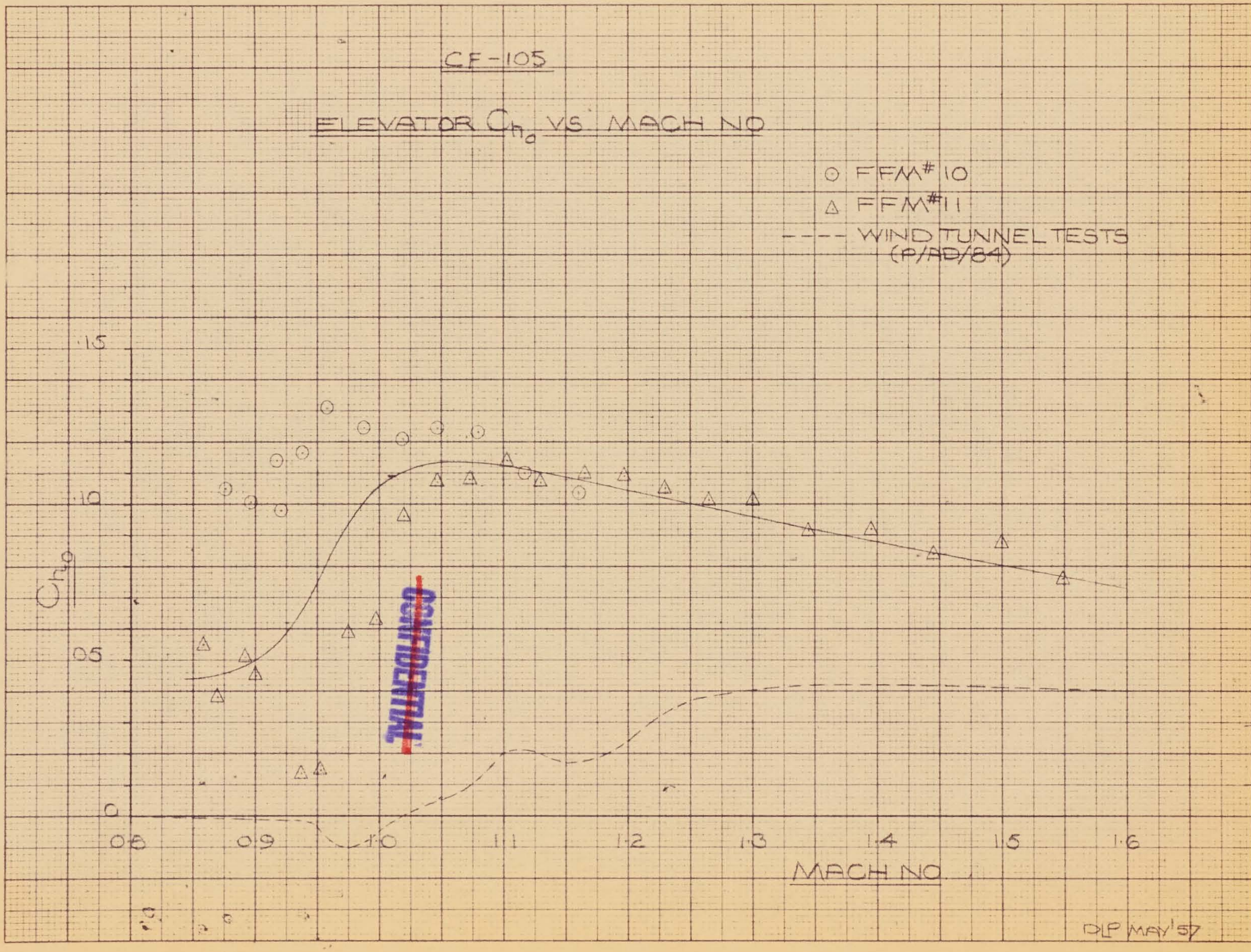
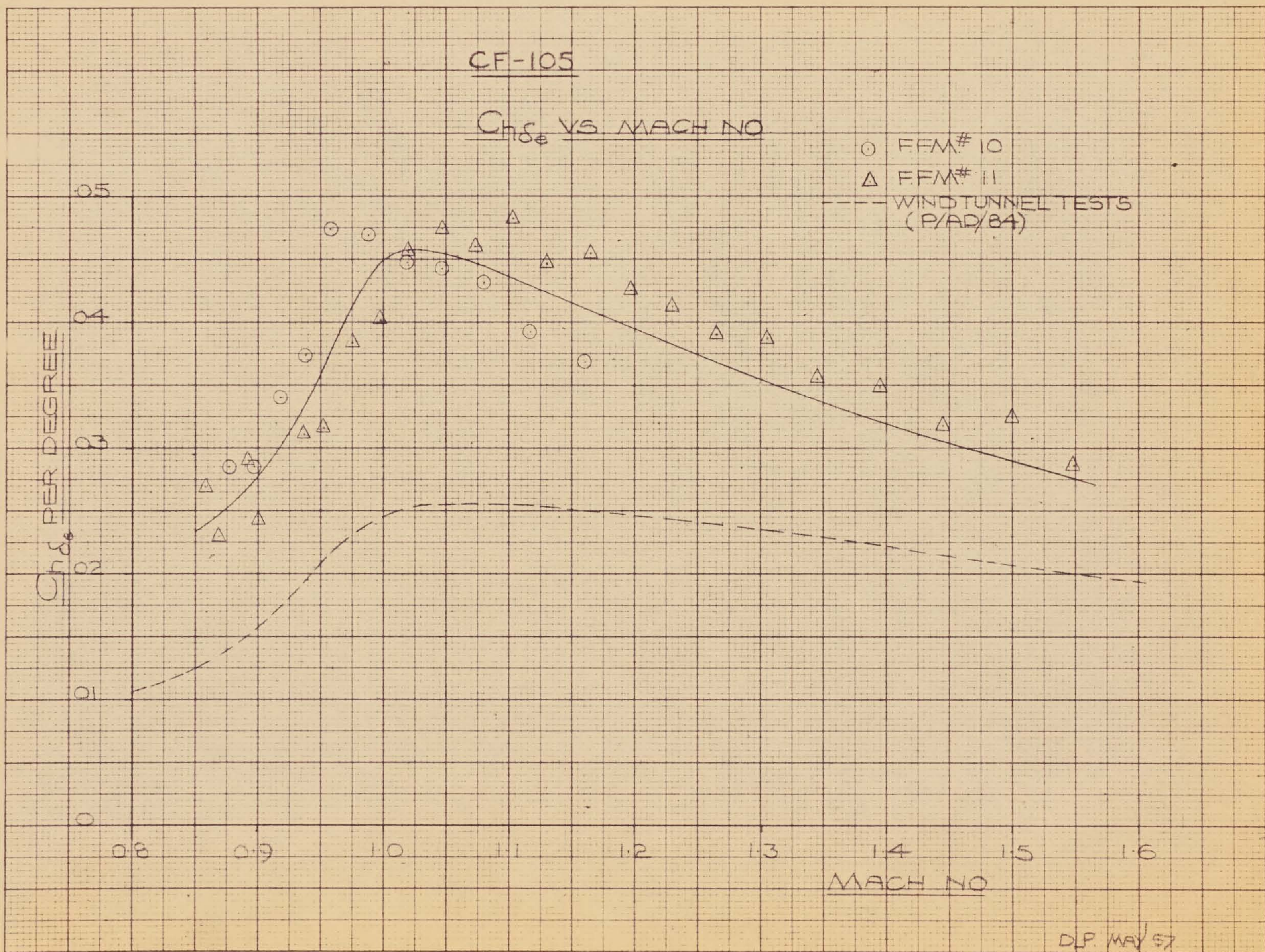
