

QGX
Avro
CF105
MR-4

FILE IN VAULT

38

CF-105 **SECRET**
MONTHLY PERFORMANCE REPORT
NO. 4 **CLASSIFIED**
ANALYZED January 1956.



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by (Name): J.M.D. Henrie

(Dept.): DND Coordinate, Access to Information

Date: Aug 4, 1992

Rene Henrie
Signature



A. V. ROE CANADA LIMITED
MALTON - ONTARIO

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TECHNICAL DEPARTMENT (Aircraft)

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AIRCRAFT: CF-105

REPORT NO. Monthly Report No.

FILE NO:

NO. OF SHEETS:

TITLE:

ANALYZED

PERFORMANCE

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CF-105 MONTHLY PERFORMANCE REPORT

(Issued Mid-Monthly)

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

FORM 1316A

12416100

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INTRODUCTION

This is the fourth of a series of monthly performance reports for internal usage, to be issued from the Aerodynamics Department.

Only the maximum performance in the stratosphere has been revised since the third report. The alterations are due to

- Revision of the trim drag estimate
- Revision of Orenda PS 13 maximum thrust estimate

The pertinent changes are noted in their appropriate sections.

A note on the effect of installing Sparrow II Missiles in place of Falcon missiles has been included as subsequent performance reports are to be based on the CF-105 with a sparrow missile pack.

Successive reports will present the latest data, with the alterations from the previous report noted. The report is divided into three major sections

1. CF-105 Performance
2. CF-105 Drag
3. Engine Data

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PERFORMANCE NOTE ON THE

EFFECT OF INSTALLING SPARROW II MISSILES IN PLACE OF FALCONS

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The latest weight and c.g. estimate (by no means finalized) for the CF-105 with 4 Sparrow II missiles submerged in the armament bay shows the following changes over that of the CF-105 carrying 8 fully submerged Falcons.

	<u>Weight Increase</u>	<u>Fwd. Shift in C.G.</u>
CF-105 - P.S. 13	1243 Lb.	1.09% M.A.C.
CF-105 - J-75	1243 Lb.	1.04% M.A.C.

The performance in this and previous Monthly Reports have been based on Falcon missile armament.

Based on the above data then, the CF-105 will suffer a 6% reduction in 'g' at 1.5 M.N. at 50,000 ft. on installing Sparrow Missiles. Subsequent Monthly Performance Reports will be based on Sparrow missile armament.

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1. CF-105 PERFORMANCE

The performance in this issue is sub-divided into two parts:

- 1A. CF-105 Performance with Pratt and Whitney JT4A-25 Engines
- 1B. CF-105 Performance with Orenda PS 13 Engines

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1A: CF-105 PERFORMANCE WITH PRATT AND WHITNEY (J-75) JT 4A-25 ENGINES

(C.G. = 29% M.A.C.)

The following CF-105 - (J-75) JT 4A-25 performance estimate is based on the Wind Tunnel configuration designated B2V1W1E10N5D8-4 (except that the nose cone angle has been reduced to 30°). The particular feature of this configuration is the extended, notched and cambered leading edge of the wing.

The drag of this configuration is summarized (Extract P/Perf/112) and is presented in section 2 of this report. A more direct approach of estimating supersonic trim drag has been employed, resulting in reduced drag.

No revision has been made to the installed engine data.

Corrections for the above alteration has been applied directly to the maximum performance data in the stratosphere only. No revision has been made to the mission profiles.

The pertinent CF-105 Performance Changes are listed below:

Δ Combat 'g' at 1.50 M.N. at 50,000 feet	= + .09
Δ Maximum Speed at 50,000 feet	= + 3 knots
Δ Combat Ceiling at 1.50 M.N.	= + 1100 feet

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January 1956

LOADING AND PERFORMANCE - 4Performance Under N.A.C.A. Standard Atmospheric ConditionsTo R.C.A.F. Specification AIR 7-4

(With 2 J-75 Engines)

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WEIGHT:

Take-Off Weight with 15,356 Lb. Fuel (77.1% Max.)	Lb.	59,228
Operational Weight Empty	Lb.	43,872
Combat Weight (1/2 Fuel)	Lb.	51,550
Landing Weight (With Reserve Fuel + Missiles)	Lb.	44,390
Wing Loading at Normal Take-Off Weight	Lb./sq/Ft.	47.2
Power Loading at Normal Take-Off Weight	Lb./Lb. Thrust	1.60

SPEED

True Air Speed in Level Flight		
At Sea Level at Combat Weight		
Maximum Thrust	Kts.	* 755
Military Thrust	Kts.	640
True Air Speed in Level Flight		
At 50,000 Ft. at Combat Weight		
Maximum Thrust	Kts.	1,073

CEILING

Combat Ceiling at Combat Weight, Rate of Climb = 500 F.P.M.		
Maximum Thrust at 1.5 M.N.	Ft.	56,600

RATE OF CLIMB

Steady Rate of Climb at Sea Level, Combat Weight		
Maximum Thrust at M.N. = .92	F.P.M.	51,400
Military Thrust at 530 Kts.	F.P.M.	15,800
Steady Rate of Climb at 50,000 Ft., Combat Weight		
Maximum Thrust at M.N. = 1.5	F.P.M.	6,100

TIME TO HEIGHT

Time to 50,000 Ft. M.N. = 1.5 from Engine Start at Take-Off		
Weight = 59,228		
Maximum Thrust	Mins.	4.9

MANOEUVRABILITY

Combat Load Factor at Combat Weight		
Maximum Thrust at M.N. = 1.50 at 50,000 Ft.		1.48

* Placard Speed = 720 Kts.

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TAKE-OFF DISTANCE

Take-Off Distance over 50 Ft. Obstacle at Sea Level
Take-Off Weight = 59,228 Lb.

Maximum Thrust	Ft.	3,400
Military Thrust	Ft.	6,700
Maximum Thrust, Hot Day	Ft.	4,600

LANDING DISTANCE

Landing Distance over 50 Ft. Obstacle at Sea Level at Combat Wt. Ft. 5,300

STALLING SEPPED

True Stalling Speed in Landing Configuration at Combat Weight
at Sea Level Kts. 110

RANGE

Combat Radius of Action at 50,000 Ft., Climb at M.N. = .92, Cruise out
at M.N. = 1.5, Combat for 5 Mins. at M.N. = 1.50, Cruise Back at M.N. = .92,
15 Min. Stack at 40,000 Ft., 5 Min. Fuel Reserve on Landing

High Speed Mission with 15,356 Lb. Fuel	N.M.	200
High Speed Mission with Full Internal Fuel	N.M.	309

Combat Radius of Action at 50,000 Ft., Mission as above except climb
at 530 Kts. and cruise out at M.N. = .92

Maximum Range Mission with 15,298 Lb. Fuel	N.M.	406
Maximum Range Mission with Full Internal Fuel	N.M.	605

Combat Radius of Action at Sea Level, Cruise out at .6 M.N. and
Combat at M.N. = .92 at Sea Level, Cruise Back at .92 M.N. at
40,000 Ft., 15 Min. Stack, 5 Min. Fuel Reserve on Landing

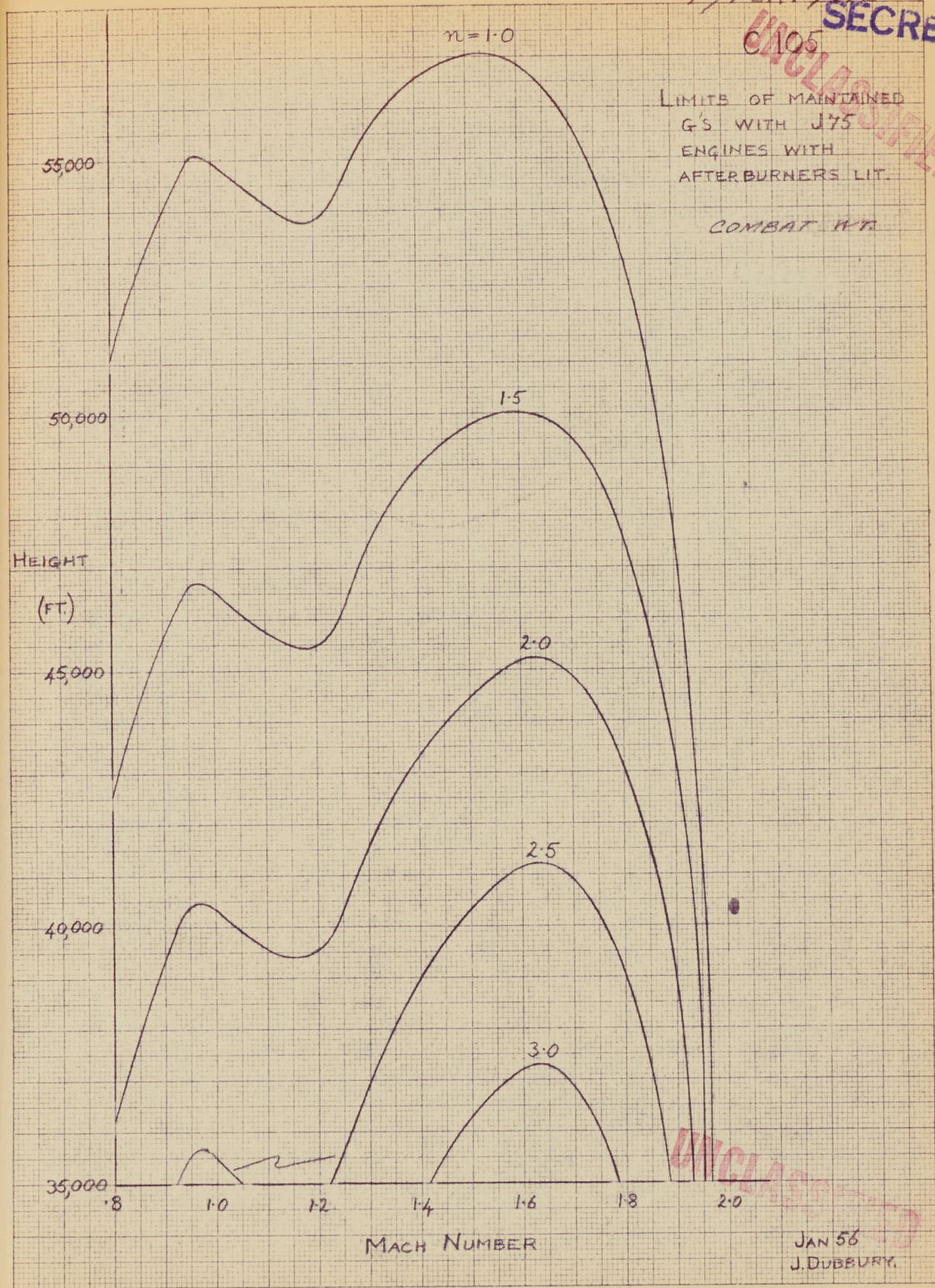
Sea Level Mission with 15,356 Lb. of Fuel	N.M.	325
Sea Level Mission with Full Internal Fuel	N.M.	470

Ferry Range Mission at Economical Cruise Speed (M = .92 and Height,
including 15 Mins. Stacking at 40,000 Ft., 5 Min. Fuel Reserve on
Landing

Range with Full Internal Fuel and 500 Gal. - External Tank .	N.M.	1,859
Range with Full Internal Fuel	N.M.	1,609

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P/PERE/112
6105
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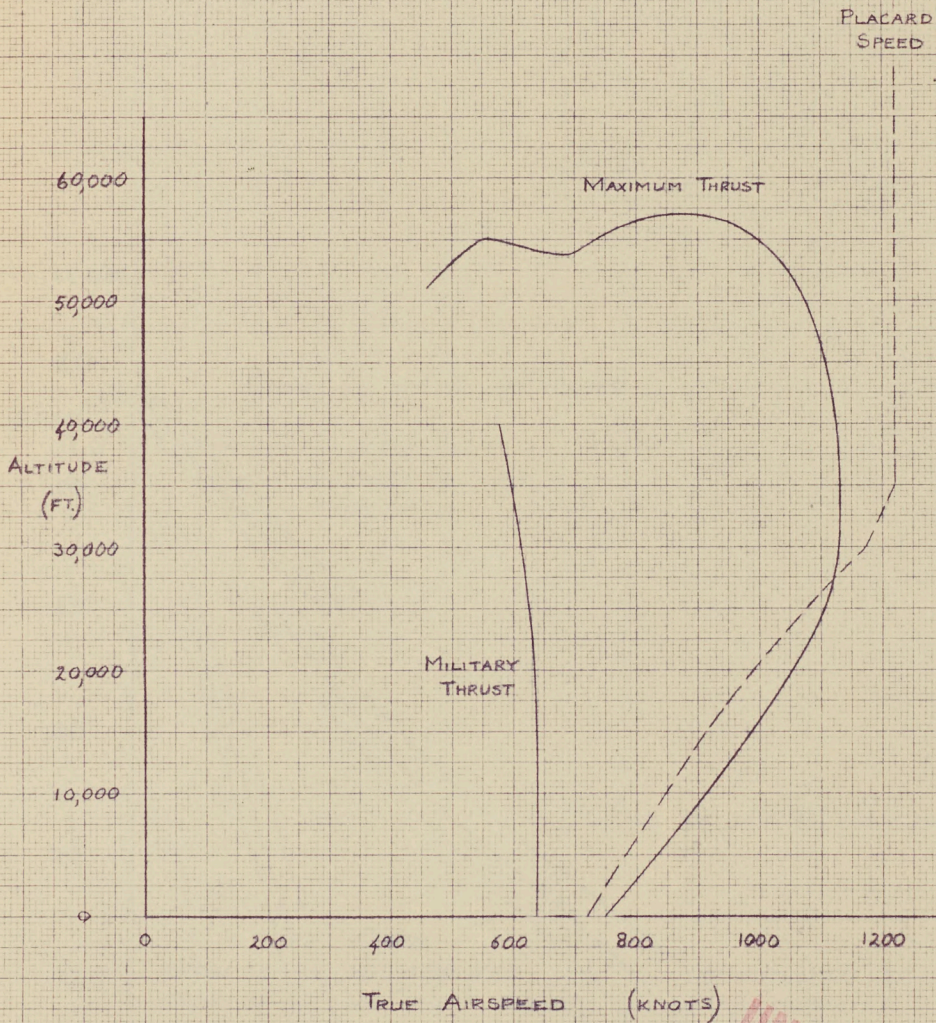
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C105

J75 ENGINES

LEVEL FLIGHT TRUE AIRSPEED
COMBAT WT.



