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NOTE ON ELEVATOR POWER AND PITCHING MOMENT AT ZERO LIFT OF CF-105

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NOTE ON ELEVATOR POWER AND PITCHING MOMENT AT ZERO LIFT OF CF-105

The Sub-committee on Aerodynamics Meeting which took place on November 22nd, 1955 at Avro has shown there was a considerable amount of difference between Avro and N.A.E. with regard to interpretation and extrapolation of existing experimental data on elevator power as applied to CF-105 aircraft.
There was a similar situation concerning extrapolation of pitching moment at zero lift.

Various statements made by N.A.E. representatives at that meeting were since investigated in detail by Avro and this note presents a summary of these investigations and conclusions reached by Avro.

1. Discrepancy in C_{M_δ} at constant C_L over the Mach range covered by tests at Cornell.

   Avro figures as presented on graph 1 are in agreement with factual evidence.

   Departure of N.A.E. figures can be explained by inaccuracy in their work due to neglect of elastic distortion of wind tunnel model. Errors incurred at several Mach numbers are given on sheet 2 and actual cross-plots on sheet 3. *Only partly. NAE pointed out at abovementioned meeting that slopes were drawn such as to fit the −5° & −10° points since these values were relevant to performance calculations.*

2. Direct comparison with available N.A.C.A. experimental evidence.

   Reports RM A52D01c and RM L54G12a were referenced by N.A.E. and results compared with CF-105 on N.A.E. graph No. 5a, and this shows Avro estimate to lie above experimental points.

   Avro analysis of the same reports plus RM A52L04 is presented on graph 4: it shows that the relevant configuration of A52D01c (i.e. constant chord elevator) gave experimental points above Avro estimate.

   Report L54G12a gives higher than Avro C_{M_δ} at constant C_L up to M = 1.46 and report A52L04 up to M = 1.6.

   Following are the believed reasons for this divergence of interpretation.

   (i) area correction was applied by N.A.E. to data of report A52D01c but ⊗ not to report L54G12a although it amounts to 17%. Apparently this correction is either applied or not according as to whether it helps or not to prove N.A.E. postulates. Graph No. 5 shows how completely irrelevant is this discrepancy (even allowing for different estimates of the aerodynamic centre).

   ⊗ Pointed out that we were not interested in absolute value

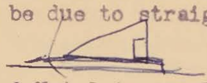
   (ii) tip loss correction was ignored by N.A.E. *(said to be small — from TN 1660)*

   (iii) data used was presumably derived from N.A.C.A. presented slopes. Avro directly cross plotted relevant wind tunnel data and obtained different results to N.A.C.A. (see for example graph No. 6.).

We "correct" Avro's slope
Avro " N.A.C.A. "

(iv) there might have been some differences in reading slopes from N.A.C.A. curves in report RM L54G12a but enclosed graphs 7 to 10 (reproductions from that report) show that the slopes are quite well defined and any substantial difference in reading must be due to straight error.

Points of interest -5° to -16°



4. Avro presented direct comparisons of N.A.C.A. results based implicitly on linear supersonic flow theory just to show what the result is if N.A.E. apparent ground rules are used correctly and applied equally to all experimental evidence.

Actually Avro method of estimating supersonic C_{M_δ} is different and is based on comparisons of experimental results and theory which allows for non-linear effects due to finite thickness of control surfaces. Also C_{M_δ} is obtained by predicting separately its components that is arm of action (a.c. and elevator c.p.) and elevator lift effectiveness (C_{L_δ}). These items are reviewed separately below. It may be noted here that N.A.E. during the meeting greatly stressed the point of actually directly dealing with C_{M_δ} at constant C_L and that they do not consider as correct the separate procedure.⊗ Examinations of reports RM A52D01c and L54G12a will show that neither of them present $C_{M_\delta}(C_L)$ as such and therefore N.A.E. must have been obtaining their values by exactly the same procedure as Avro.

5. Elevator Lift Effectiveness (C_{L_δ})

Results of a number of N.A.C.A. supersonic wind tunnel tests available to us were analysed. For each of these configurations (all of which were 60° or 63° delta wings with fuselages - CF-105 L.E. sweep = 61° 27') theoretical value of C_{L_δ} was predicted and then the ratios of experimental to theoretical value obtained. This is plotted versus Mach number on graph No.11. It can be seen that the data for all the elevators (which varied considerable in geometry) have been very successfully collapsed between Mach No. 1.4 and 2.0 with average scatter of about 3%. The theory used does not hold below Mach number of 1.3. In the range applicable this theory is very superior to linear theory which is overestimating C_{L_δ} by 20% to 30%.

Theory neglects interaction

Theory used by Avro is based on NACA TN 1660 and TR 1041. It consists of:

(i) conical flow theory allowing for tip effects

(ii) thickness correction.

As the thickness and trailing edge angle go down it may be expected that the thickness correction factor will approach unity. This is well in agreement with experimental evidence - see graph No. 12

Note that CF-105 lies within experimental points examined and <u>does not</u> involve any extrapolation of data.

6. Aerodynamic Centre (a.c.)

Experimental data available are given on graph No. 13. Supersonic level for CF-105 (see graph No. 14) was established by combined considerations of these results and CF-105 Cornell Transonic Tunnel tests (up to M = 1.23). Modifications of the wing have shown consistent trend forward in transonic tests (see graph No. 14) and this was reflected in our supersonic extrapolation. Also Convair F-102 data were given relatively more weight.

7. Elevator Incremental Load Centre Of Pressure (c.p.)

Although all evidence considered was taken from near 60° deltas changes on elevator geometry between configurations examined cause considerable scatter when c.p. is plotted in terms of % wing M.A.C. vs Mach No. - See graph No. 15. However replotting it in terms of difference between the experimental c.p. and the centroid of elevator area arranges the data in more orderly manner - see graph No. 16. The extrapolation for CF-105 (also shown on graph No. 16) was arrived at taking rather pessimistic point of view as most of experimental points lie aft of the centroid thus giving longer arm and hence higher C_{M_δ}. It was felt, however, that this is safer as the movement of the c.p. aft of centroid is caused by boundary layer - shock waves interaction and thus might be subject to some Reynolds No. effect.

8. Pitching Moment At Zero Lift (C_{M_0})

The variation of C_{M_0} with Mach No. was obtained from three dimensional theoretical calculation results of which are given on graph No. 17. This curve is used only on proportional basis and different wing configurations of CF-105 resulting in different levels of C_{M_0} at M. No. 1.23 from Cornell tests are then extrapolated accordingly.

The N.A.E. procedure of lowering C_{M_0} curves by a constant amount which supposedly was based on Cornell tests is quite unsound theoretically and the experimental basis for it is non-existent. Graph No. 18 shows there is no constant difference in C_{M_0} between various CF-105 configurations tested at Cornell (contrary to N.A.E. claim) that is if we do not consider variations of +27% to -70% as negligible and we at Avro do not.

Effect is small

Emotional statement

Conclusions

This investigation was conducted as thoroughly as was possible and whenever numerical data of N.A.C.A. tests were available they were used to obtain our own plots and cross-plots in preference to using N.A.C.A. read slopes.

The results of this investigation confirm fully the values of all the derivatives disputed as per original Avro estimates. This applies to the entire Mach No. range.