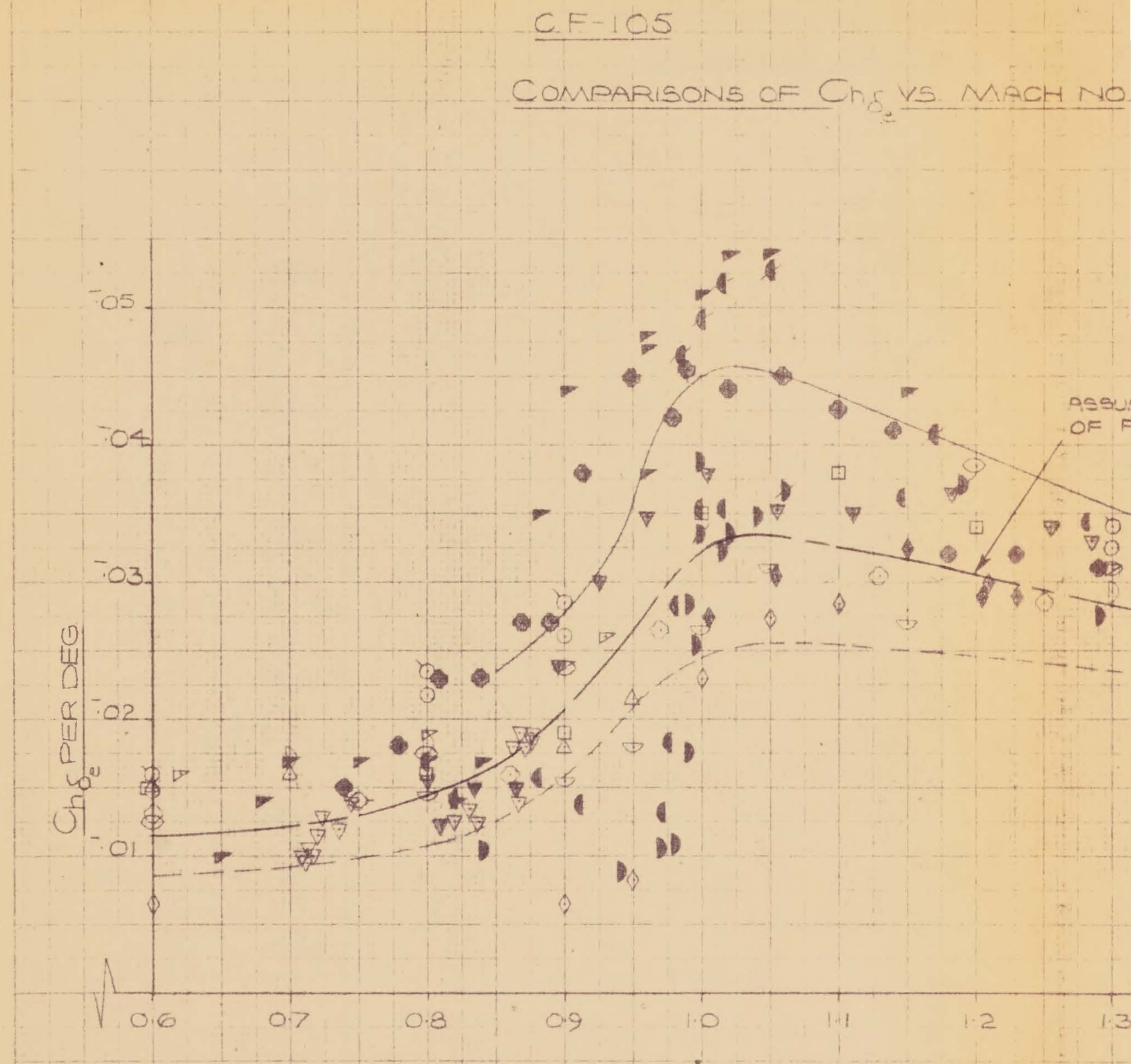
SHEET 9