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F/PERF/112

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C 105

RATE OF CLIMB (STEADY STATE)

J75 ENGINES

ALTITUDE

(FT x 10⁻³)

60

50

40

30

20

10

0

CLIMB AT M=1.5 MAX THRUST

45,000 LB.

50,000 LB.

55,000 LB.

CLIMB AT M=.92 MAX THRUST

CLIMB AT 530 KTS
MILITARY THRUST

45,000 LB.

50,000 LB.

55,000 LB.

45,000 LB.

50,000 LB.

55,000 LB.

RATE OF CLIMB (FT/MIN x 10⁻³)

0

10

20

30

40

50

60

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P/PERF/112
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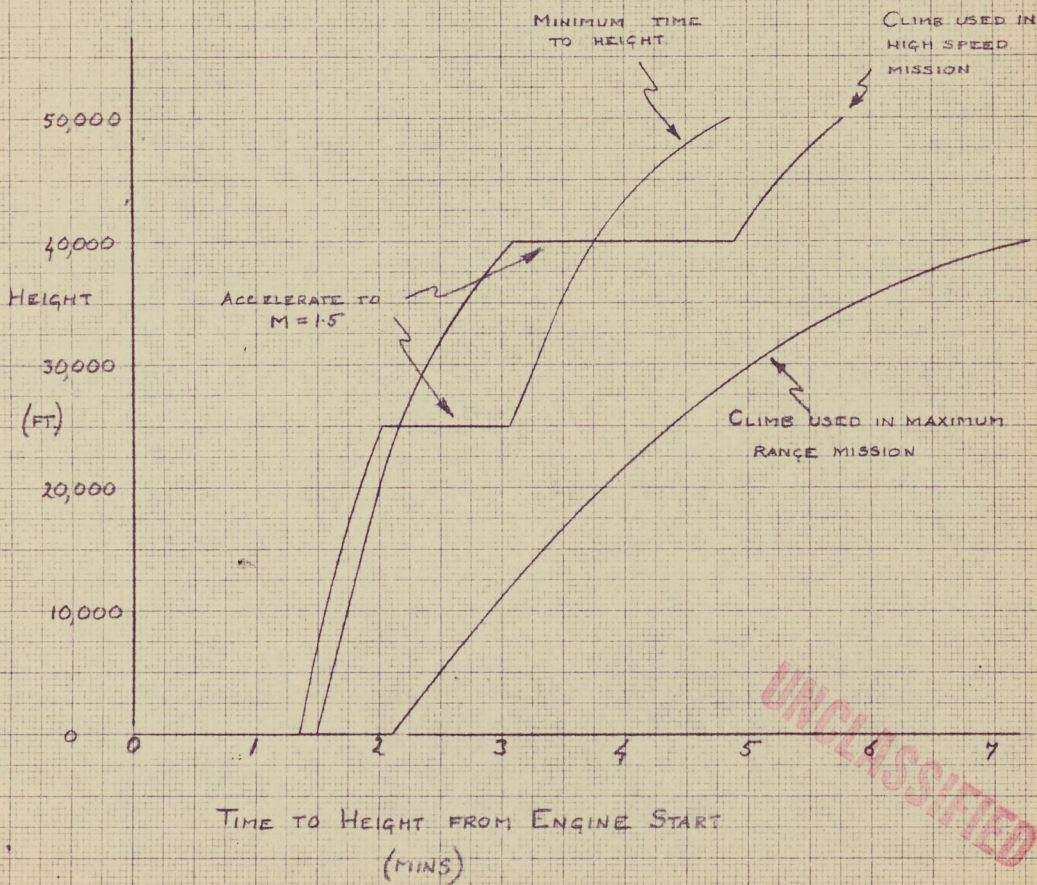
C 105

J75 ENGINES

TIME TO HEIGHT

TAKE-OFF WT. = 57,222 LB

NOTE: ONE HALF MINUTE ALLOWED FROM
ENGINE START TO MILITARY
RATING.



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JT4A-25

COMPONENT

SHEET No. _____

REPORT No. P/PERF/105

DATE _____

PREP BY _____

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TAKEOFF DISTANCE AT SEA LEVEL

- standard day with a/b
- - - standard day without a/b
- hot day (100 °F) with a/b

distance to clear 50 ft obstacle

ground run

TAKEOFF DISTANCE — FT

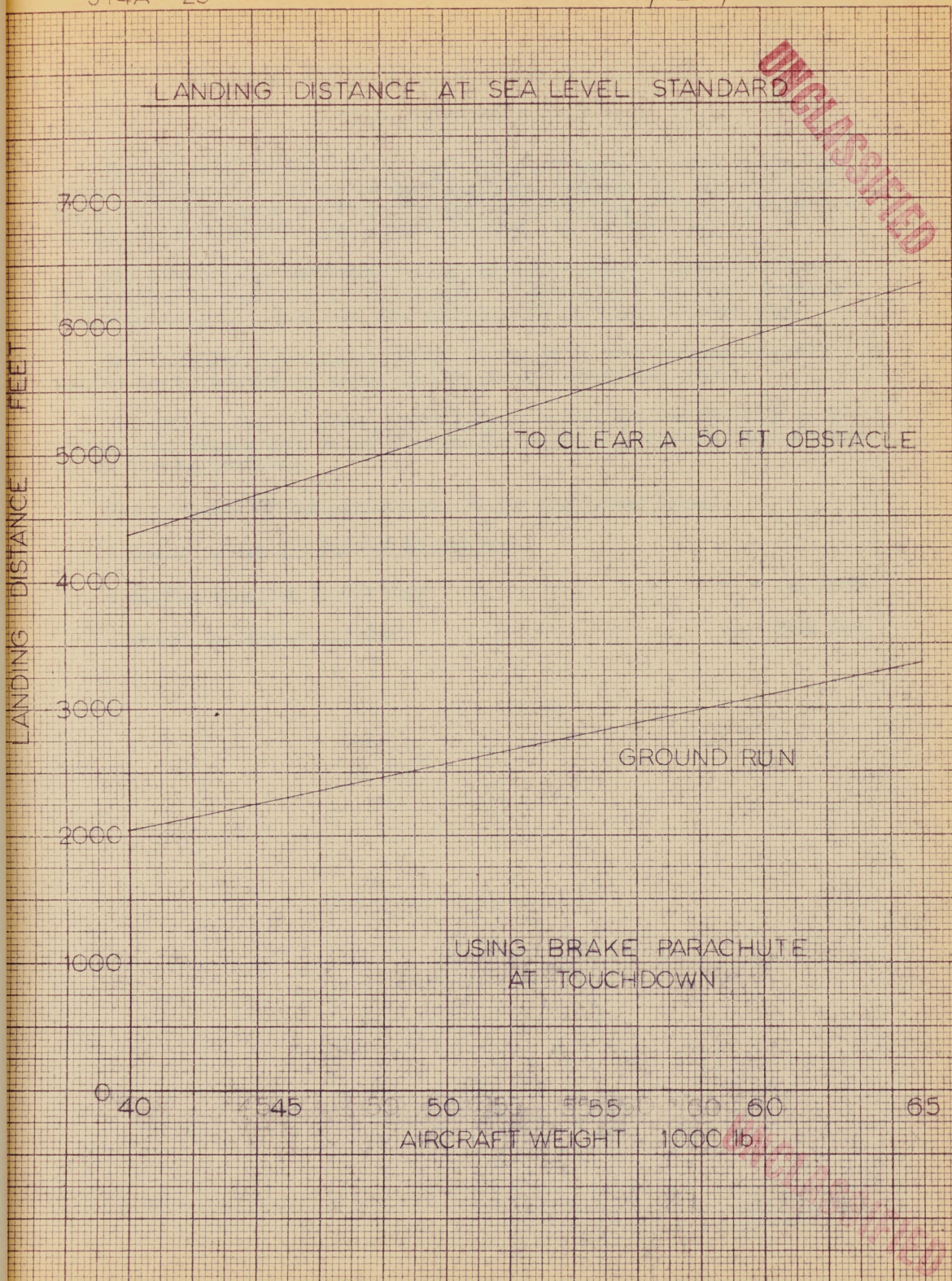
AIRCRAFT WEIGHT LB

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January 1956.

1B: CF-105 PERFORMANCE WITH ORENDA PS 13 ENGINES

(C.G. = 29% M.A.C.)

The following CF-105 - PS 13 performance estimate is based on the Wind Tunnel configuration designated B₂V₁W₁E₁₀N₅D₈-4 (except that the nose cone angle has been reduced to 30°). The particular feature of this configuration is the extended, notched and cambered leading edge of the wing.

The drag of this configuration is summarized (Extract P/Perf/112) and is presented in section 2 of this report. A more direct approach of estimating supersonic trim drag has been employed, resulting in reduced drag.

The installed stratosphere thrust of the PS 13 with maximum afterburning has been re-estimated using the latest non-dimensional curves.

Corrections for the above alterations have been applied directly to the maximum performance data in the stratosphere only. No revision has been made to the mission profiles.

The pertinent CF-105 performance changes are listed below:

Δ Combat 'g' at 1.5 M.N. at 50,000 feet	= + .15
Δ Maximum Speed at 50,000 feet	= + 30 knots
Δ Combat Ceiling at 1.5 M.N.	= + 1800 feet

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LOADING AND PERFORMANCE - 4

P/PERF/112

January 1956.

Performance Under N.A.C.A. Standard Atmospheric Conditions

To R.C.A.F. Specification AIR 7-4

With Two PS 13 Engines

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WEIGHT:

Take-Off Weight with 15,510 Lb. Fuel (78.2% Max)	Lb.	55,889
Operational Weight Empty	Lb.	40,379
Combat Weight (1/2 Fuel)	Lb.	48,130
Landing Weight (With Reserve Fuel + Missile)	Lb.	42,200
Wing Loading at Normal Take-off Weight	Lb./Sq.Ft.	44.5
Power Loading at Normal Take-off Weight	Lb./Lb. Thrust.	1.19

SPEED

True Air Speed in Level Flight		
At Sea Level at Combat Weight	Kts.	* 720
Maximum Thrust	Kts.	650
Military Thrust		
True Air Speed in Level Flight		
At 50,000 Ft. at Combat Weight	Kts.	1,140
Maximum Thrust		

CEILING

Combat Ceiling at Combat Weight, Rate of Climb = 500 F.P.M.	Ft.	64,000
Maximum Thrust at 1.5 M.N.		

RATE OF CLIMB

Steady Rate of Climb at Sea Level, Combat Weight	F.P.M.	50,000
Maximum Thrust at M.N. = .92	F.P.M.	25,200
Military Thrust at 530 Kts.		
Steady Rate of Climb at 50,000 Ft., Combat Weight	F.P.M.	15,000
Maximum Thrust at M.N. = 1.5		

TIME TO HEIGHT

Time to 50,000 Ft. M.N. = 1.5 from Engine Start at Take-Off		
Weight = 55,889 Lb.		
Maximum Thrust	Mins.	4.0

MANOEUVRABILITY

Combat Load Factor at Combat Weight		1.99
Maximum Thrust at M.N. = 1.50 at 50,000 Ft.		

* Placard Speed = 720 Kts.