Avro does not claim that the supersonic extrapolation of these derivatives must be absolutely correct - only supersonic tests can establish that. However it does claim that on the basis of experimental evidence available up to the present these are rationally correct extrapolations.

References

1. TN 1660 Characteristics of thin triangular wings with constant-chord partial span control surfaces at supersonic speeds

   By Warren A. Tucker & Robert L. Nelson - July 1948

2. TR 1041 Equations and charts for the rapid estimation of hinge-moment and effectiveness parameters for trailing-edge controls having leading and trailing edges swept ahead of the mach lines.

   By Kennith L. Goin

3. RM A52L04 Experimental investigation of Aerodynamically balanced trailing-edge control surfaces on an aspect ratio 2 triangular wing at subsonic and supersonic speeds

   By John W. Boyd and Frank A. Pfyl

4. RM A7J05 Wind-tunnel investigation at a mach number of 1.53 of an airplane with a triangular wing

   By Richard Scherrer and William R. Wimbrow

5. RM A52D01c Aerodynamic characteristics of two 25-percent-area trailing-edge flaps on an aspect ratio 2 triangular wing at subsonic and supersonic speeds

   By John W. Boyd

References (Continued)

6. RM L54G12a — Effects of overhang balance on the hinge-moment and effectiveness characteristics of an unswept trailing-edge control on a 60° delta wing at transonic and supersonic speeds

By Lawrence D. Guy

K+E 10 X 10 TO THE ½ INCH 359-12
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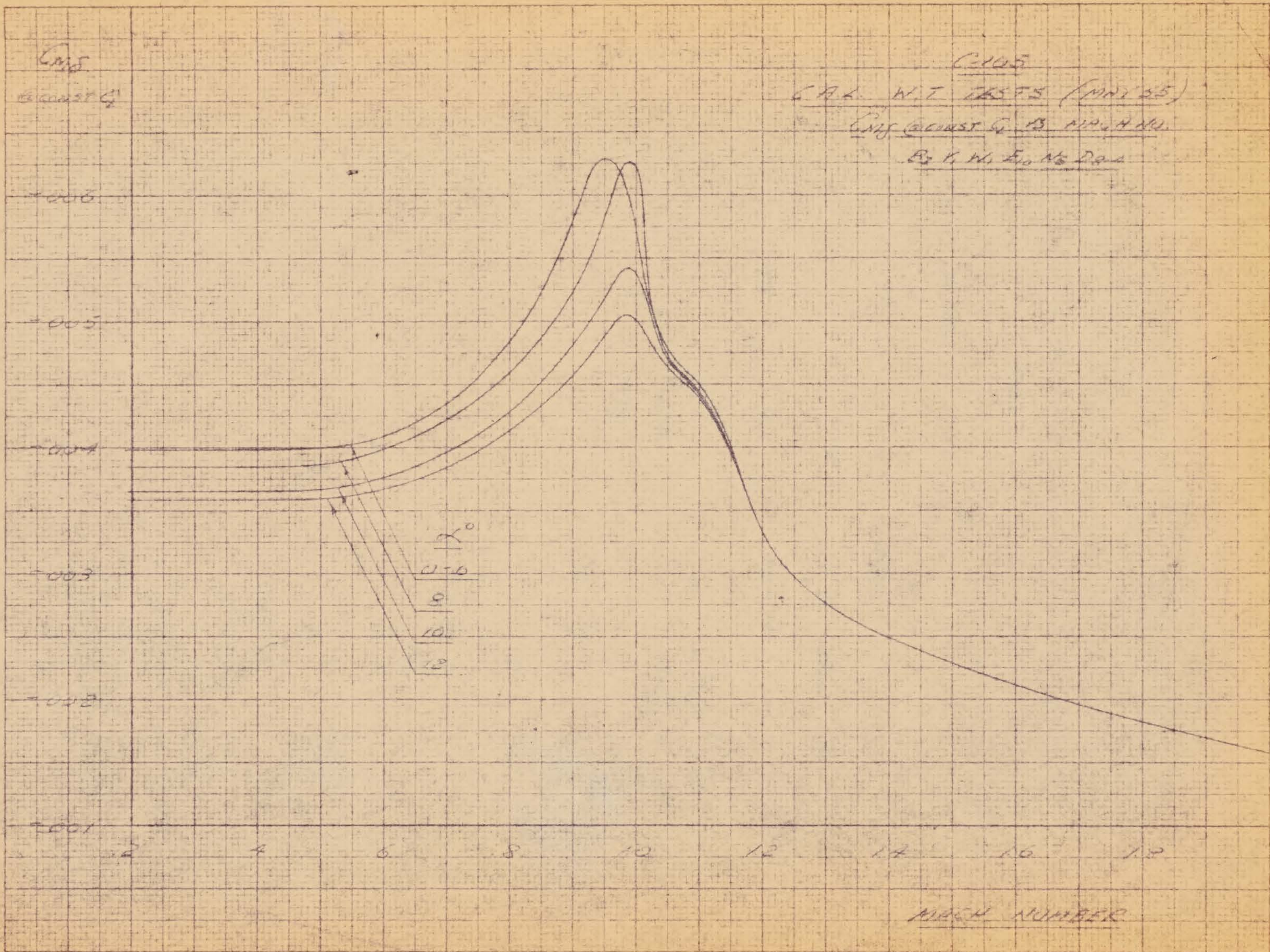

A. V. ROE CANADA LIMITED
MALTON · ONTARIO
TECHNICAL DEPARTMENT (Aircraft)

REPORT NO.
SHEET NO.

AIRCRAFT: C 105.

PREPARED BY	DATE
Kwiatkowski	Dec /57.
CHECKED BY	DATE

(2)

ERROR DUE TO NEGLECTING THE HINGE MOMENT CORRECTION

REF. P/WT/80 sh 3.2.1

C_M vs δ_e at $C_L = \cdot 1$

$-5^\circ < \delta_e < 10^\circ$ — LINEAR RANGE

Not interested in this range 0 → −10° for performance.

M	$C_{M\delta}$ TRUE	$C_{M\delta}$ NEGL. H.M. CORR	ERROR %
1·23	−·00308	−·00292	5·1 ~
1·15	−·00397	−·00375	5·5
1·10	−·00456	−·00435	4.6
1·05	−·00465	−·00450	3·2