CF105 C_{m_δ} vs MACH No C.G. 26.7 $\bar{C}$
(AT CONSTANT α)
△ F.F.M.# 10
⊙ F.F.M.# 11
MEAN CURVE OF FFM 10 & 11 RESULTS
WIND TUNNEL (P/AD/24)
⊡ FFM # 11 DERIVED FROM ONE ELEVATOR SETTING & MEAN FFM C_{m_0}
C_{m_δ} PER DEGREE
.010
.008
.006
.004
.002
0
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
MACH NUMBER
CONFIDENTIAL
P/FFM/57
M.Y. JENKINS JUNE '57


CF-105
ELEVATOR C_{h_α} VS MACH NO
⊙ FFM# 10
△ FFM# 11
---- WIND TUNNEL TESTS (P/AD/84)
C_{h_α}
·15
·10
·05
0
0·8
0·9
1·0
1·1
1·2
1·3
1·4
1·5
1·6
MACH NO
CONFIDENTIAL
DLP MAY '57

SHEET 11·1
P/FFM/57

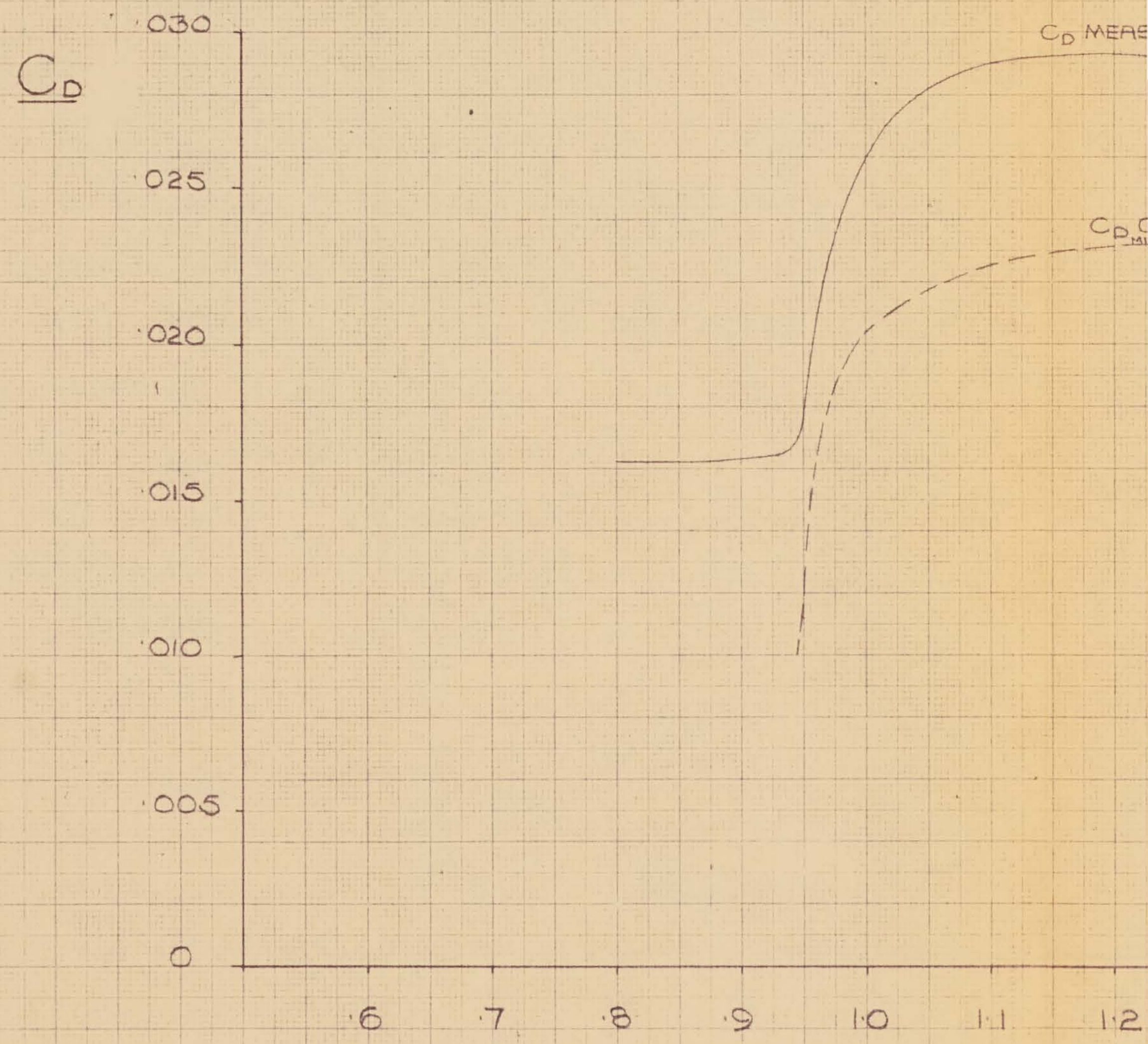




C.F-105
COMPARISONS OF $C_{h_{\delta_e}}$ VS. MACH NO.
$C_{h_{\delta_e}}$ PER DEG
-.05
-.04
-.03
-.02
-.01
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
ASSU
OF