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TAKE-OFF DISTANCE

Take-Off Distance over 50 Ft. Obstacle at Sea Level
 Take-Off Weight = 55,889 Lb.
 Maximum Thrust Ft. 2,500
 Military Thrust Ft. 3,800
 Maximum Thrust Hot Day Ft. 3,300

LANDING DISTANCE

Landing Distance over 50 Ft. Obstacle at Sea Level at Combat Weight Ft. 5,000

STALLING SPEED

True Stalling Speed in Landing Configuration at Combat Weight at Sea Level Kts. 105

RANGE

Combat Radius of Action at 50,000 Ft., Climb at M.N. = .92, Cruise out at M.N. = 1.5, Combat for 5 mins. at M.N. = 1.50, Cruise Back at M.N. = .92, 15 Min. Stack at 40,000 Ft., 5 Min. Fuel Reserve on Landing
 High Speed Mission with 15,510 Lb. Fuel N.M. 200
 High Speed Mission with Full Internal Fuel N.M. 318

Combat Radius of Action at 50,000 Ft. Mission as above except Cruise Out at M.N. = .92

Maximum Range Mission with 15,510 Lb. Fuel N.M. 315
 Maximum Range Mission with Full Internal Fuel N.M. 491

Combat Radius of Action at Sea Level, Cruise Out at .6 M.N. and Combat at M.N. = .92 at Sea Level, Cruise Back at .92 M.N. at 40,000 Ft., 15 Min. Stack, 5 Min. Fuel Reserve on Landing

Sea Level Mission with 15,510 Lb. of Fuel N.M. 217
 Sea Level Mission with Full Internal Fuel N.M. 318

Ferry Range Mission at Economical Cruise Speed (M = .92 and Height, including 15 Mins. Stacking at 40,000 Ft., 5 Min. Fuel Reserve on Landing

Range with Full Internal Fuel and 500 Gal. - External Tank. N.M. 1,675

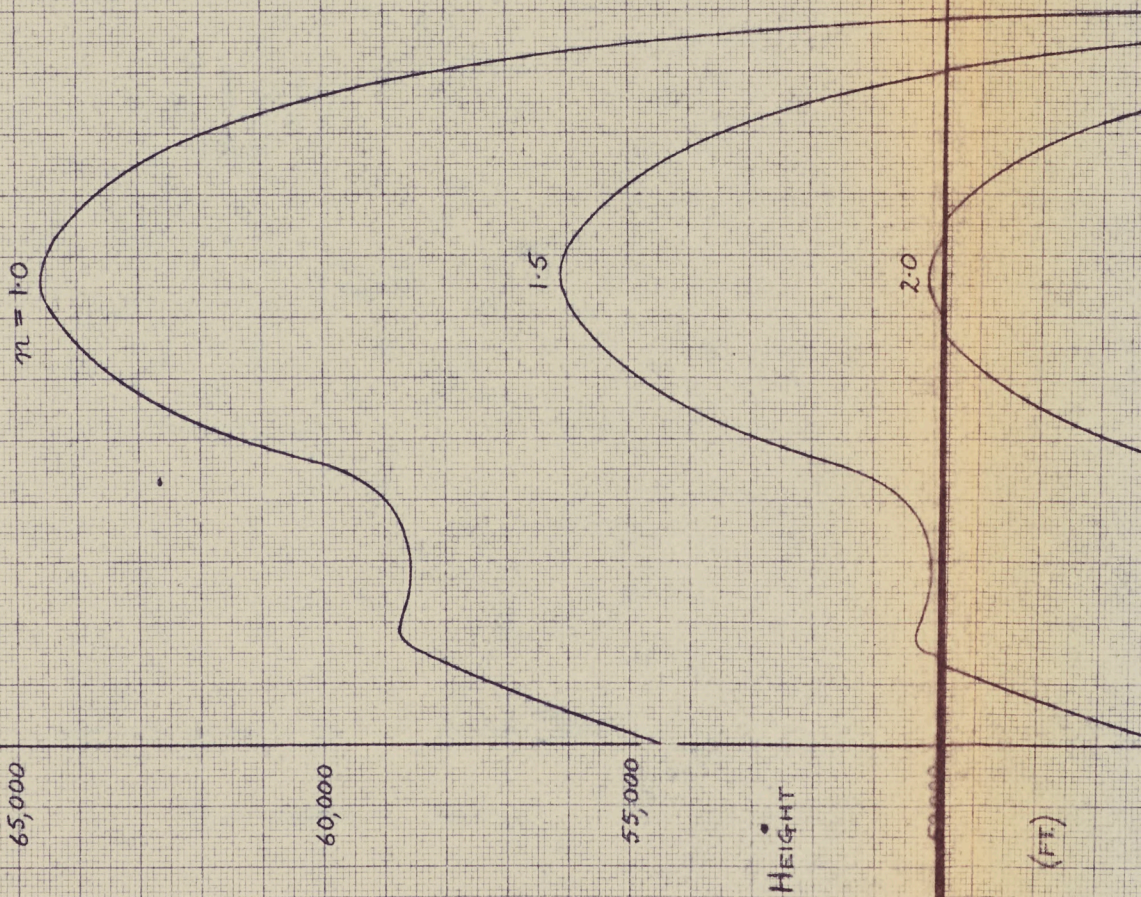
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C 105

PS 13 ENGINES WITH AFTER BURNERS
LIT

AVAILABLE STEADY G'S

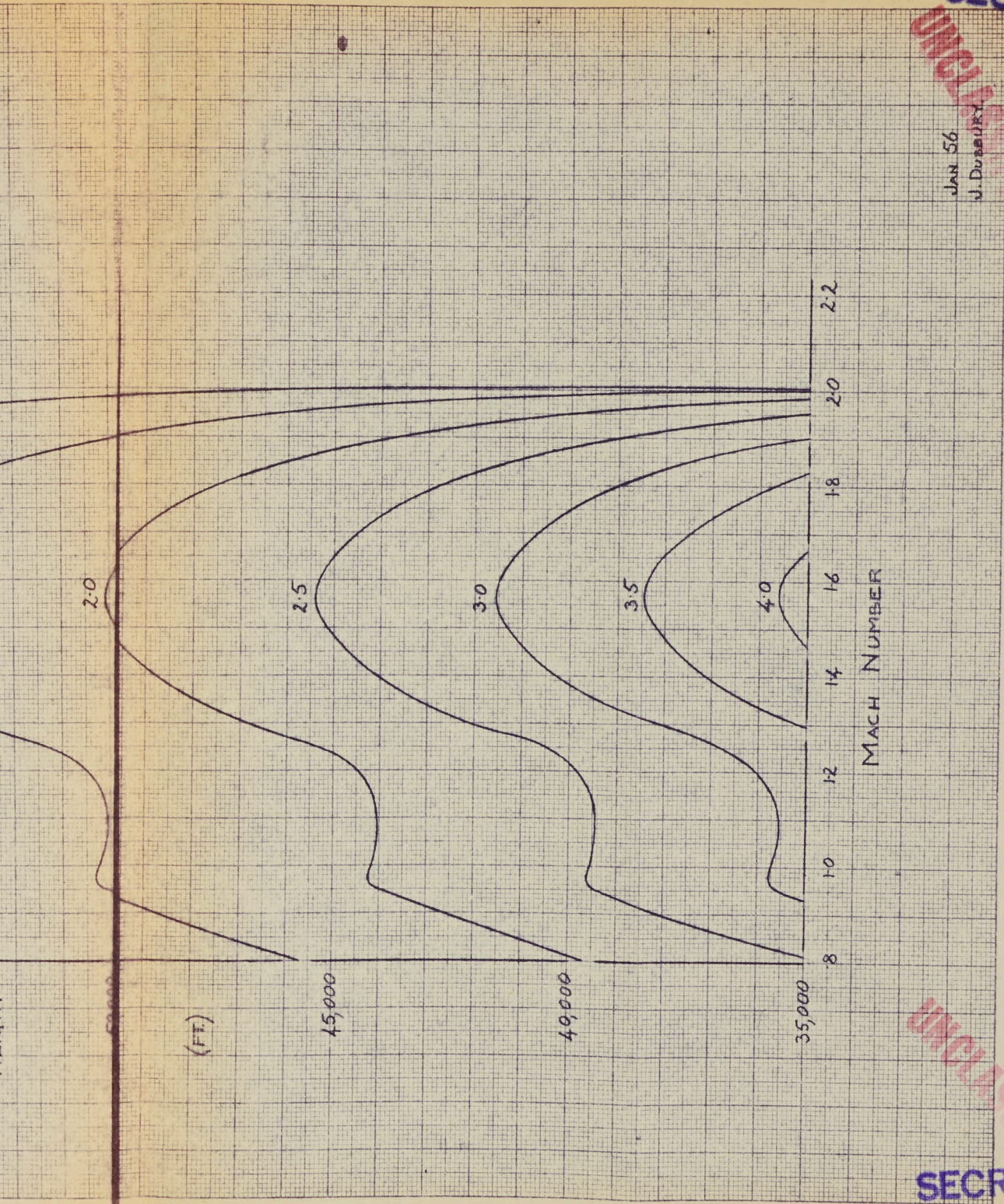
COMBAT W.P.



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J. DURRANT



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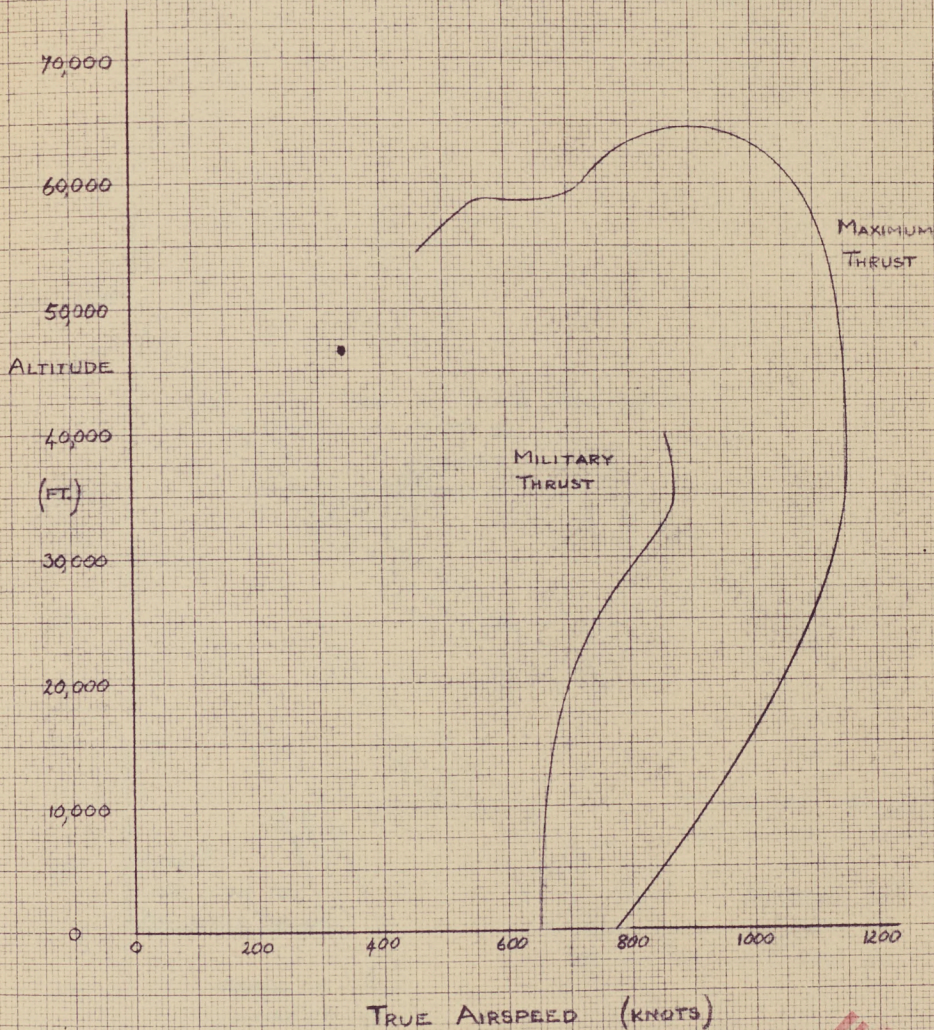
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PS13 ENGINES

LEVEL FLIGHT TRUE AIRSPEED
COMBAT WT.