$\frac{.308-.292}{.00308} = \frac{.016}{308} = 5.2\%$

or $\frac{.308-.292}{.00292} = \frac{.016}{.00292} = 5.5\%$

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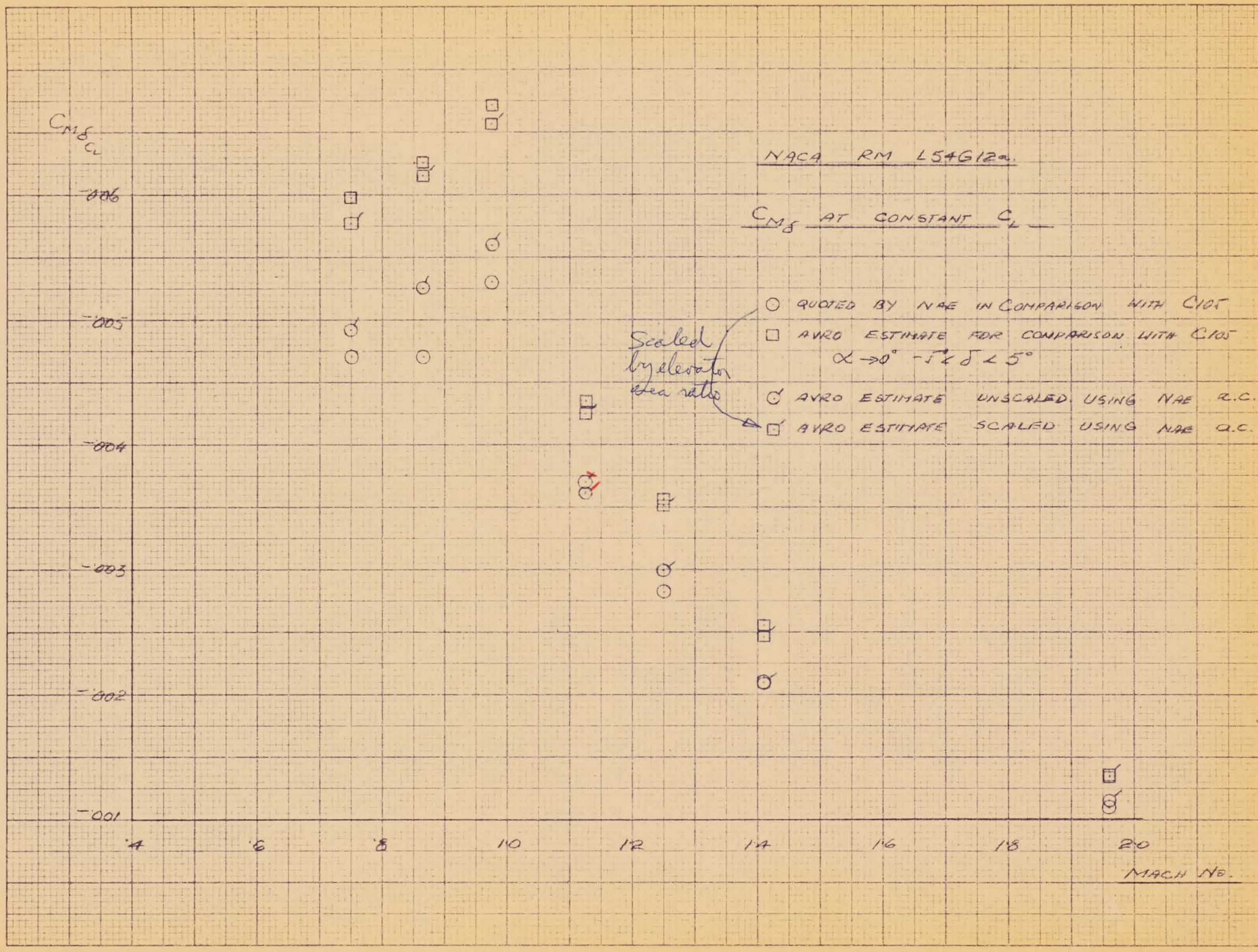