C-105 FREE FLIGHT RO

VARIATION OF $C_{D_{MIN}}$ WITH M



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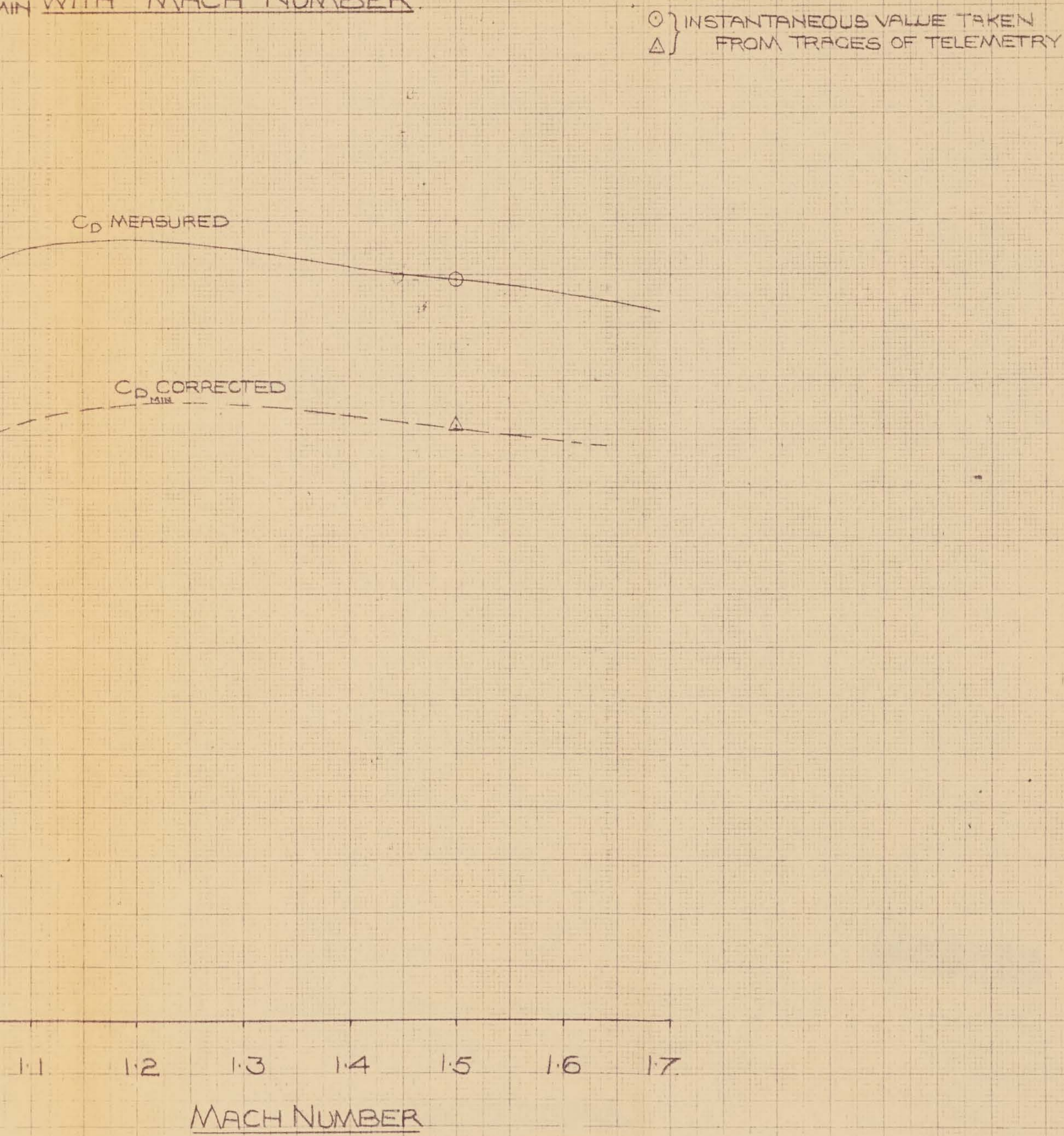
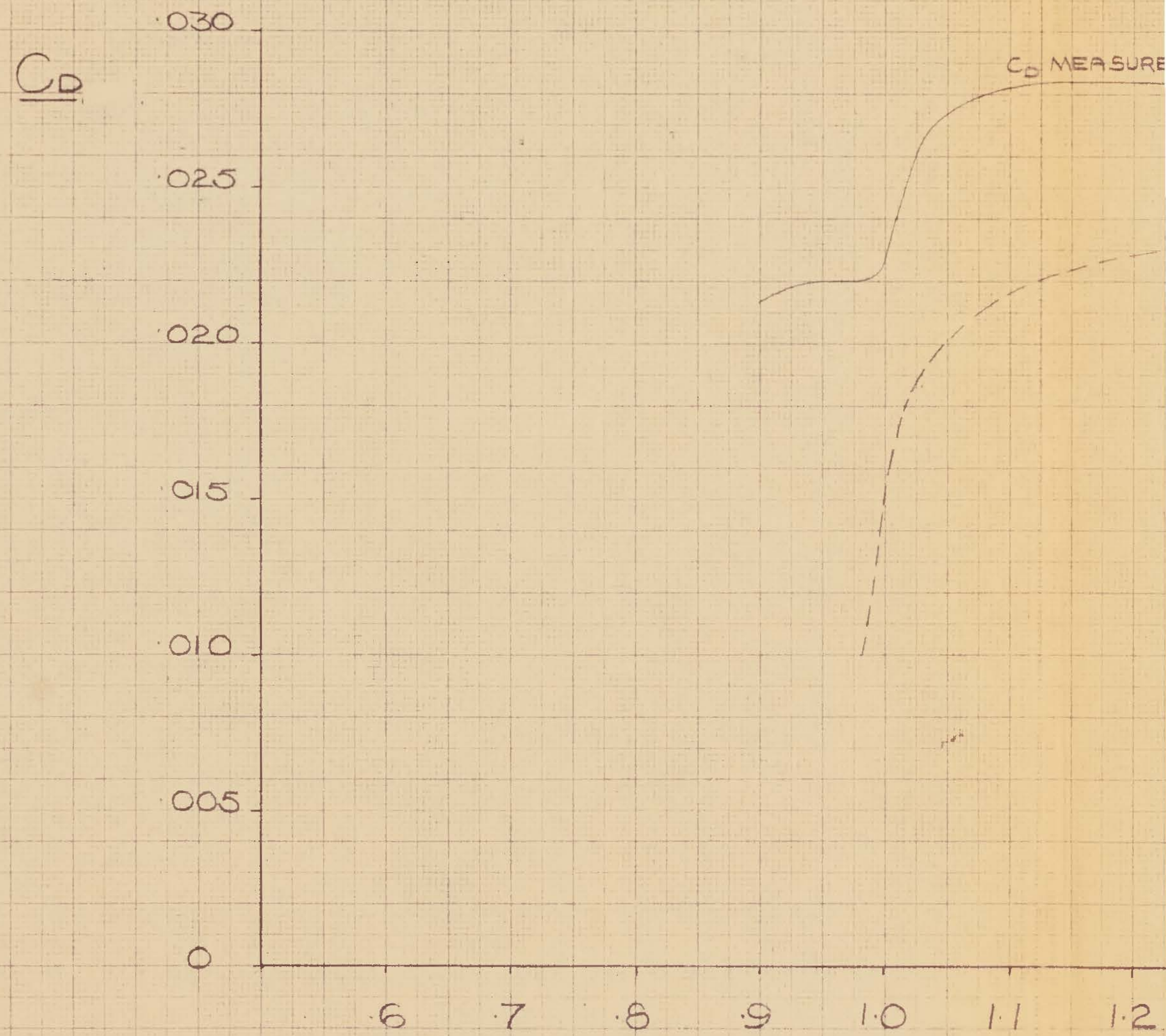
...GHT ROCKET MODEL # 5

...MIN WITH MACH NUMBER.