DRAG

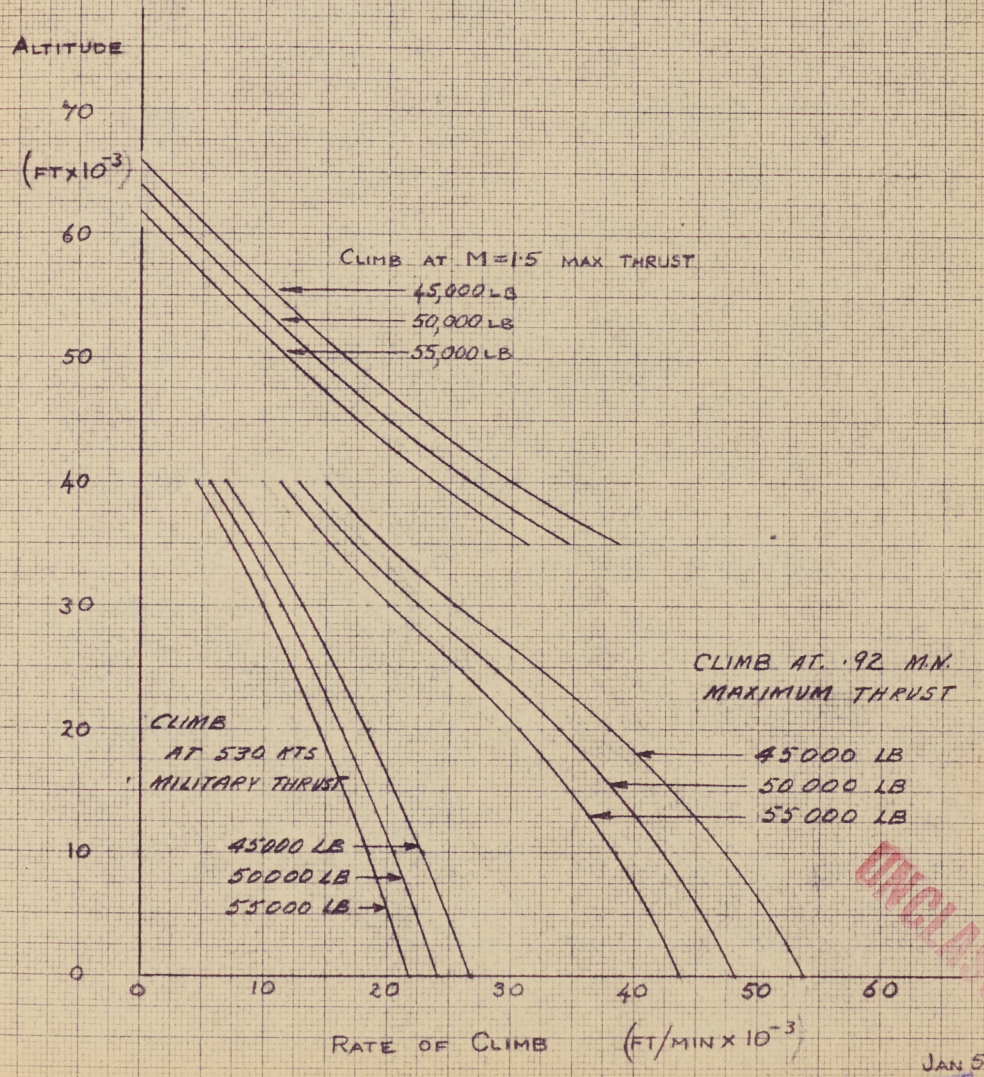
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J. DUBBURY
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C 105

PS 13 ENGINES

RATE OF CLIMB (STEADY STATE)



DRAG

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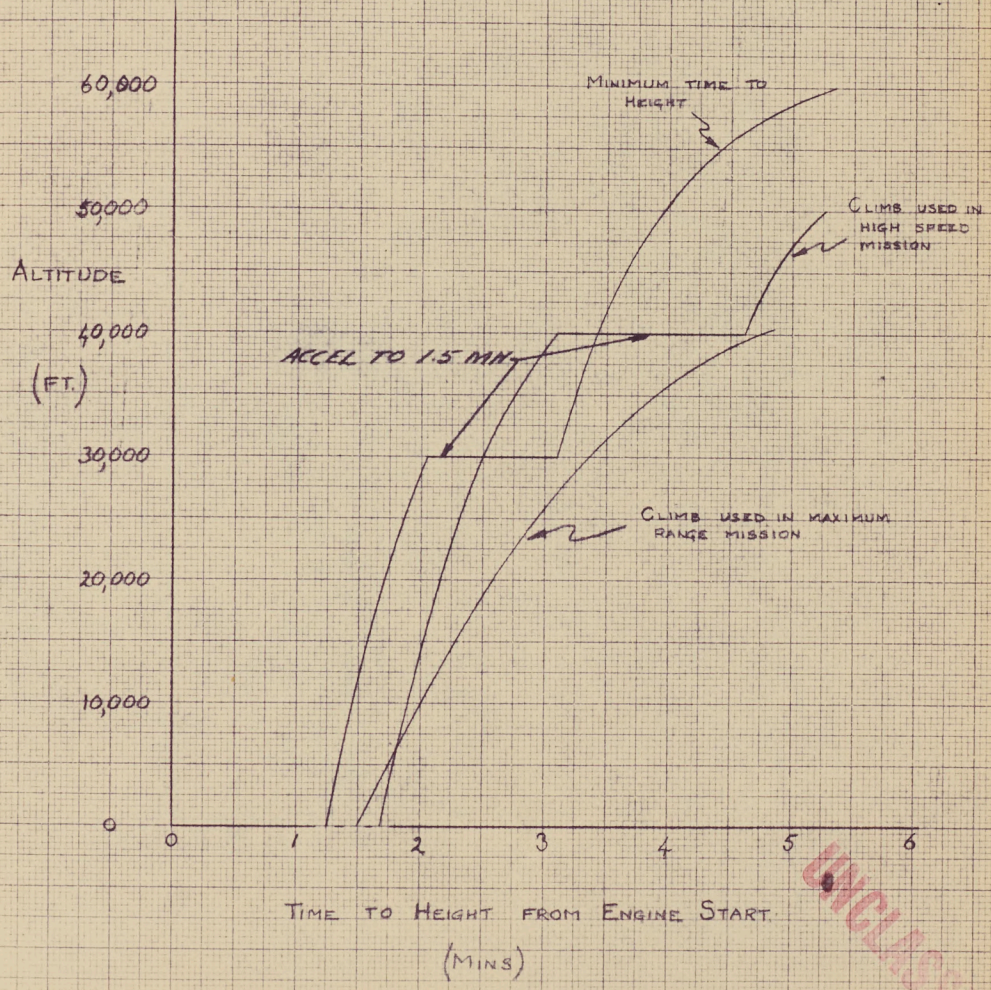
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PS 13 ENGINES

TIME TO HEIGHT

TAKE OFF WEIGHT 30,000

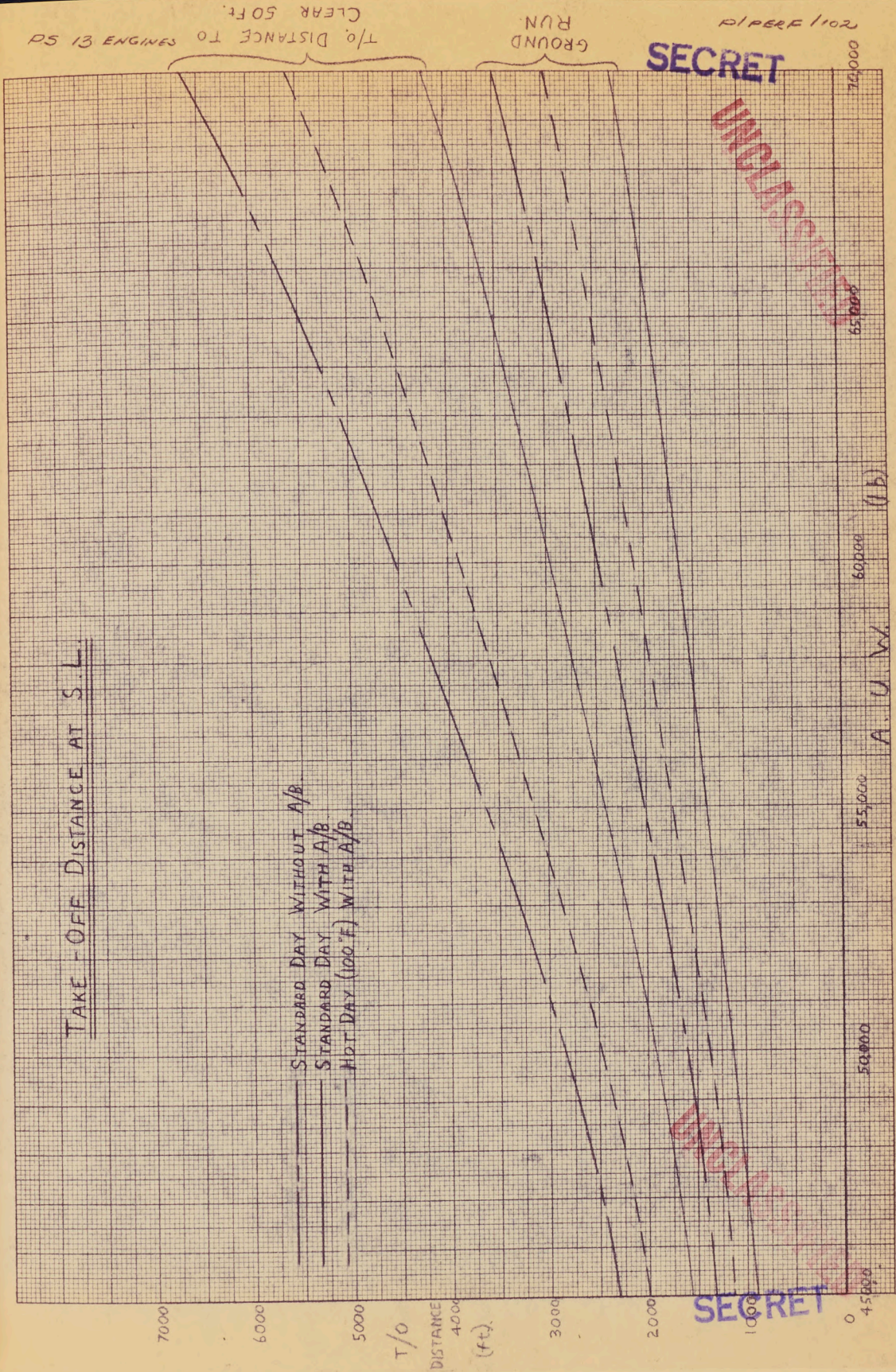


DRAG

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TAKE-OFF DISTANCE AT S.L.



T/O DISTANCE TO ENGINES 31 50
CLEAR 50 FT.

GROUND RUN

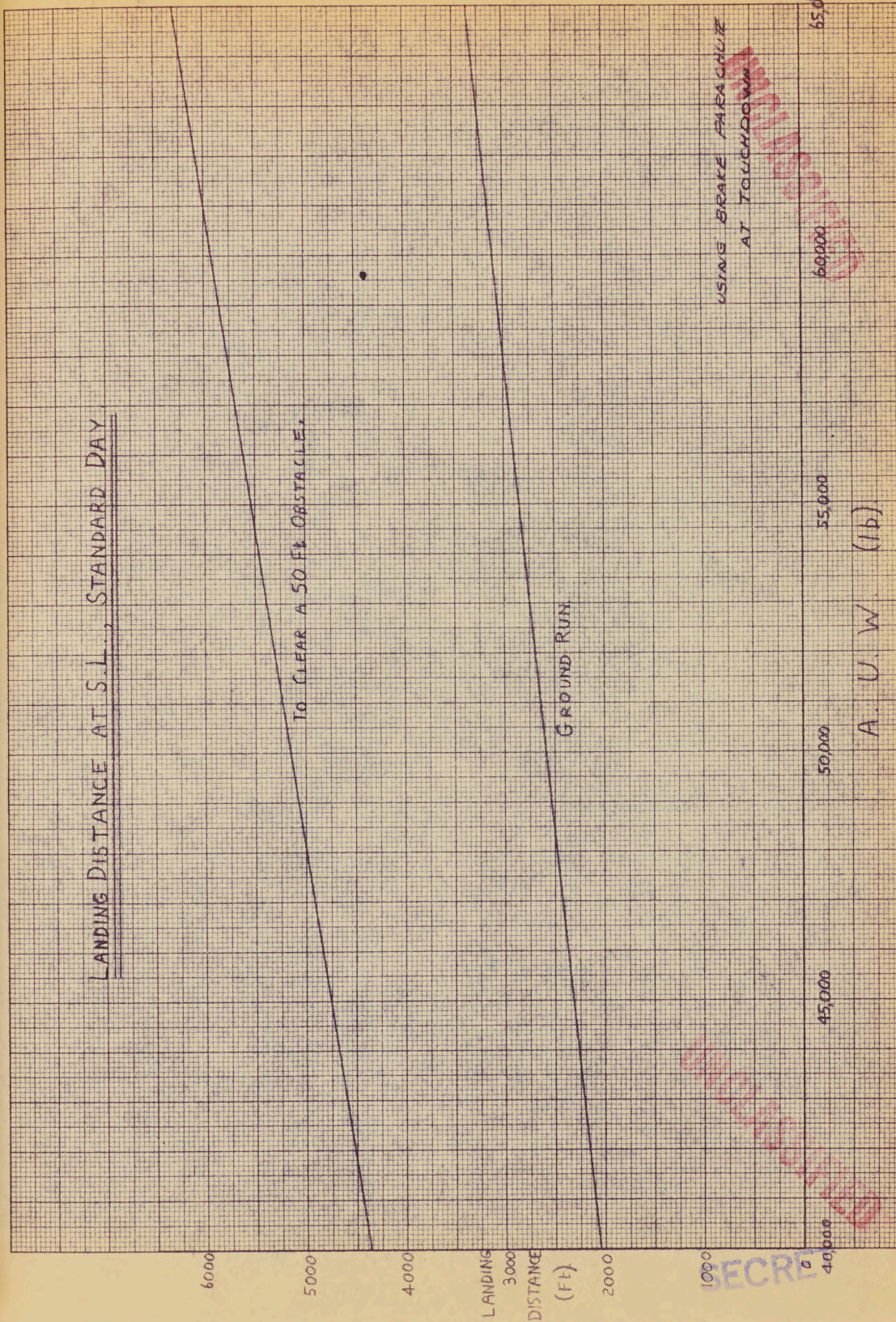
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DRAG



DRAG

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Extract P/Perf/112

January 1956.