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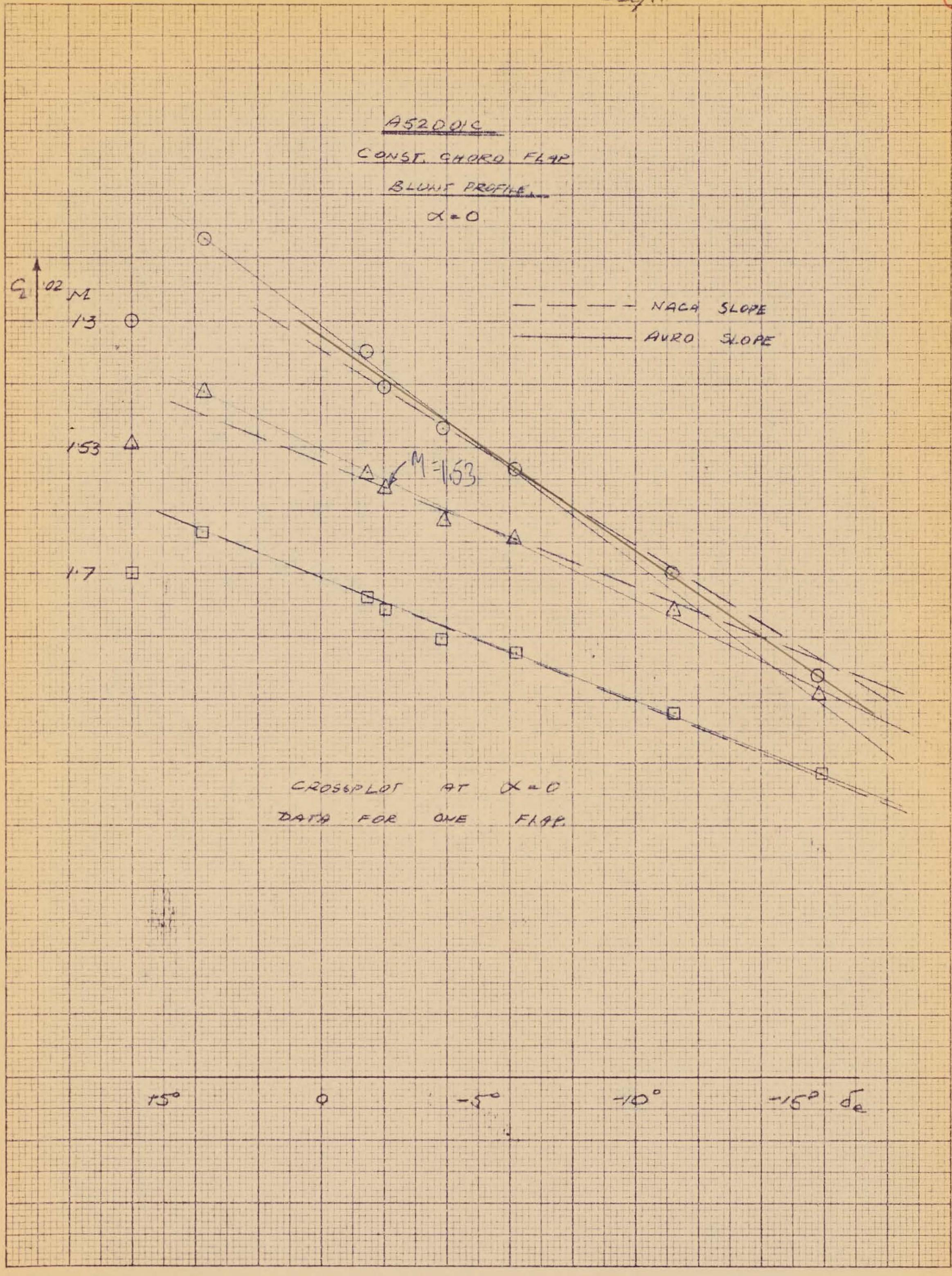
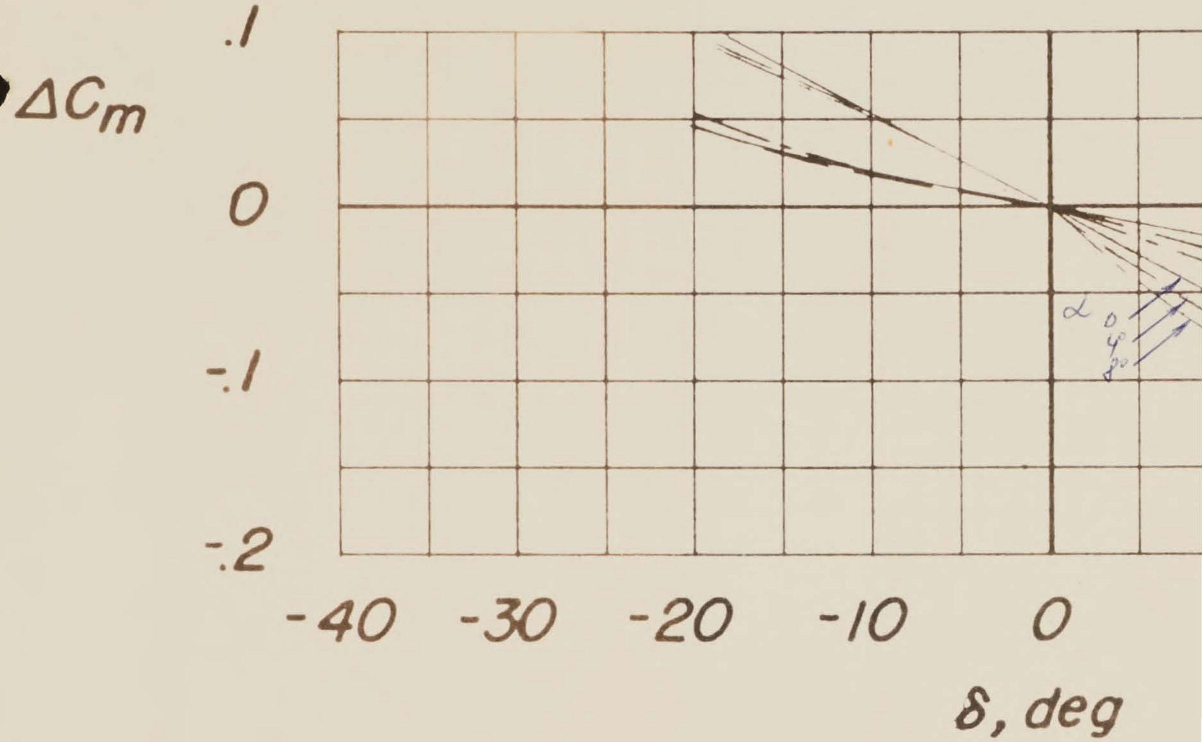