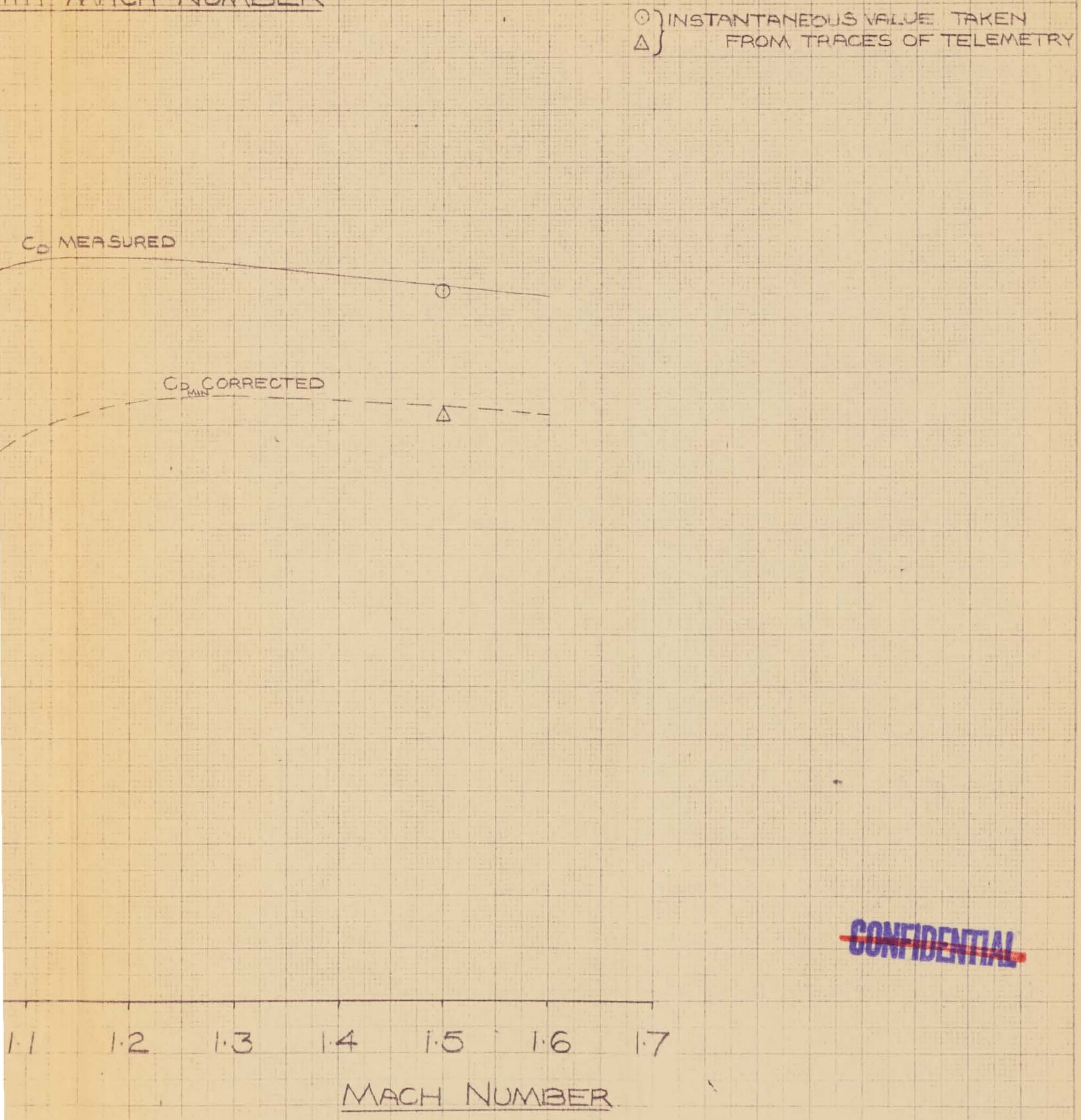
C-105 FREE FLIGHT ROCKE

VARIATION OF $C_{D_{MIN}}$ WITH MACH



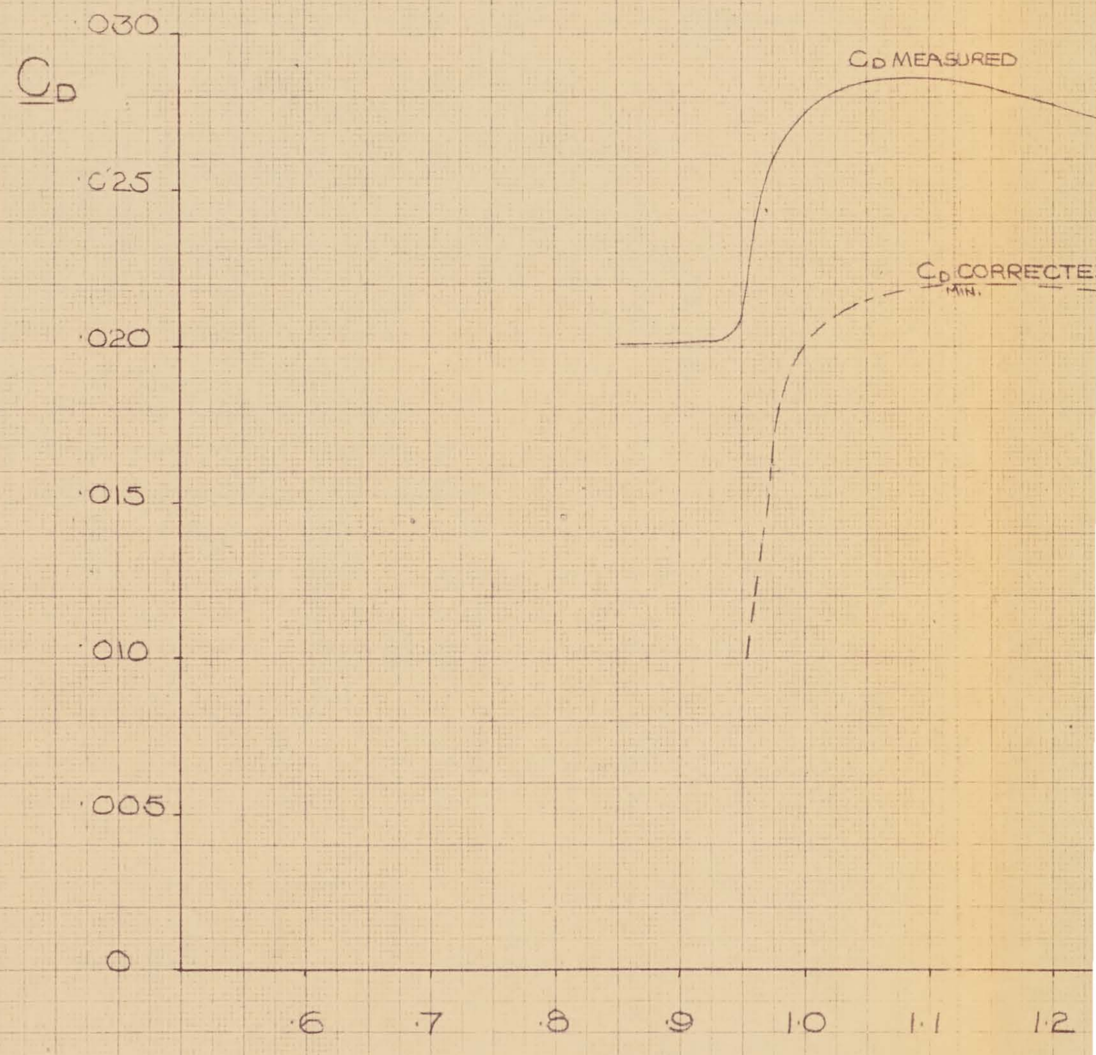
T ROCKET MODEL # 6 (2ND DRAG)