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CF-105 DRAG NOTE

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This extract contains the latest CF-105 drag data used for performance estimations. The particular feature of this configuration is the extended, notched, and cambered leading edge of the wing, and can be identified by the wind tunnel designation B₂V₁W₁E₁₀N₅D₈₋₄ except that the nose cone angle has been reduced to 30°.

The supersonic C_{DMin} has been anchored by the selection of C_{DMin} = .02 at 1.5 M.N. This is based on the first CF-105 free flight model test and 'area rule' estimate. Similarly, the subsonic value is based on the free flight model test and estimates.

The drag due to lift, including elevator drag to trim, has been obtained (up to 1.23 M.N.) from C.A.L. Wind Tunnel Project No. W.A.844-DD3 results. The model was .04 scale, the Mach number range was from .5 M.N. to 1.23 M.N. with the corresponding Reynolds' number range going from 1.6 to 2.5 x 10⁶. No allowance has been made for scale effect.

At Mach numbers greater than 1.23, the drag coefficients have been extrapolated where possible by data from N.A.C.A. reports. Of particular interest is the method of estimating trim drags at supersonic speeds. A preliminary note (extract P/Perf/114) on this subject is included in this report following the drag curves.

The subsonic drags are unaltered from that given in Monthly Report No. 1. However, the supersonic drag is now determined from -

$$D/P = 126800M^2 \left\{ \left\{ C_{DMin} + \frac{(C_{LA} - C_{LC_{DMin}})^2}{\pi Re} \right\}_{\delta=0} + \left\{ \left(\frac{K_2}{a_2} - \frac{2K_2}{a_1} + \frac{1}{\pi Re} \right) (a_2 \delta)^2 + \left(\frac{K_2}{a_1} - \frac{1}{\pi Re} \right)^2 (C_{LA} - C_{LC_{DMin}}) a_2 \delta \right\} \right\}$$

Trim Drag

$$\text{and } -K\delta = \frac{C_{LA} (h - a.c.) + C_{M_0}}{C_{M_0} C_{CL}}$$

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CF-105 DRAG NOTE (Cont'd.)

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Where -

- D - Total Drag - Lb.
- P - Ambient Pressure - Lb./Sq.In.
- M - Mach Number
- C_{DMin} - Minimum Drag Coefficient
- C_{LA} - Aircraft Lift Coefficient
- $C_{LC_{DMin}}$ - Lift coefficient at C_{DMin}
- e - Aerodynamic Drag Efficiency Factor ($\delta = 0$)
- AR - Aspect Ratio (1.995)
- a_2 - $\partial C_{LA} / \partial \delta$
- a_1 - $\partial C_{LA} / \partial \alpha$
- δ - Control Angle
- α - Angle of attack
- h - Centre of Gravity % M.A.C.
- a.c. - Aerodynamic centre % M.A.C.
- C_{M_0} - Pitching moment coefficient at $C_L = 0, \delta = 0$
- C_{M_δ} - Elevator Pitching Effectiveness at constant C_L
- K - Non-linearity factor for C_{M_δ}
- K_2 - Lift increment on control/lift increment on wing
(see Extract P/Perf/114)

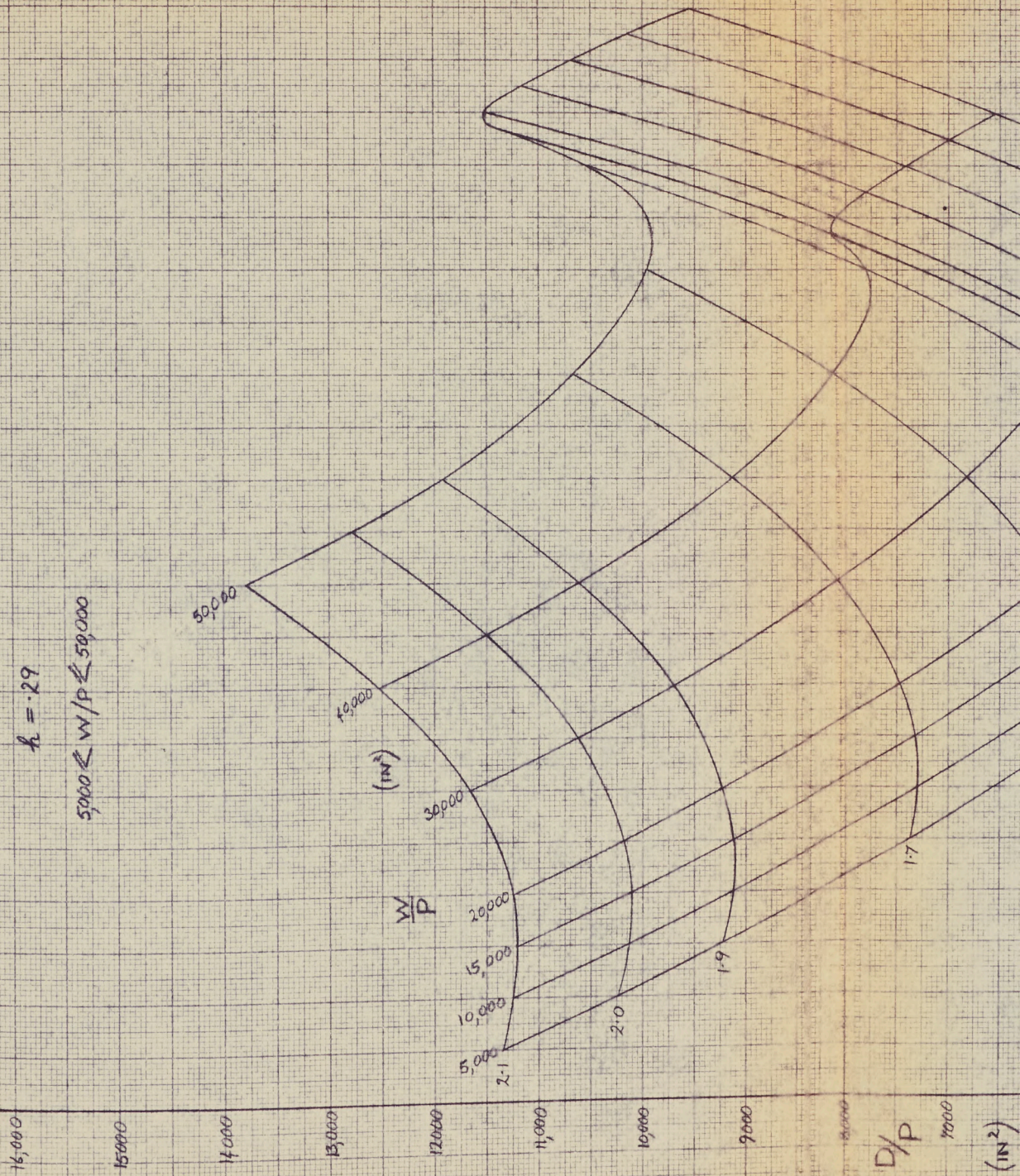
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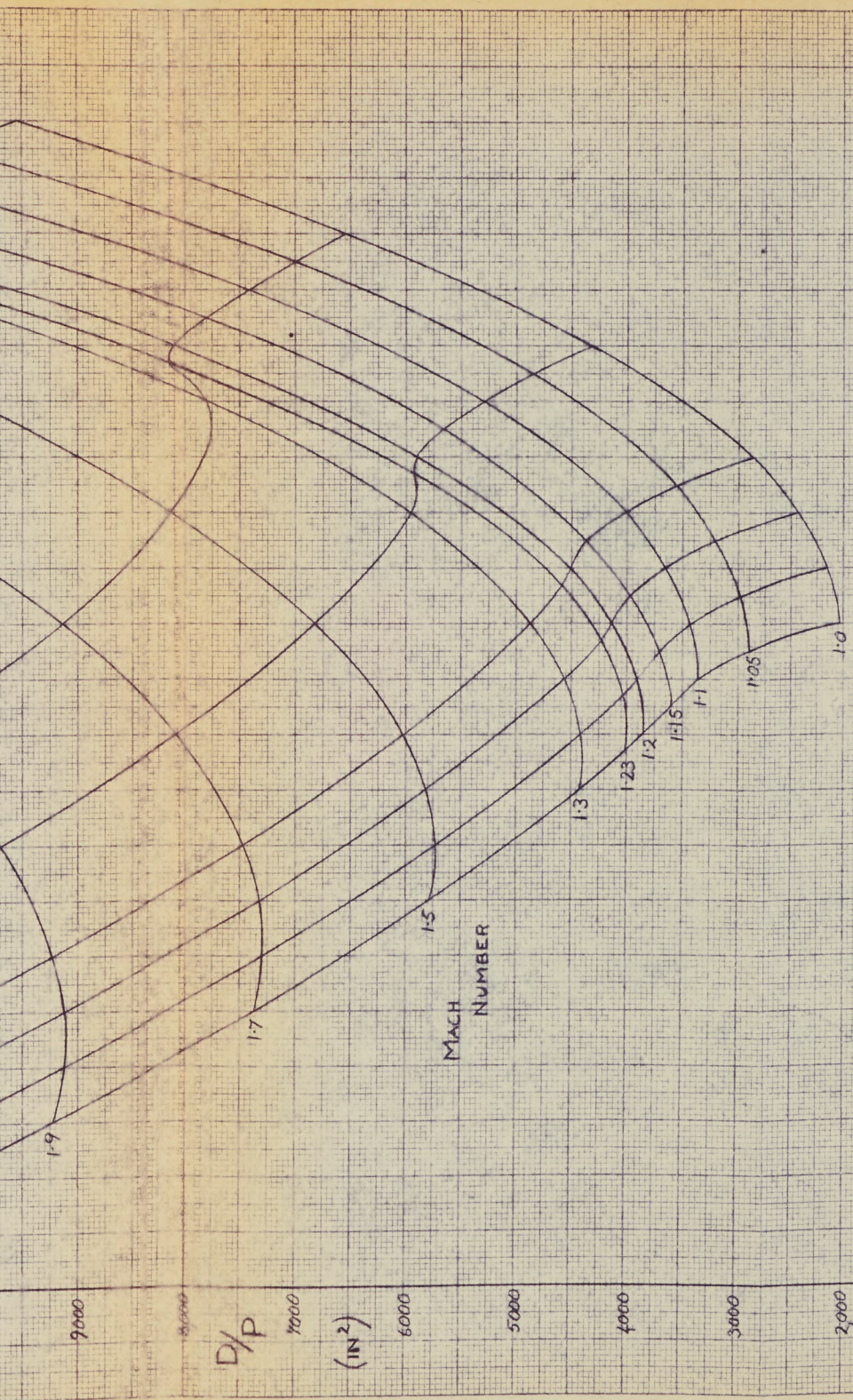
C105 SUPERSONIC DRAG

$$k = .29$$

$$5000 \leq W/P \leq 50,000$$



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$$\frac{P}{\rho} = 101 M^2 S \left[\left\{ C_{D_{MIN}} + \frac{C_L - C_{L_{CD_{MIN}}}}{\pi A R E} \right\}^2 + \left\{ \frac{K_2 - 2K_1}{R_1} + \frac{1}{\pi A R E} \right\} (a_2 \delta)^2 + \left(\frac{K_2 - 1}{R_1} \right) \frac{1}{\pi A R E} \right] 2 (C_L - C_{L_{CD_{MIN}}}) a_2 \delta \quad \text{TRIM DRAG} \quad M \geq 1.23$$

FOR $1.0 \leq M \leq 1.23$ TUNNEL TESTS USED
(CORRECTED FOR C_{DB})

$$\text{FOR } \delta_{TRIM} \quad \frac{C_L (L - ac) + C_{MB}}{C_{M_{SC}}} = -K_8$$

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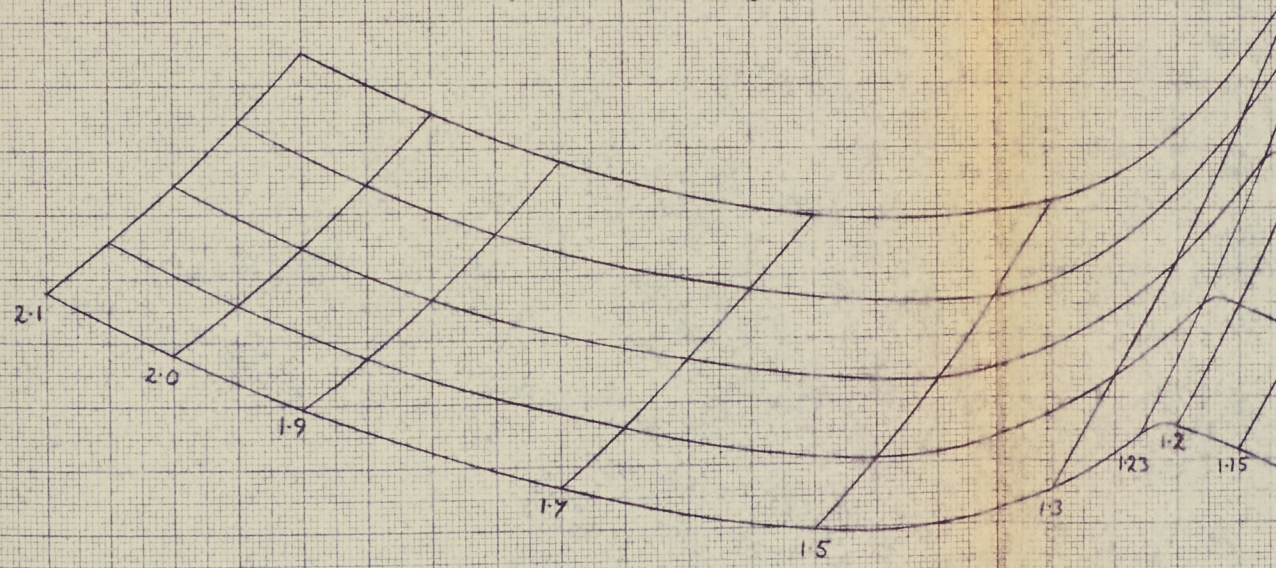
F/P (lb/ft²)