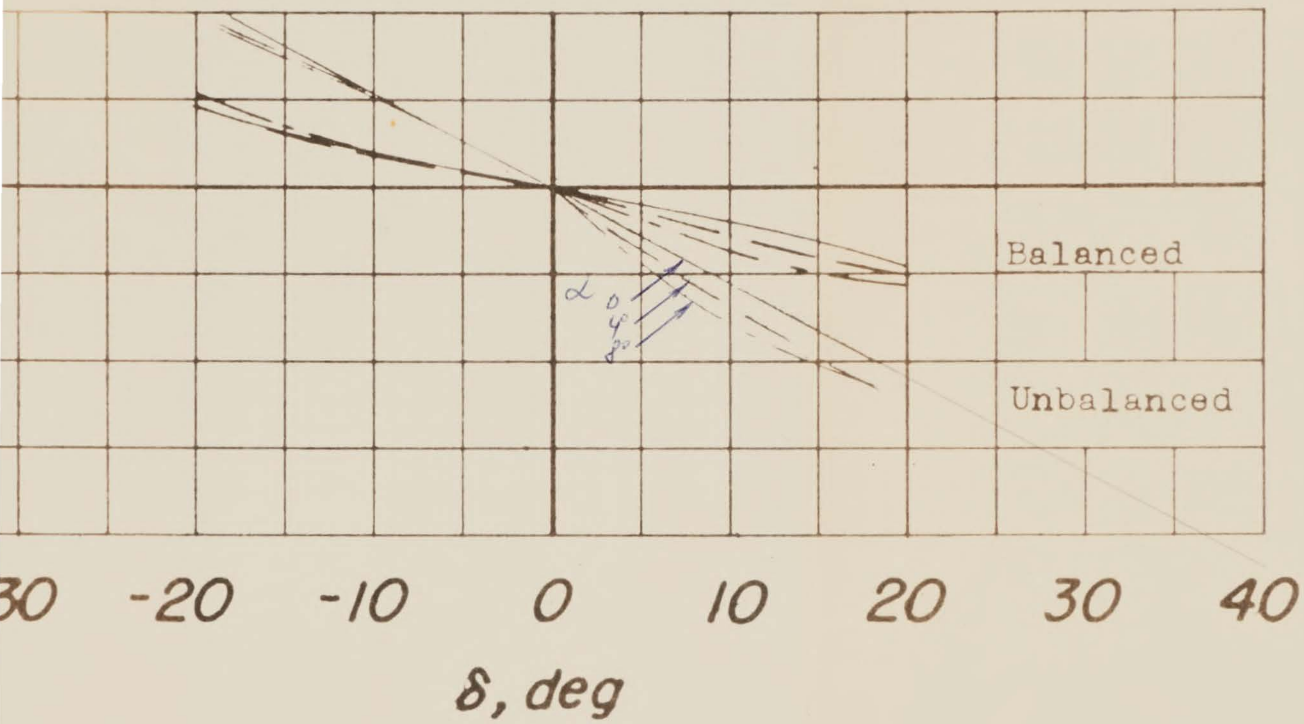


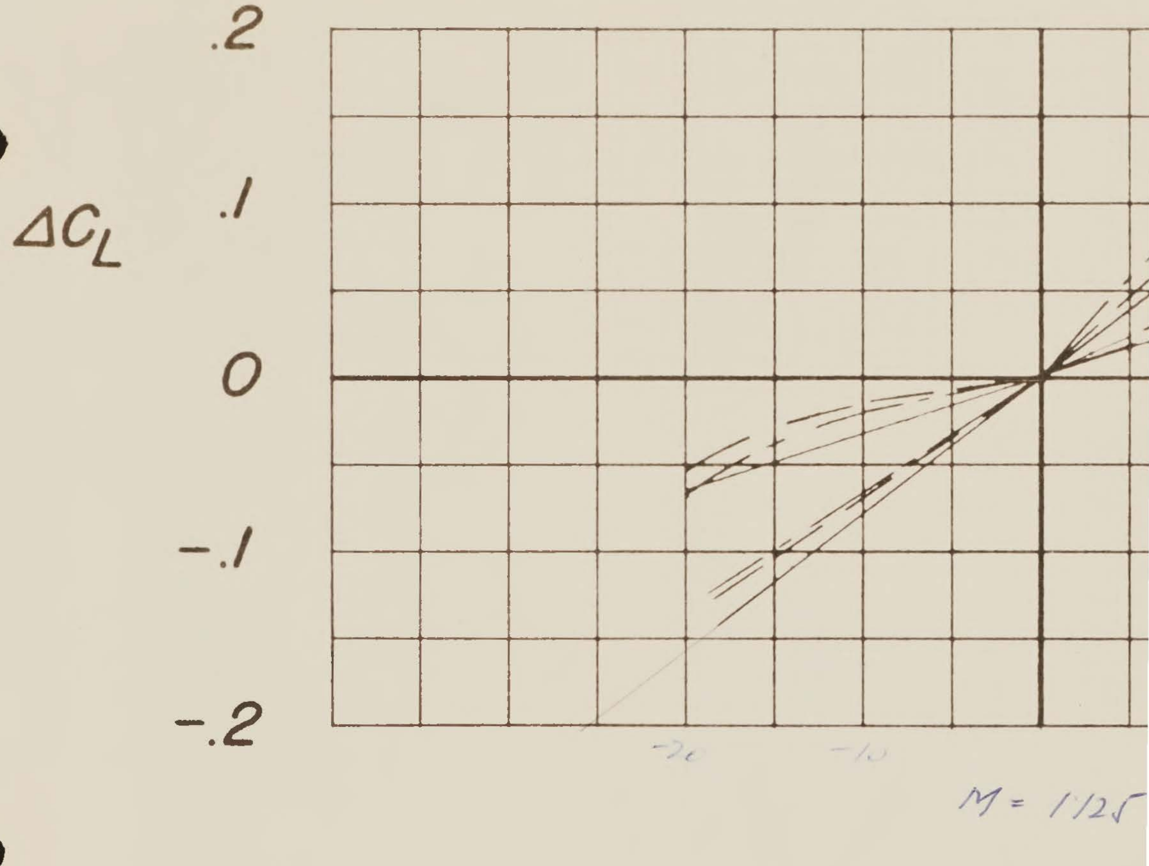
K+E 10 X 10 TO THE ½ INCH KEUFFEL & ESSER CO. 359-12 MADE IN U.S.A.