ITH MACH NUMBER



C-105 FREE FLIGHT ROC

VARIATION OF $C_{D_{MIN}}$ WITH MACH N



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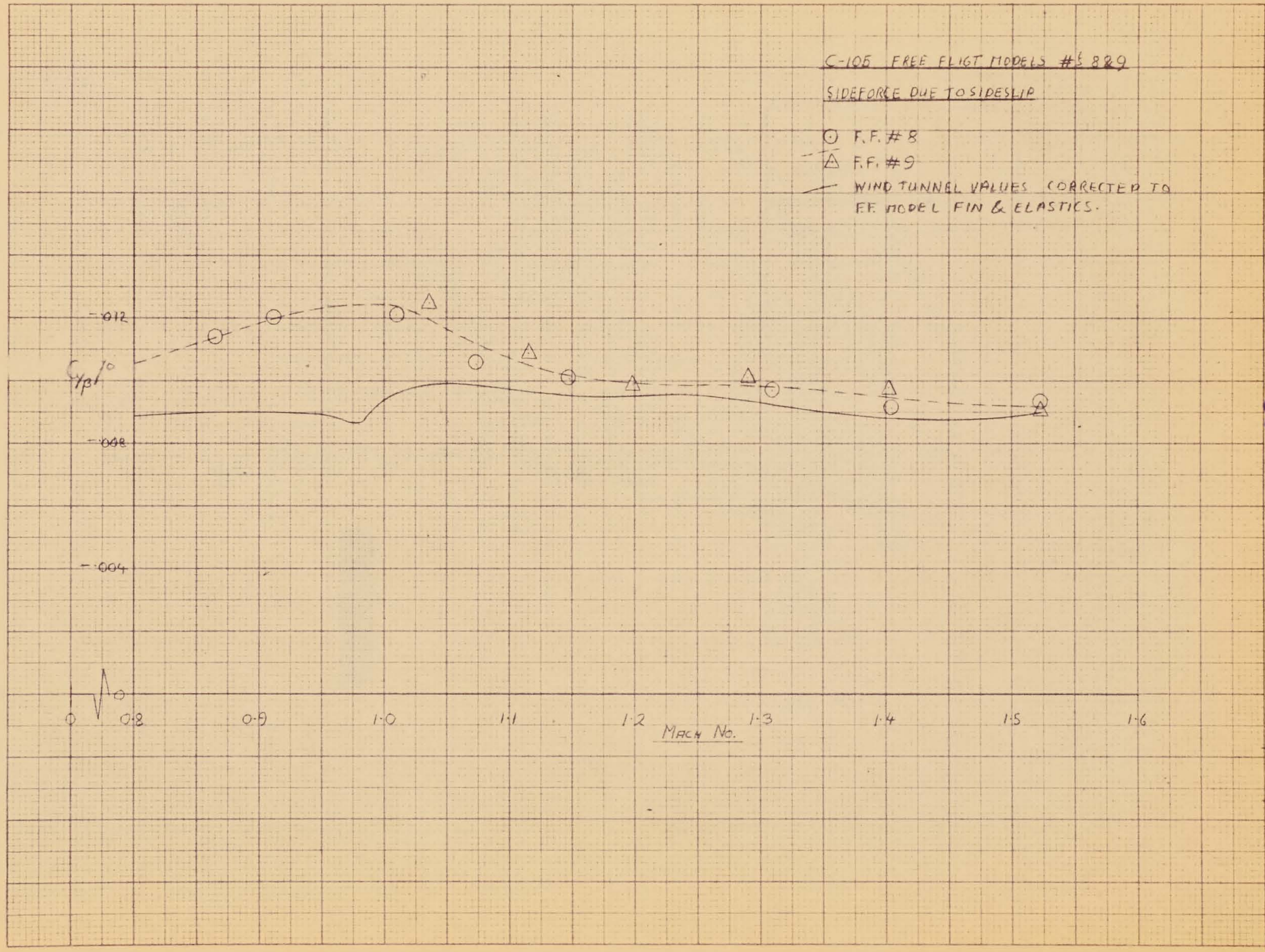
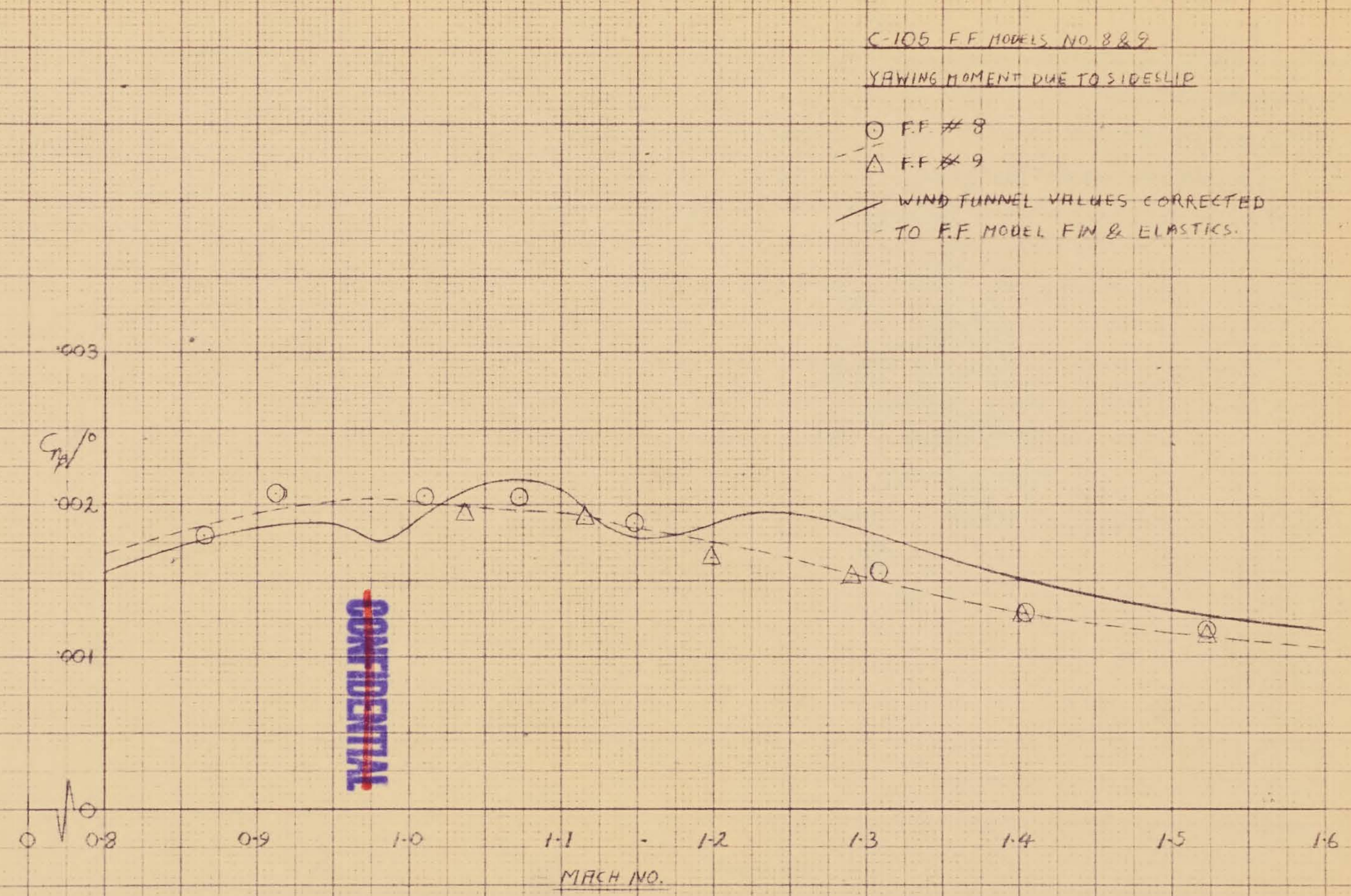
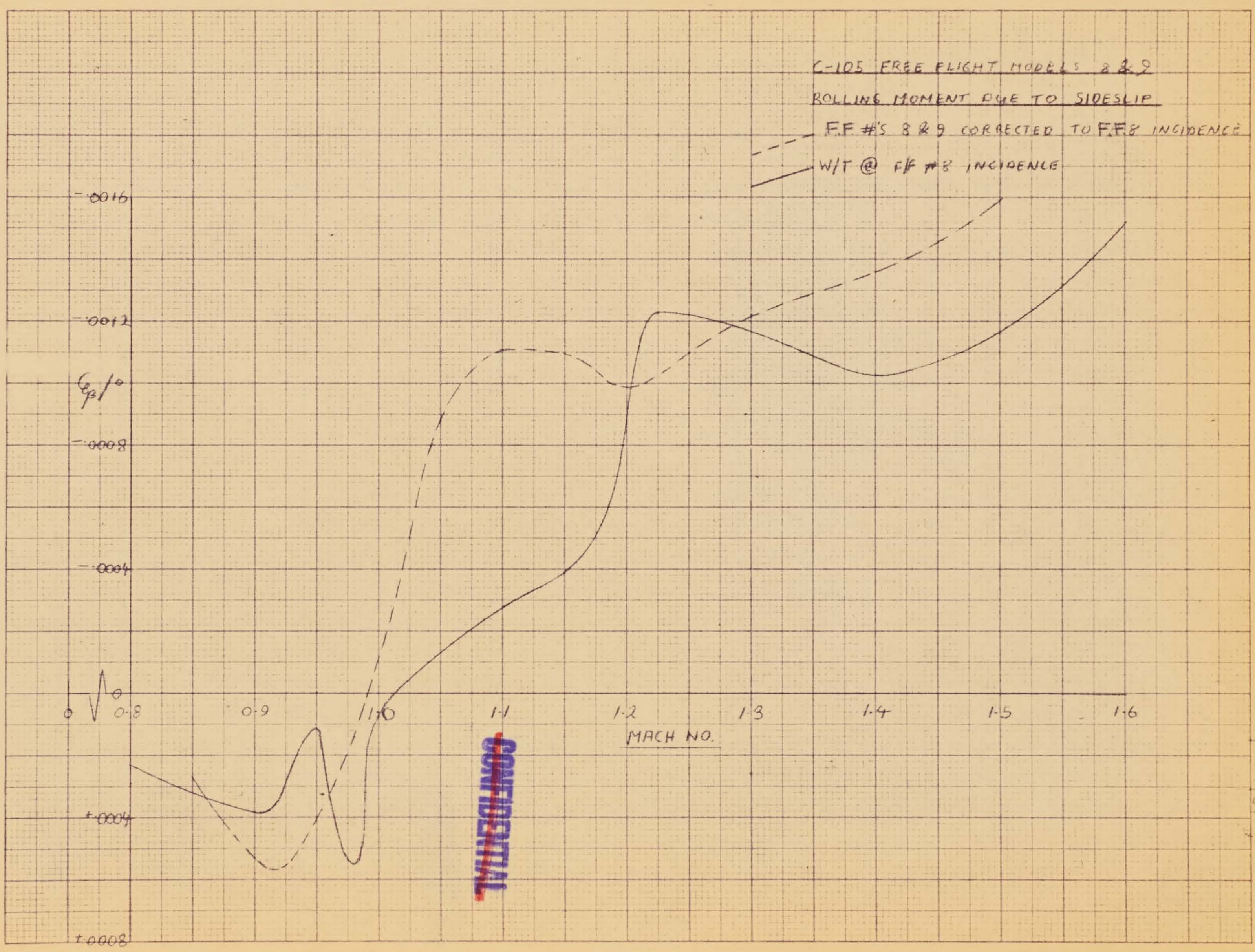
VB/6.27.57
P/FFM/57 SHEET 13