C 105 SUPERSONIC DRAG

$h = .29$

$50,000 \leq W/P \leq 70,000$

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



$$\frac{D}{P} = 101 M^2 S \left\{ C_{D_{MIN}} + \frac{(C_L - C_{L_{CD_{MIN}}})^2}{\pi A R e} \right\}_{\delta=0} + \left\{ \left(\frac{K_2}{a_2} - \frac{2K_2}{a_1} + \frac{1}{\pi A R e} \right) (a_2 \delta)^2 + \left(\frac{K_1}{a_1} + \frac{1}{\pi A R e} \right) 2(C_L - C_{L_{CD_{MIN}}}) a_2 \delta \right\}$$

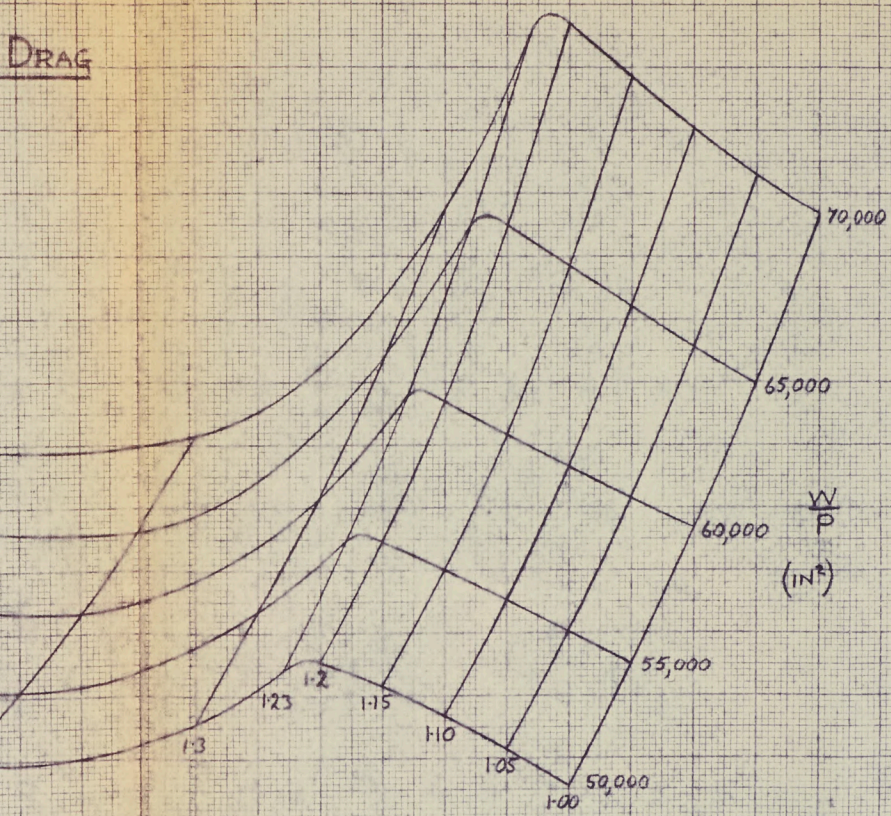
FOR δ_{TRIM}
$$\frac{C_L (h - ac) + C_{M0}}{C_{M0CL}} = -K\delta$$

FOR $1.0 \leq M \leq 1.23$ TUNNEL TESTS USED (CORRECTED FOR C_{D0})

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DRAG



$$\left[(a_2 \delta)^2 + \left(\frac{K_2}{a_1} + \frac{1}{M^2 Re} \right) 2(C_L - C_{L_{CDMIN}}) a_2 \delta \right]_{\text{TRIM DRAG}} \quad \text{FOR } M \geq 1.23$$

ECTED FOR (C_{D_0})

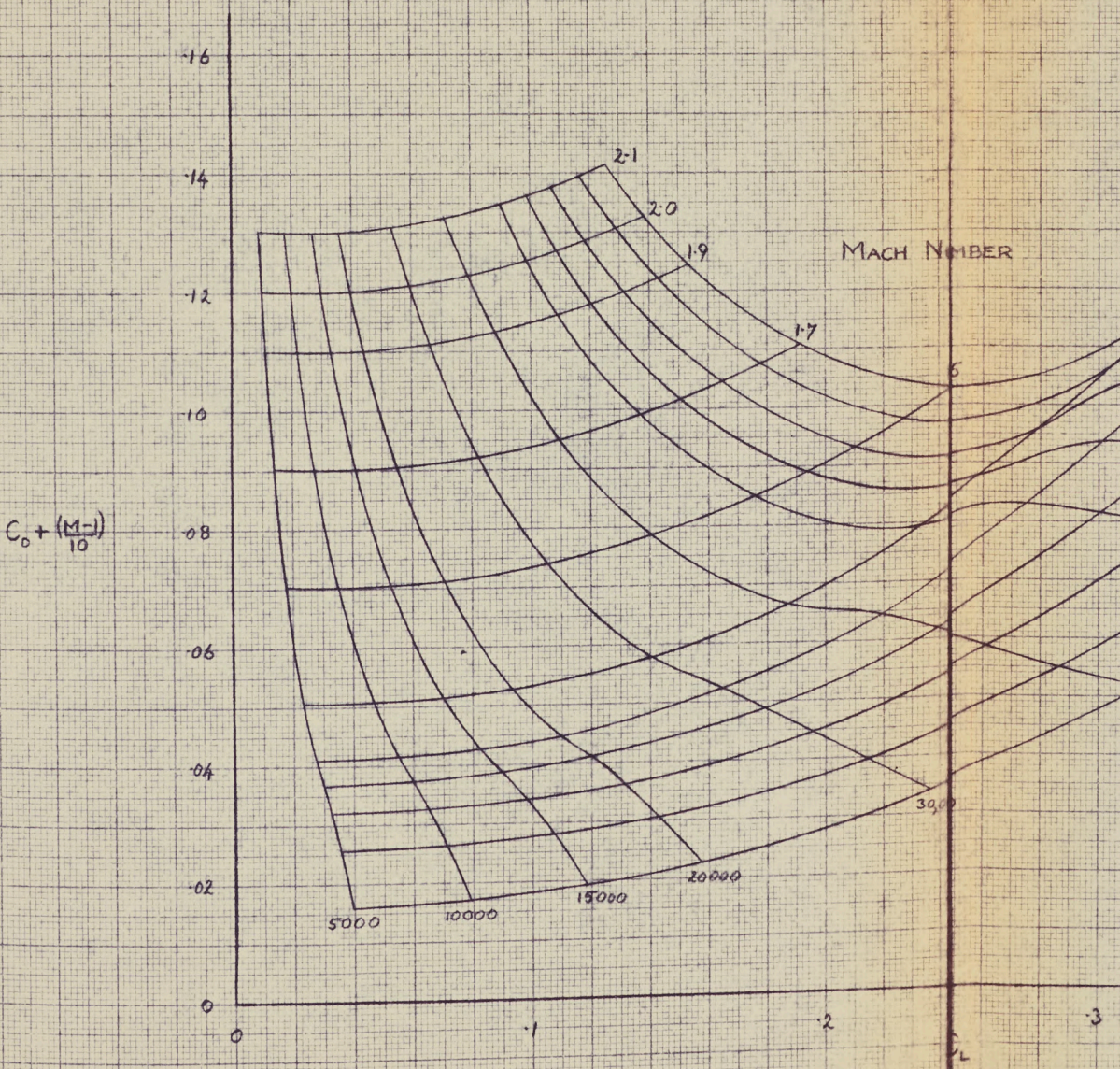
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SUPERSONIC $C_D \sim C_L$ RELATIONSHIPS

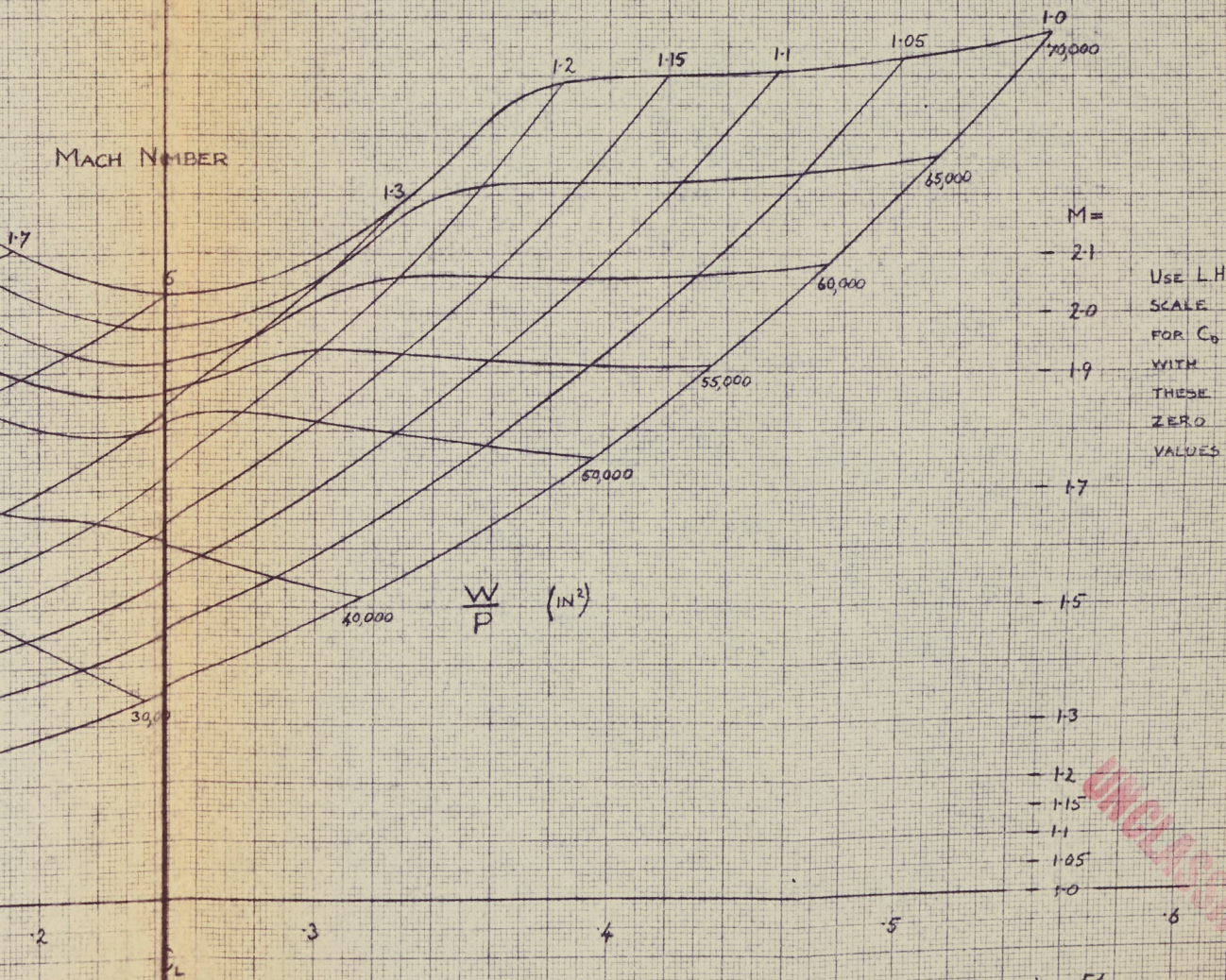


C 105

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C_L RELATIONSHIPS FOR $h = .29$



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P/PART/112
(REF. P/AERO DATA/S18)

Cross ~ Company VS MACH NO.

(CONFIG B₂, W₁, E₁, N₅, D₂-4)
EXCEPT FOR 30° NOSE CASE

0
0.005
0.01
0.015
0.02
0.025

C_{DM}

0
2
4
6
8
10
12
14
16
18
20

MACH NO.