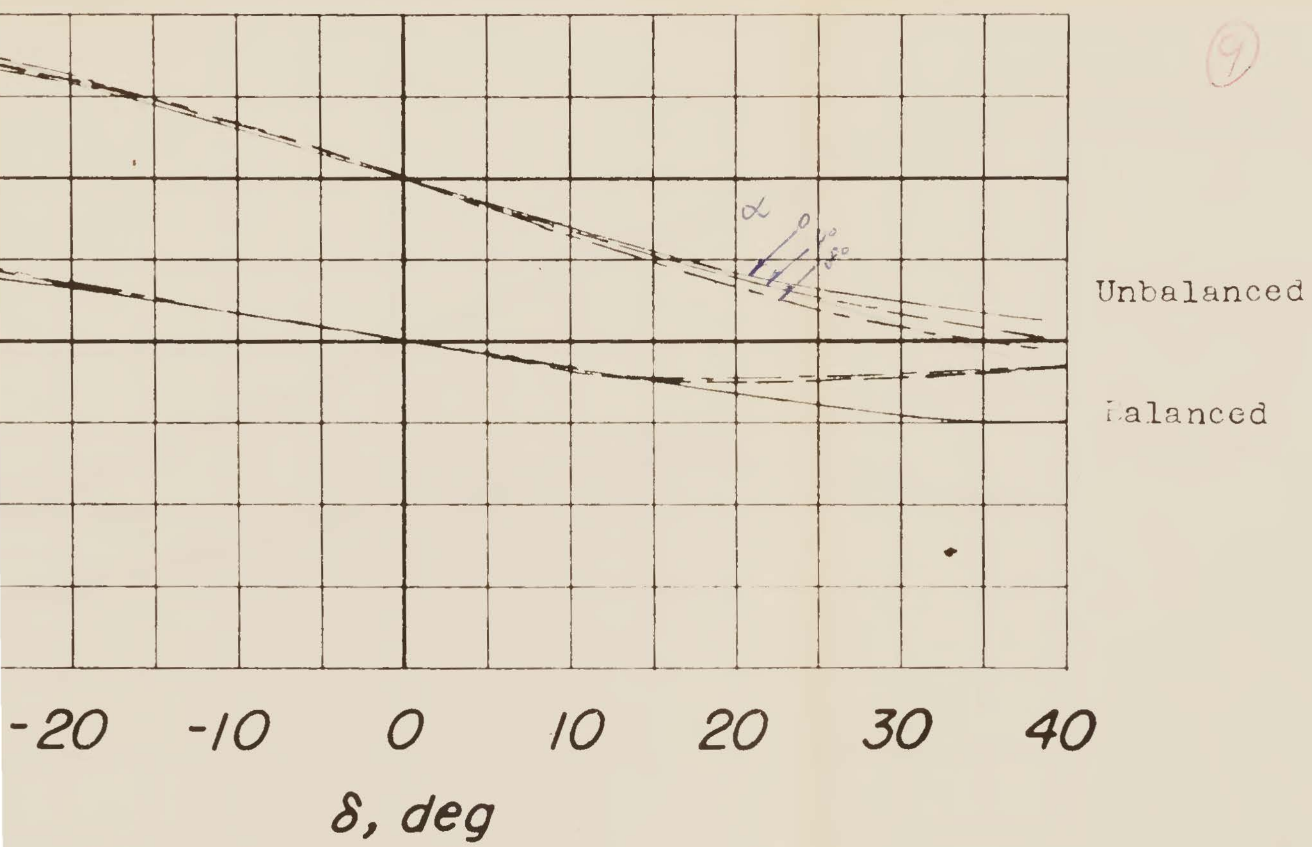


(d) M = 1.125

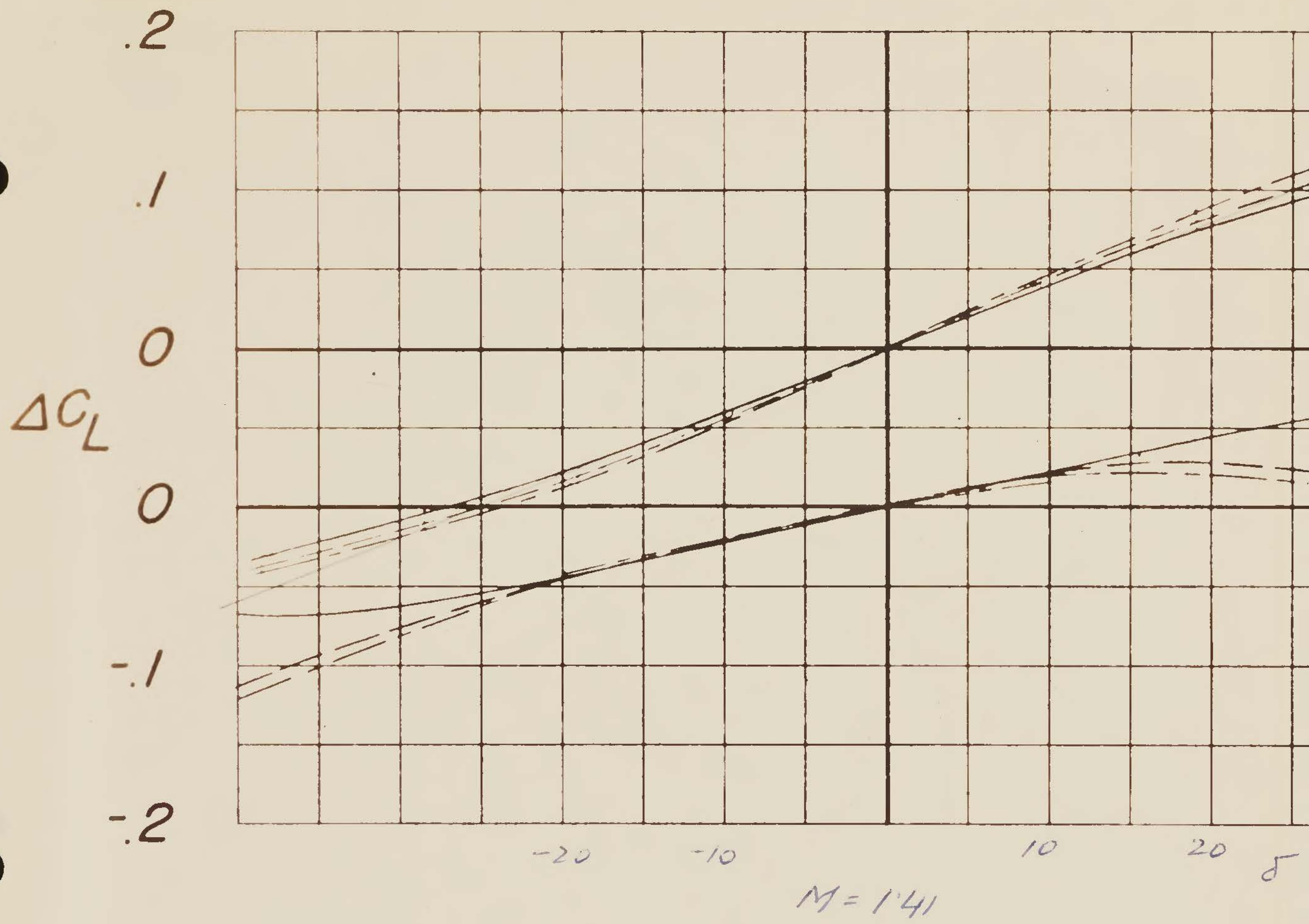


(d) M = 1.125.

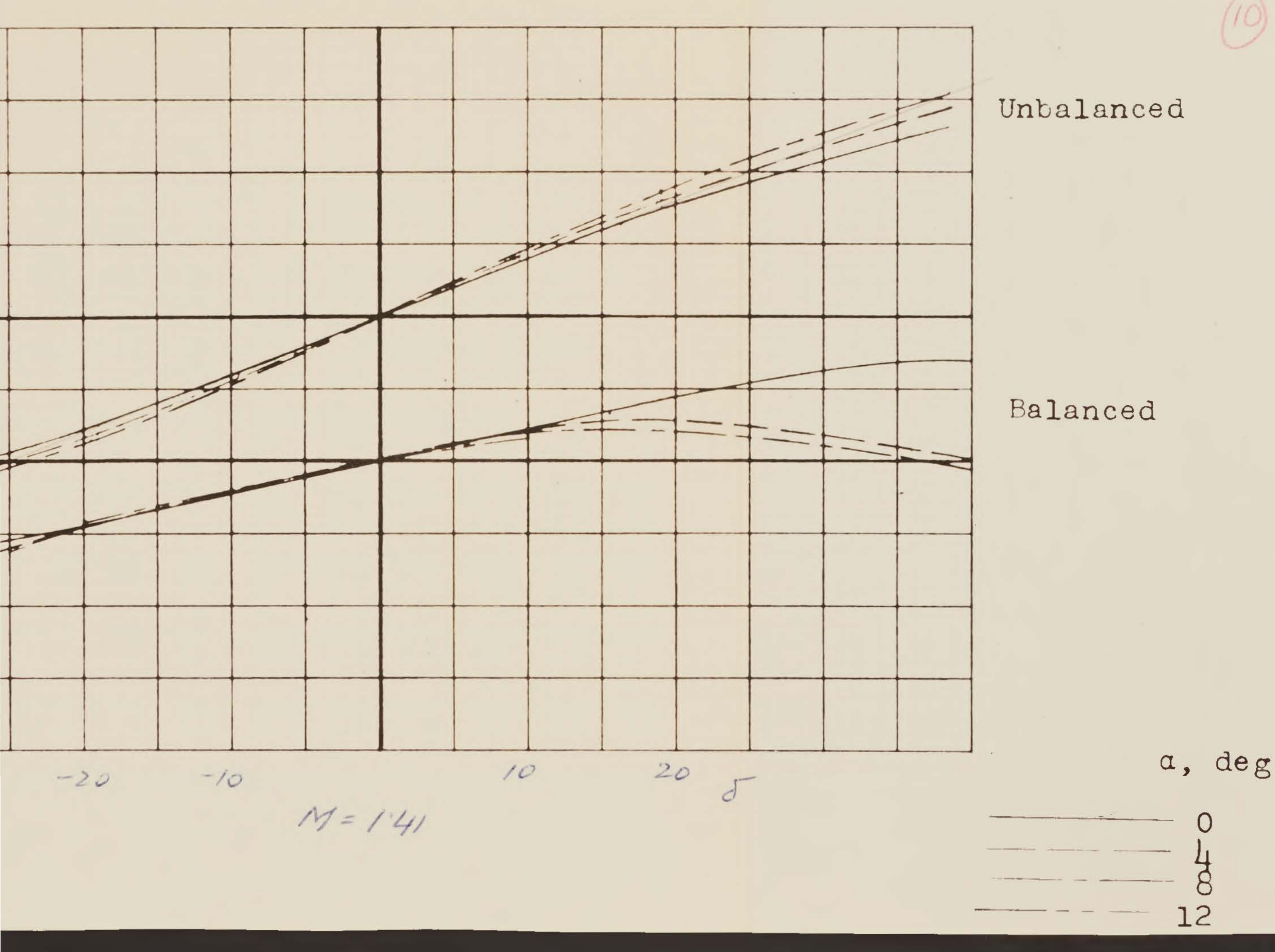

.2
.1
ΔC_L
0
-.1
-.2
-20
-10
M = 1.125



(f) M = 1.41.