G9-12
10 X 10 TO THE INCH




C-105 FREE FLIGHT MODELS 8 & 9
ROLLING MOMENT DUE TO SIDESLIP
F.F #'S 8 & 9 CORRECTED TO F.F 8 INCIDENCE
W/T @ F/F #8 INCIDENCE
-.0016
-.0012
$C_{l_\beta}/°$
-.0008
-.0004
0
+.0004
+.0008
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
MACH NO.
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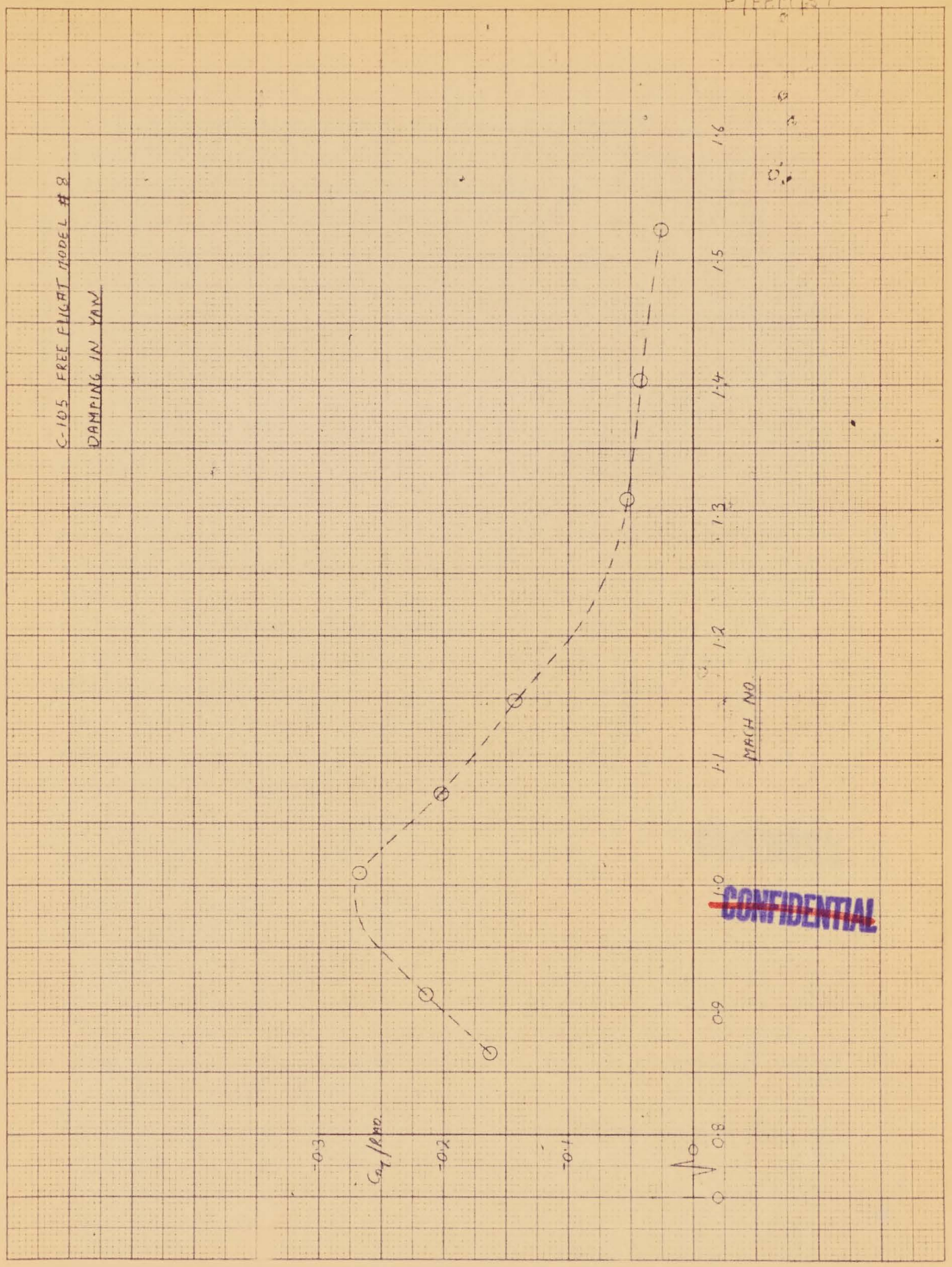
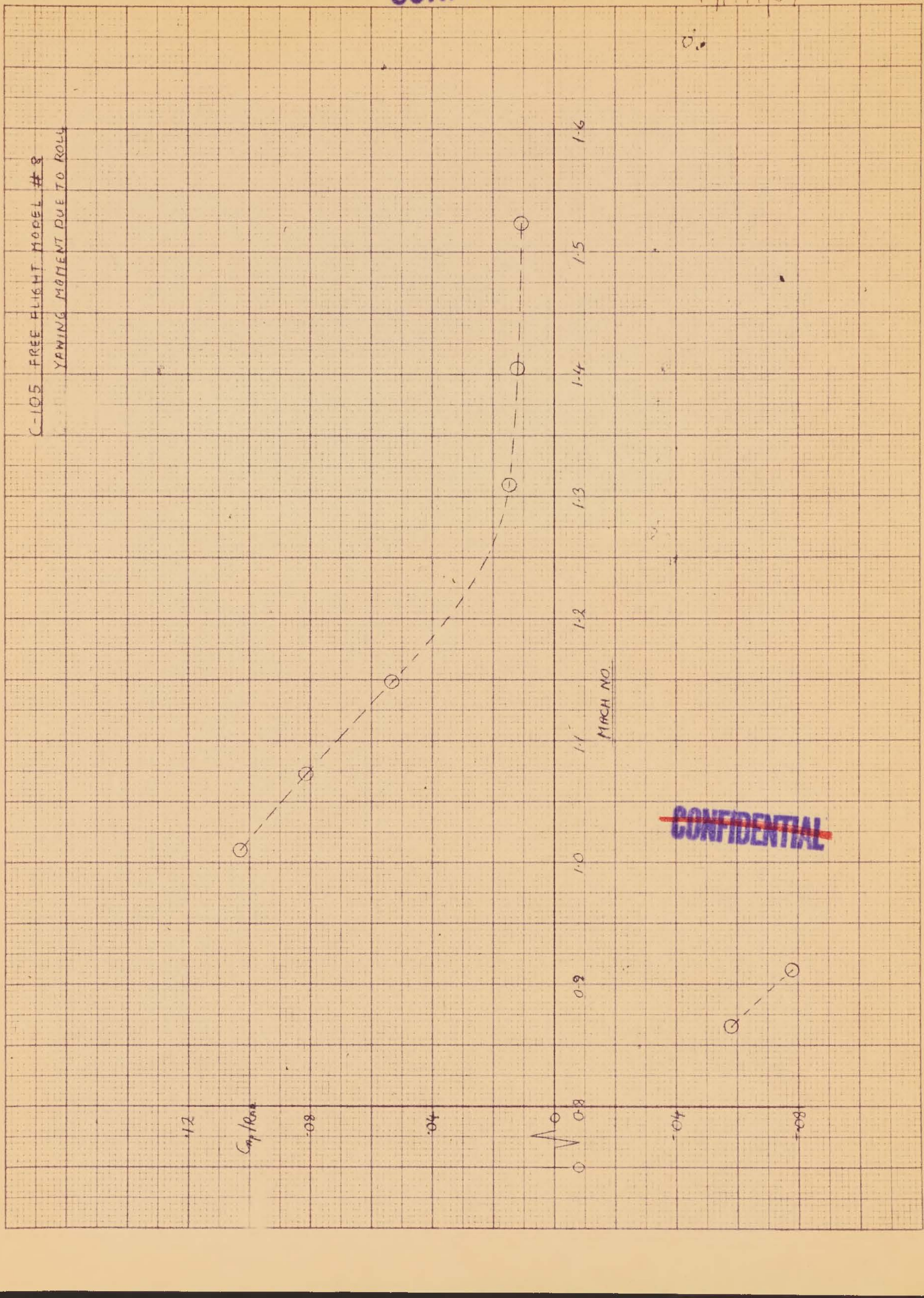
VB/6.28.57 SHEET 17

P/FFM/87





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By authority of AVRO Arrow Declassif. Board
Date 28 Jul 87
Signature [signature], Co-Chairperson
Unit / Rank / Appointment DSIS 3