UNCLASSIFIED

UNCLASSIFIED

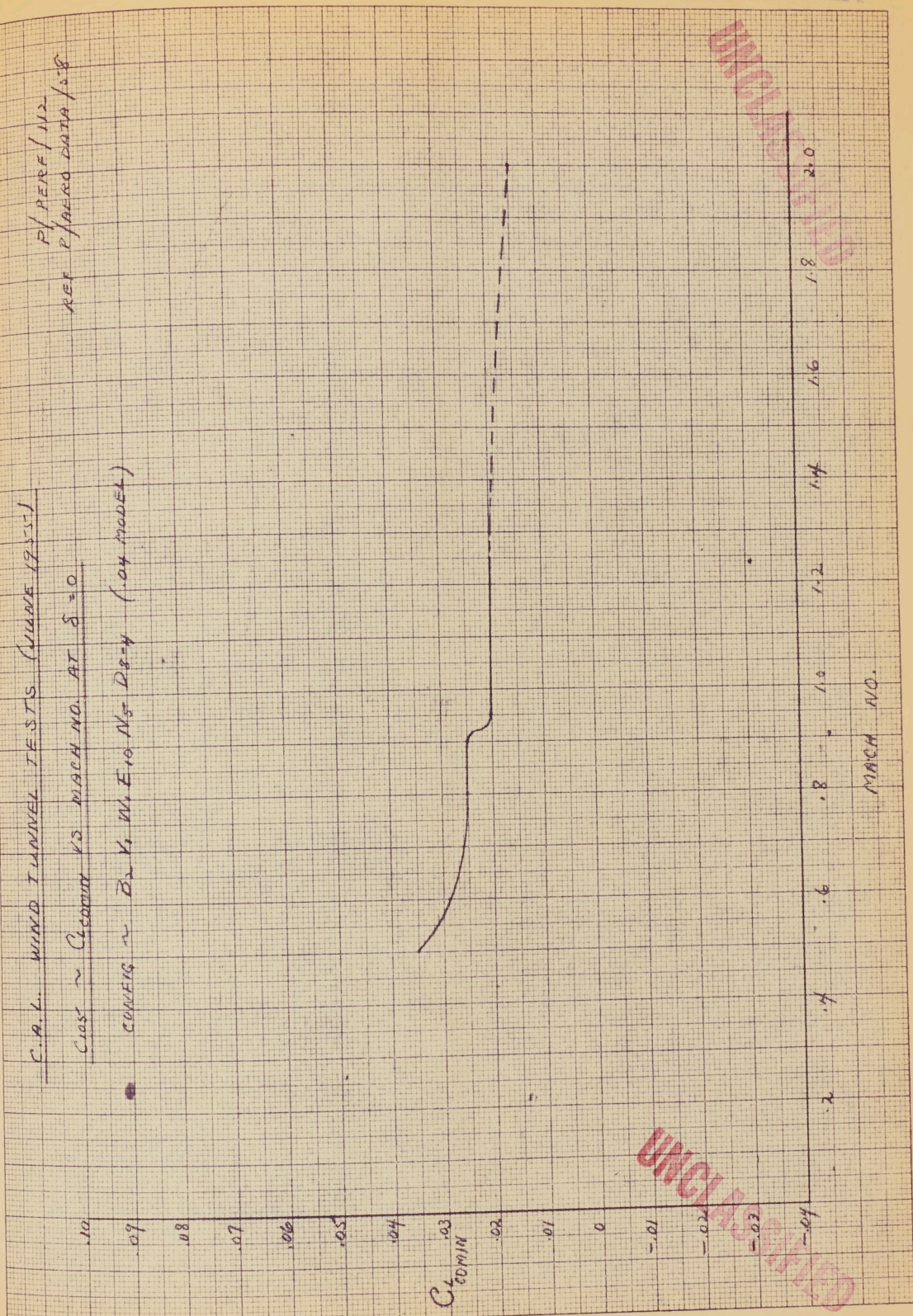
SECRET

ENGINE

SECRET

P/PERF/112
REF P/ALRO DATA/1.8

C.A.L. WIND TUNNEL TESTS (VOLUME 17-551)
COST ~ CROON VS MACH NO. AT $\delta = 0$
CONFIG ~ B₂ V₂ W₁ E₁₀ N₅ D₈₋₄ (104 MODEL)



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ENGINE

SECRET

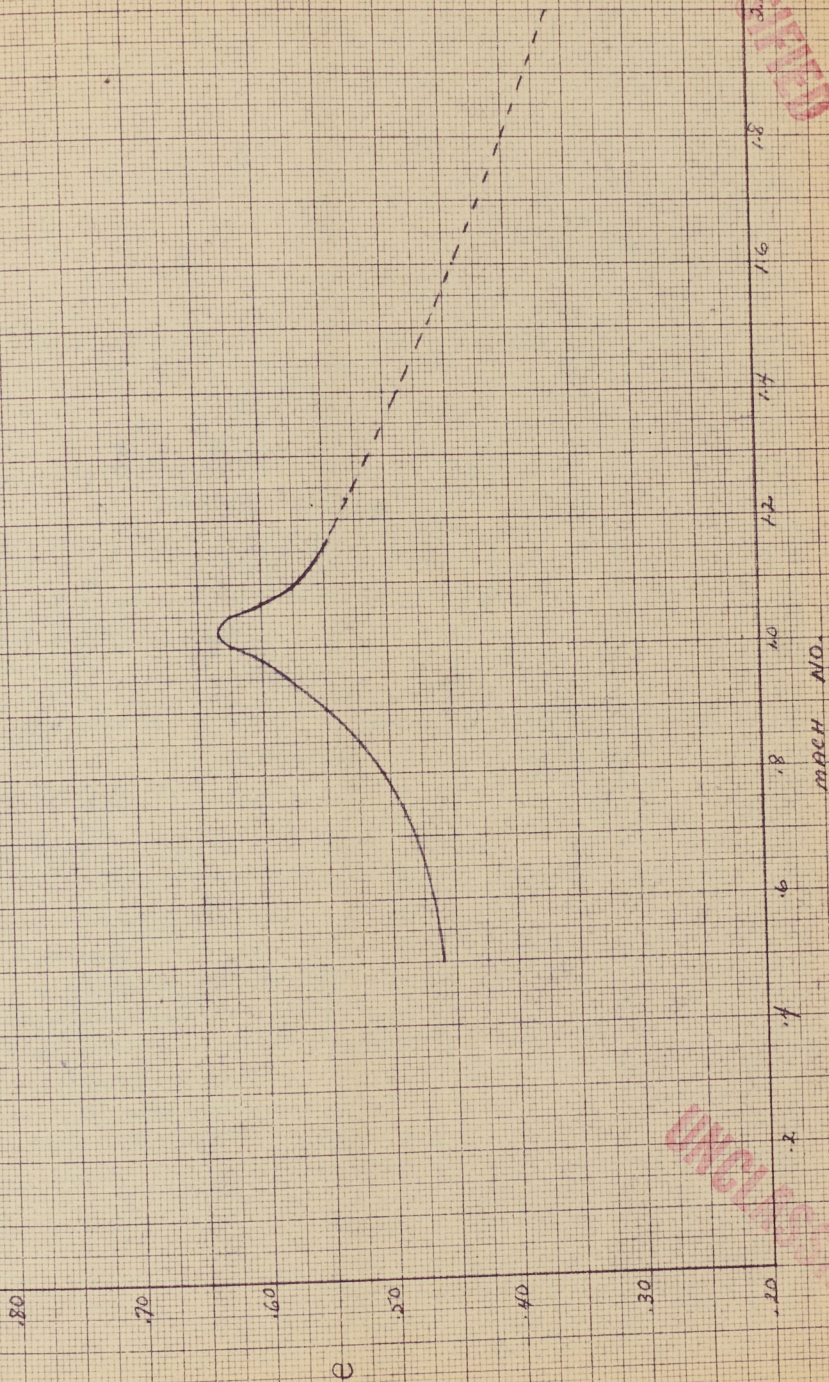
C.A.L. WIND TUNNEL TESTS (JUNE 1955)

C 105 X @ VS MACH NO AT $\delta = 0$

(CONES - $\sim B_2$, V_1 , W_1 , E_{10} , H_2 , D_2 , H_4) (1/4 MODEL)

P/REF / U²

REF. P/REF DATA / 58



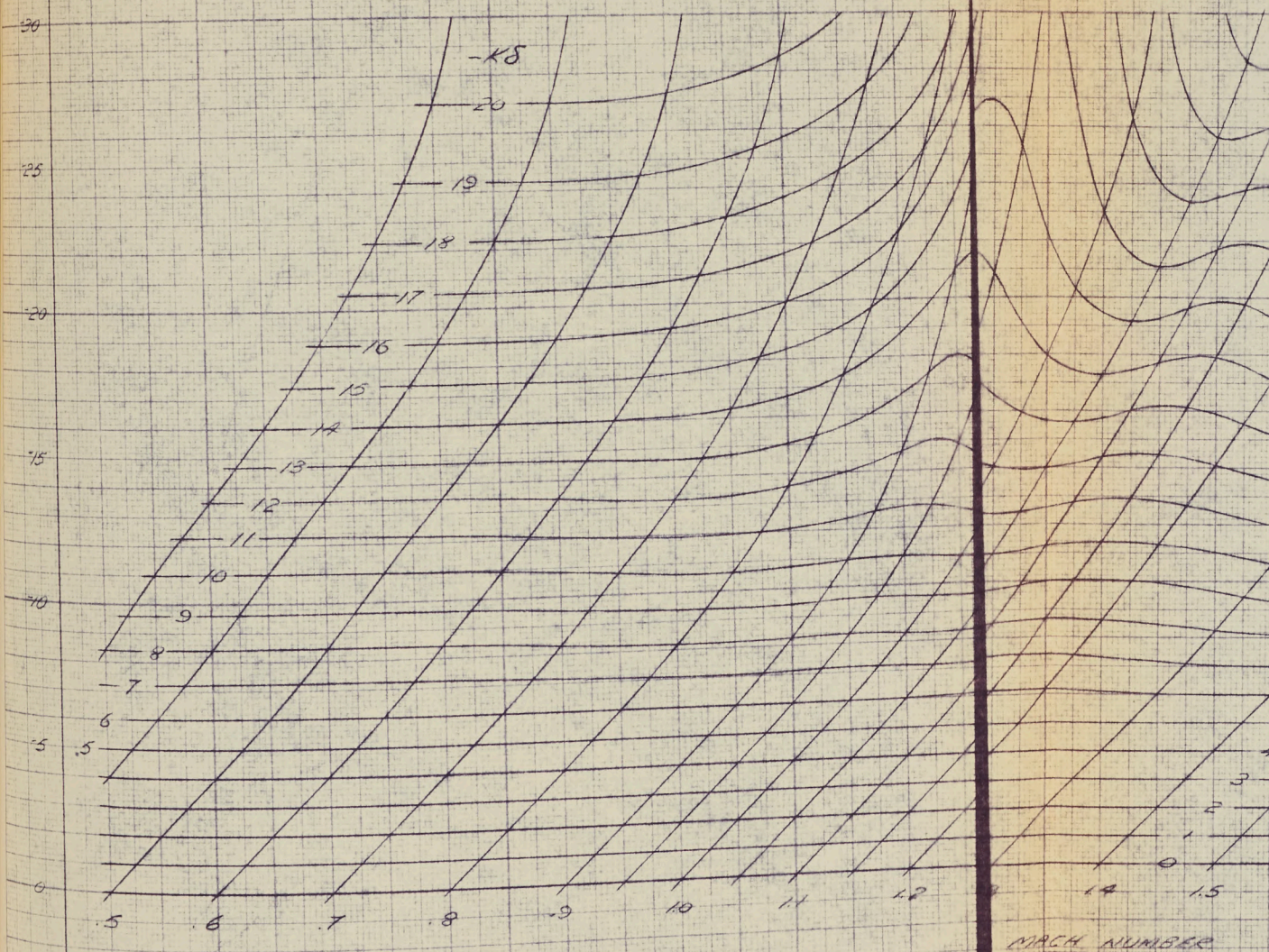
UNCLASSIFIED

SECRET

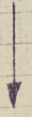
ENGINE

C.195
FOR 15 & MACH NO.