.2
.1
0
ΔCL
0
-.1
-.2
-20
-10
10
20
δ
M = 1·41


Unbalanced
Balanced
-20
-10
10
20
δ
M = 1·41
α, deg
0
4
8
12

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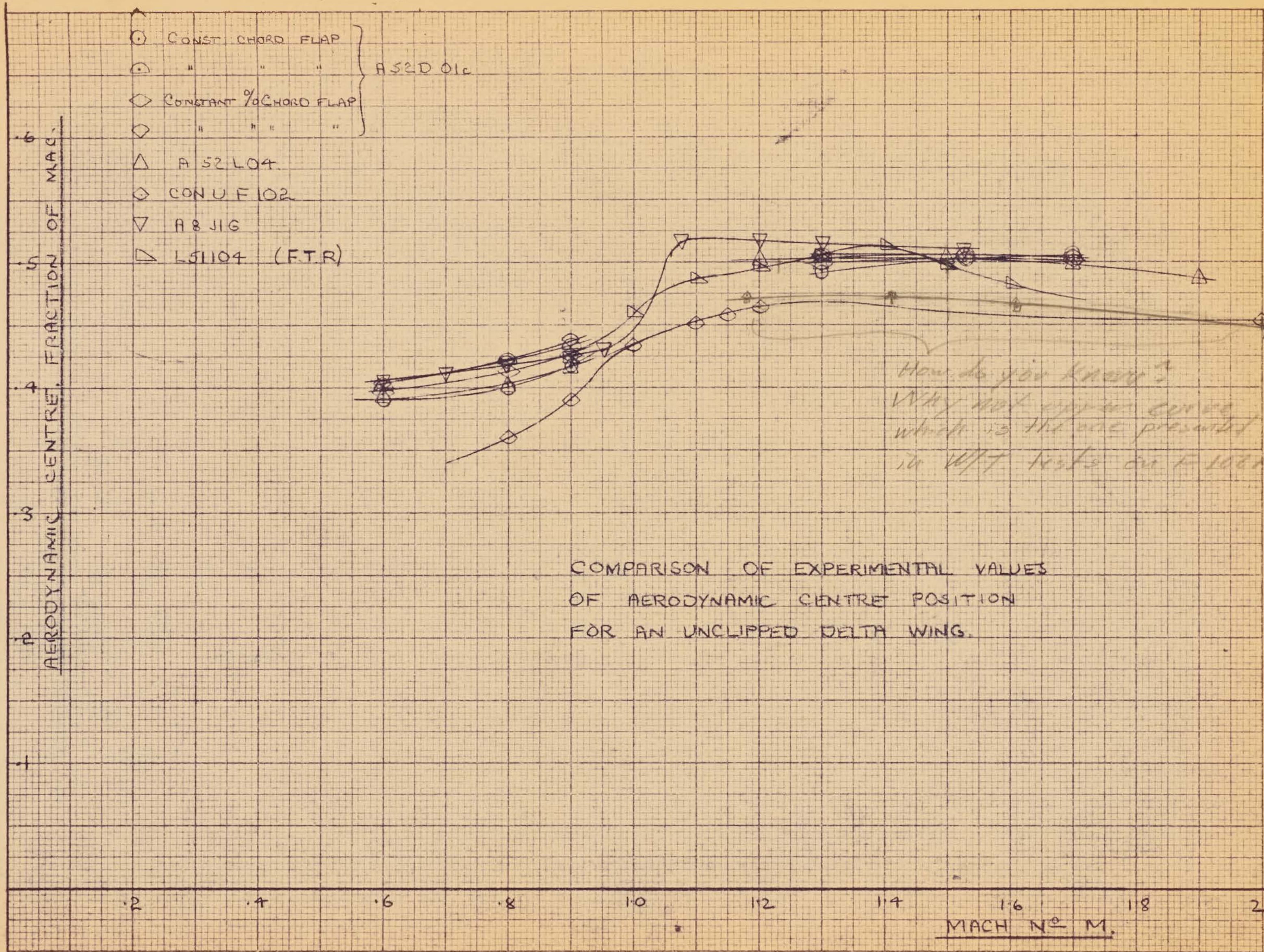
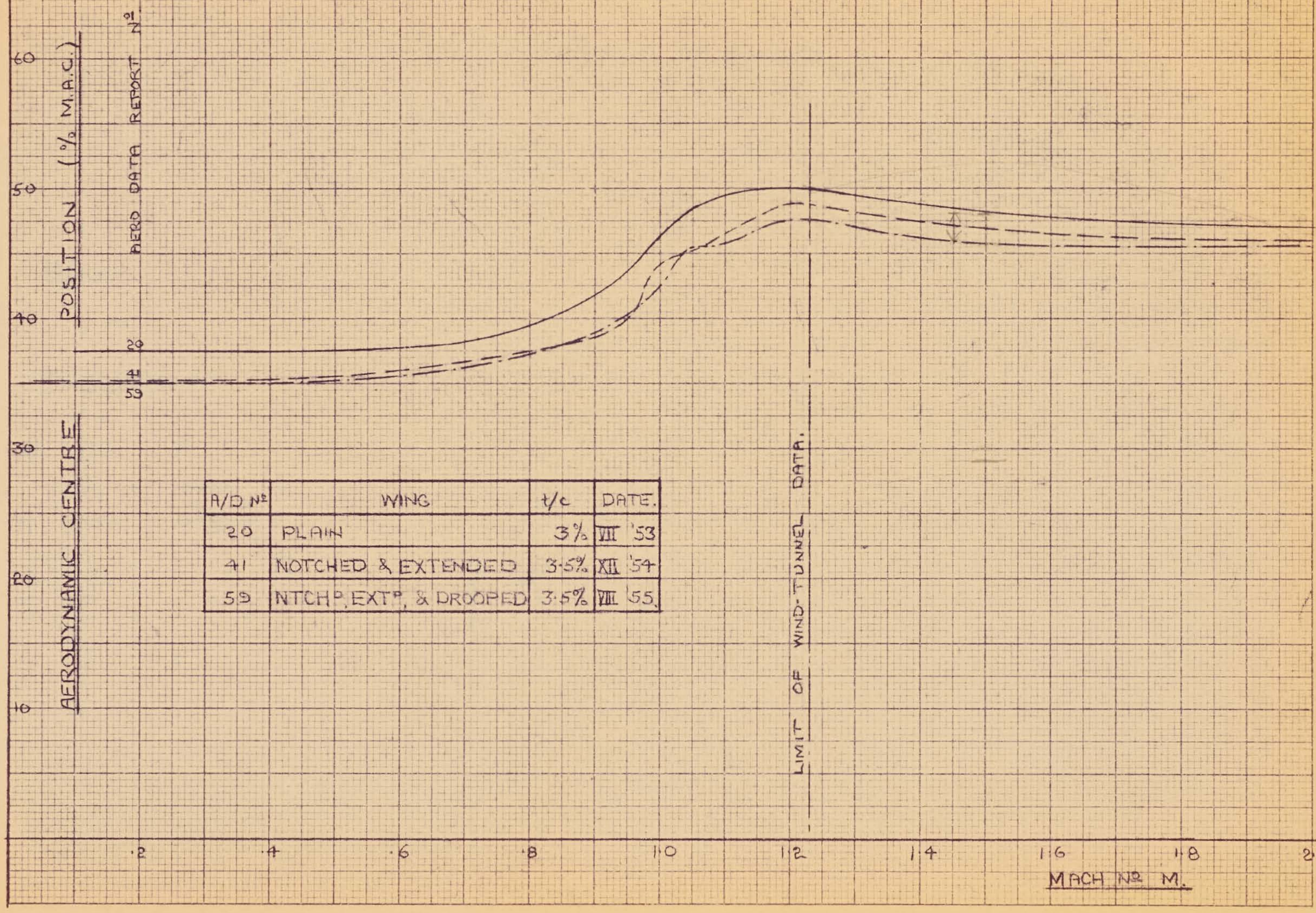
P/Control/83.
D. J. Foster Dec '55.
4.1.3.
13



P/Contd / 83 4.1.4. (14)

D. J. Foster Dec 55.

SUCCESSIVE ESTIMATES OF AERODYNAMIC CENTRE LOCATION FOR C-105



A/D Nº	WING	t/c	DATE.
20	PLAIN	3%	VII '53
41	NOTCHED & EXTENDED	3·5%	XII '54
59	NTCHD, EXTD, & DROOPED	3·5%	VIII '55

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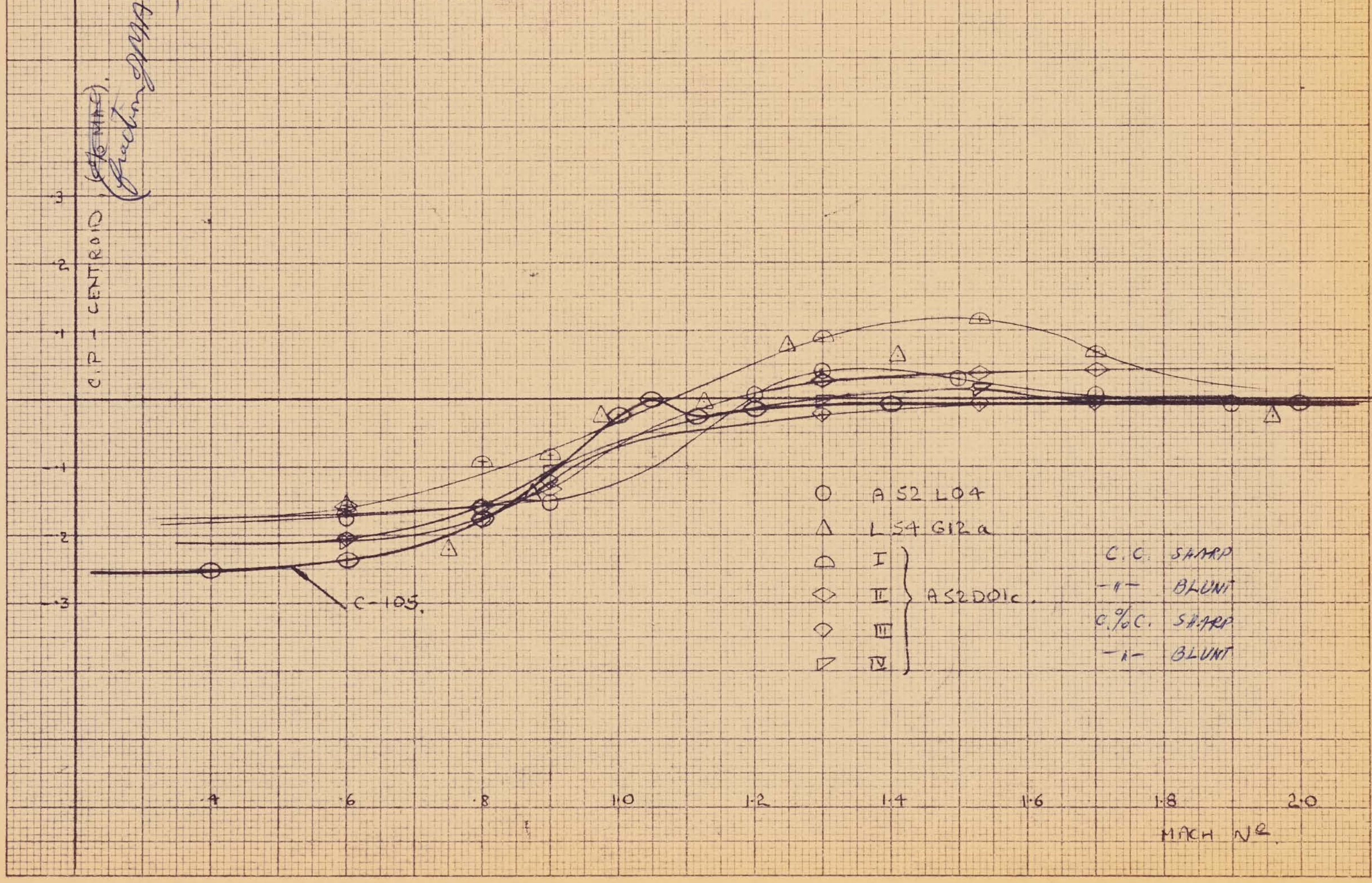
EXPERIMENTAL DISTANCE OF CENTRE OF PRESSURE OF FLAP AFT OF CENTROID OF AREA OF FLAP AS FRACTION OF WING M.A.C.

COMPARISON OF C-105 W/T TESTS & AVRO EXTRAPOLATION WITH SIX OTHER MODEL TESTS.



16

17

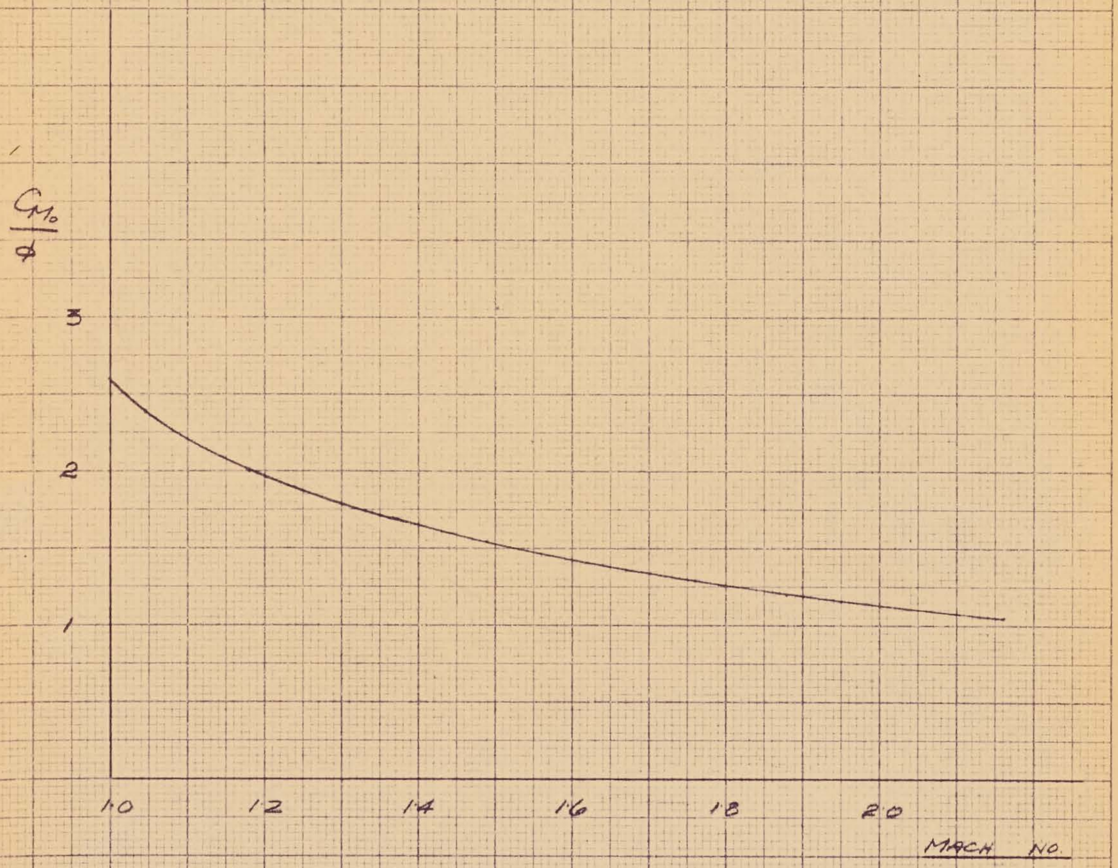
T.I. P/CONTR/83
Kuenaflenoole

C105

THEORETICAL MACH VARIATION OF C_{M_0} PER UNIT CAMBER

TRIANGULAR WING WITH PARABOLIC CAMBER TAPERED LINEARLY FROM ϕ AT ℄ TO ZERO AT THE TIP.

REF. P/LOADS/10 D.W. POUNDER p. 29-36.
TN 2497.



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