δ
-DEGS



LINEAR - $K=10$ ($0.5 \leq 10$)



MACH NUMBER

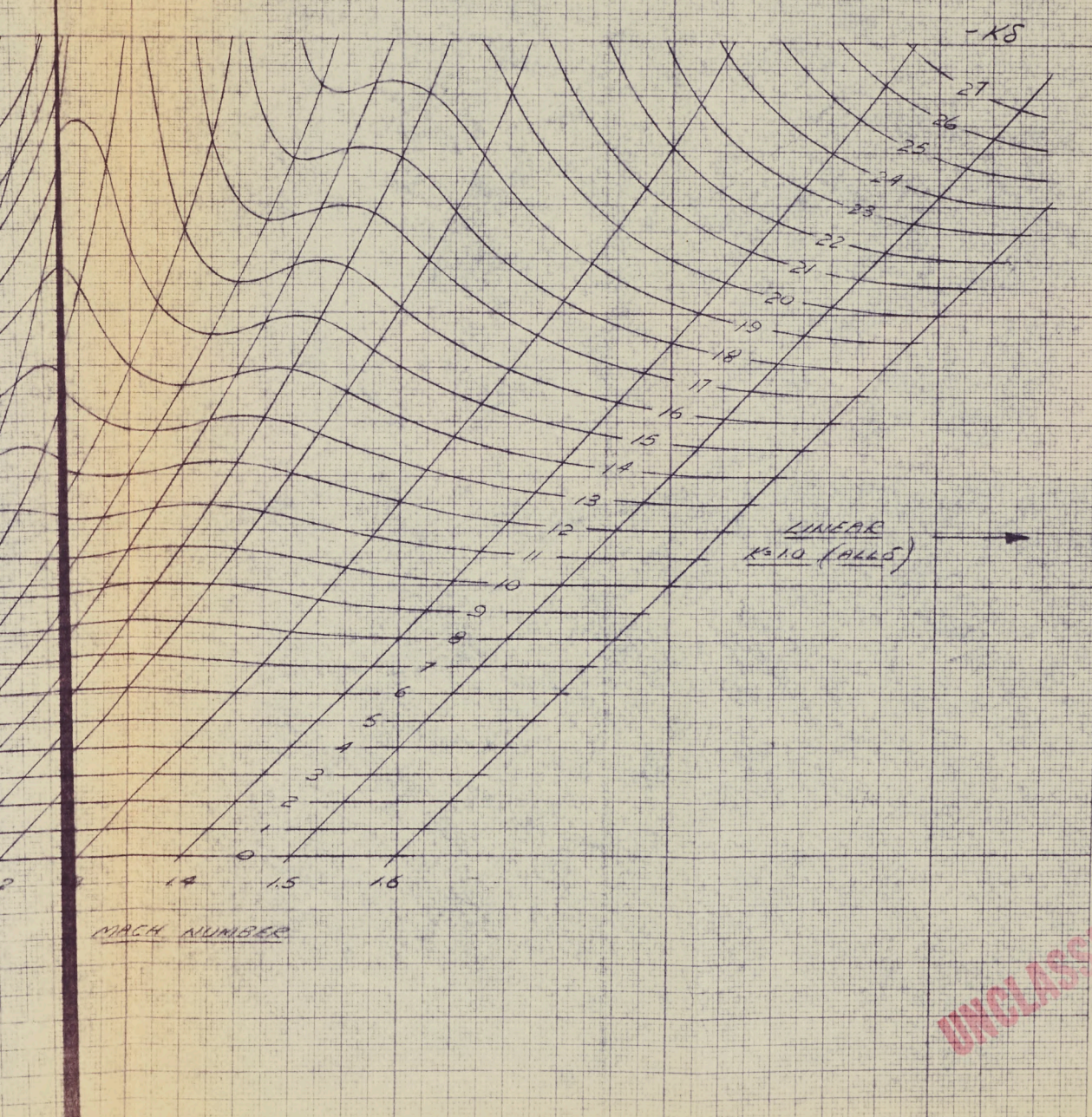
5

SECRET

JULY 55. CLARK.

C105
S.E. 15 & MACH NO.

UNCLASSIFIED



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SECRET

SECRET
MAY 55 CLARK

UNCLASSIFIED

Good
C-17 - 1000
C-16 - 1500
C-15 - 1500
C-14 - 1500

140

130

120

110

100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

TEST NUMBER



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ENGINE

SECRET

MAY 55 CLARK

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03-10-55
CLARK ENGINE TESTS
85 15 10000 NO
85 11 15 50 10000

CLARK
ENGINE

60

50

40

30

20

18

16

14

12

10

8

6

4

WATER NUMBER

UNCLASSIFIED

SECRET

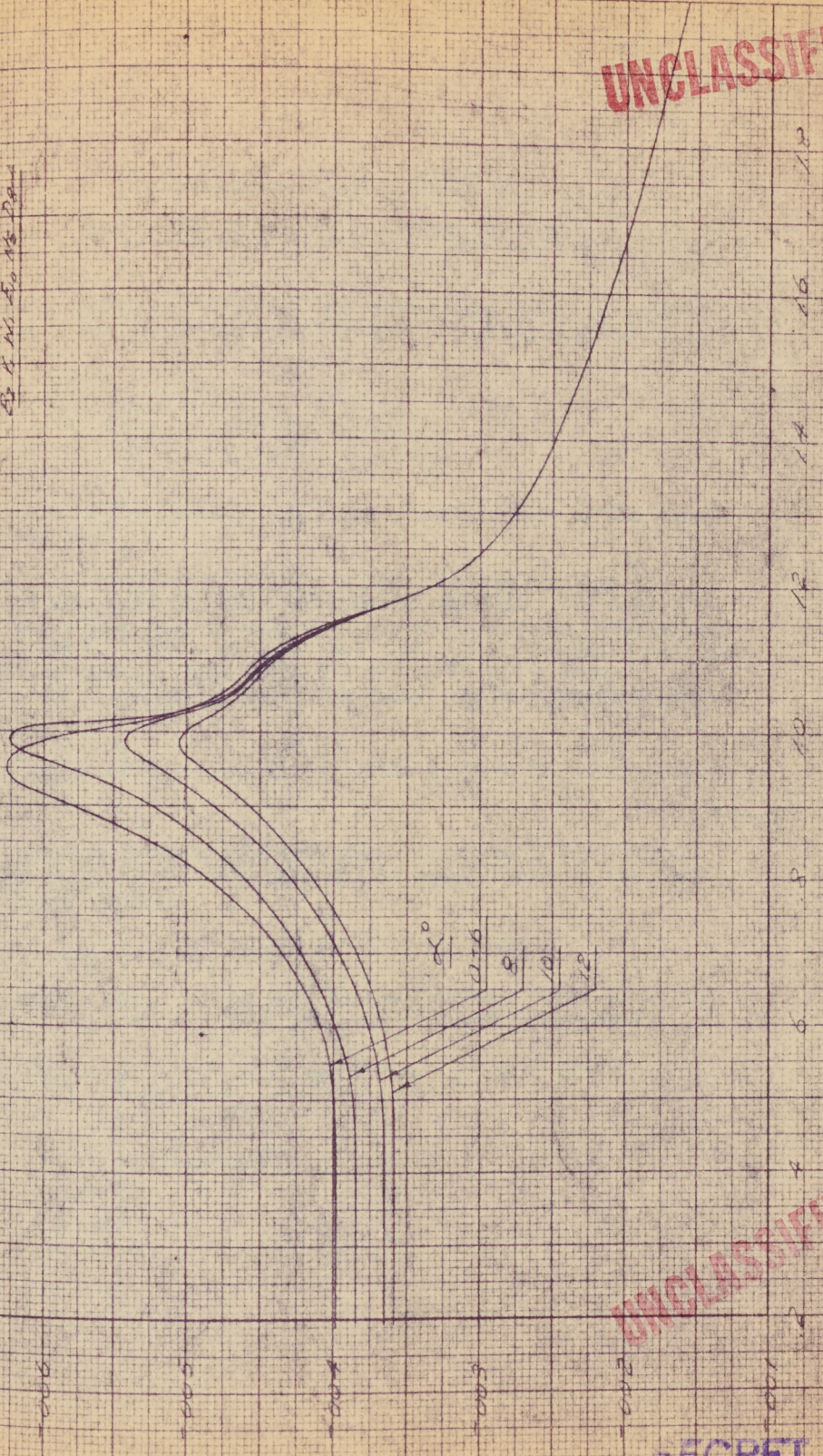
ENGINE

32
JULY 55
CLARK

UNCLASSIFIED

CLARK
AT 10:15 (10:15)
CUT SECTOR 5.15
3.4 M. TO 12.0

WAVE NUMBER



0
100
200
300
400
500
600
700

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AIRCRAFT:

CF-105

PRELIMINARY NOTE ON A METHOD OFESTIMATING TRIM DRAG AT SUPERSONIC SPEEDS

It can easily be shown that the theoretical drag, at supersonic speeds, of a two dimensional airfoil with a control surface is as follows:-

$$C_D = C_{D_0} + \frac{\partial C_D}{\partial \alpha^2} \alpha^2 + \frac{\partial C_D}{\partial (\delta + \alpha)^2} \delta^2 + \frac{\partial C_D}{\partial (\delta + \alpha)^2} 2 \delta \alpha \quad (1)$$

Obviously, the equation will have a similar form in the three dimensional case.

The first thing to establish is that the equation has the right form when compared with experimental results. The data of RM A52104 has been used to make this comparison and is presented in Figures 1 and 2. It can be seen that the equation compares very well with the experimental data up to $\alpha = 12^\circ$ & $\delta = -15^\circ$; above $\delta = -15^\circ$, the experimental drags are lower than the equation would predict.

The object of this note is to devise a method of estimating $\frac{\partial C_D}{\partial (\delta + \alpha)^2}$.

In the theoretical two dimensional case, the drag of the control surface is equal to the component of the normal force on the control in the flight direction, i.e.

$$\Delta C_{D_c} = \Delta C_{L_c} (\delta + \alpha) \cos \theta \text{ to the first order}$$

where $-\Delta C_{L_c}$ is the lift on the control divided by q_c and θ is the control leading edge sweep.

$$\text{and } \Delta C_{D_c} = \frac{\partial C_{L_c}}{\partial \delta} (\delta + \alpha)^2 \cos \theta = a_2 (\delta + \alpha)^2 \cos \theta$$

$$\frac{\partial C_D}{\partial (\delta + \alpha)^2} = a_2 \cos \theta$$

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In the three dimensional case -

$$\Delta C_{Dc} = \frac{\Delta C_{Lc}}{\Delta C_{LW}} \Delta C_{LW} (\delta + \alpha) \cos \theta$$

where $-\Delta C_{LW}$ is the lift coefficient on the aircraft due to the control.

$$\therefore \frac{\Delta C_{Dc}}{\Delta (\delta + \alpha)^2} = K_2 a_2 \cos \theta$$

$$\text{where } -K_2 = \frac{\Delta C_{Lc}}{\Delta C_{LW}}$$

The ratio of experimental to theoretical K_2 vs Mach number has been plotted in Figure 3. From these results, it would appear that the theoretical K_2 's agree very well with these obtained from experiments.

The estimated K_2 's for the CF-105 are shown in Figure 4, and the experimental K_2 's from the Cornell tests are also plotted.

It is sometimes convenient to re-arrange equation (1), substituting for Q from the lift equation,

$$C_L = a_1 Q + a_2 \delta$$

We then have -

$$C_D = C_{D_0} + \frac{C_L^2}{e\pi A} + \left(\frac{K_2}{a_2} + \frac{1}{e\pi A} - \frac{2K_2}{a_1} \right) (a_2 \delta)^2 + \left(\frac{K_2}{a_1} - \frac{1}{e\pi A} \right) 2C_L a_2 \delta \quad (2)$$

The first two terms in the above equation represents the minimum drag coefficients and the conventional induced drag and what remains we define as the trimming drag C_D^δ .

The pitching moment due to controls at constant $C_L = (h_0 - h_\delta) a_2 \delta = C_M^\delta$ and

$$C_D^\delta = \left(\frac{K_2}{a_2} - \frac{2K_2}{a_1} + \frac{1}{e\pi A} \right) \left(\frac{C_M^\delta}{h_0 - h_\delta} \right)^2 + \left(\frac{K_2}{a_1} - \frac{1}{e\pi A} \right) \frac{C_M^\delta}{(h_0 - h_\delta)} 2C_L \quad (3)$$

and in trimmed flight $-C_M^\delta = C_{M_0} + (h - h_0) C_L$

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If we include the facts that the minimum drag does not occur at $C_L = 0$ and that C_L is more generally $C_L = a_1 (\alpha - \alpha_0) + a_2 \delta$ then the drag equation becomes -

$$C_D = C_{DMin} + \frac{(C_L - C_{LC_{DMin}})^2}{e\pi A} + \left(\frac{K_2}{a_2} - \frac{2K_2}{a_1} + \frac{1}{e\pi A} \right) \left(\frac{C_M \delta}{h_0 - h_\delta} \right)^2 + \left(\frac{K_2}{a_1} - \frac{1}{e\pi A} \right) \frac{C_M \delta^2 (C_L - C_{LC_{DMin}})}{(h_0 - h_\delta)}$$

The drag coefficient vs C_L curve for the CF-105 at $M = 1.5$ has been evaluated using the above equation and is presented in Figure 5; the C_D vs C_L curve using the method outlined in CF-105 Performance Report No. 1 is also shown.

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SYMBOLS

- C_D - Drag coefficient
 C_{D_0} - Drag coefficient at zero C_L
 $C_{D_{Min}}$ - Minimum drag coefficient
 C_L - Lift coefficient
 $C_{L_{C_{D_{Min}}}}$ - Lift coefficient for minimum drag
 C_M - Pitching moment coefficient
 C_M^δ - Pitching moment coefficient due to controls
 C_{M_0} - Pitching moment coefficient at $C_L = 0, \delta = 0$
 a_1 - $\frac{\partial C_L}{\partial \alpha}$
 a_2 - $\frac{\partial C_L}{\partial \delta}$
 h_0 - Aerodynamic centre
 h_δ - Centre of elevator lift
 e - Induced drag factor
 A - Aspect ratio
 α - Angle of attack
 δ - Control angle
 C_D^δ - Trim drag coefficient

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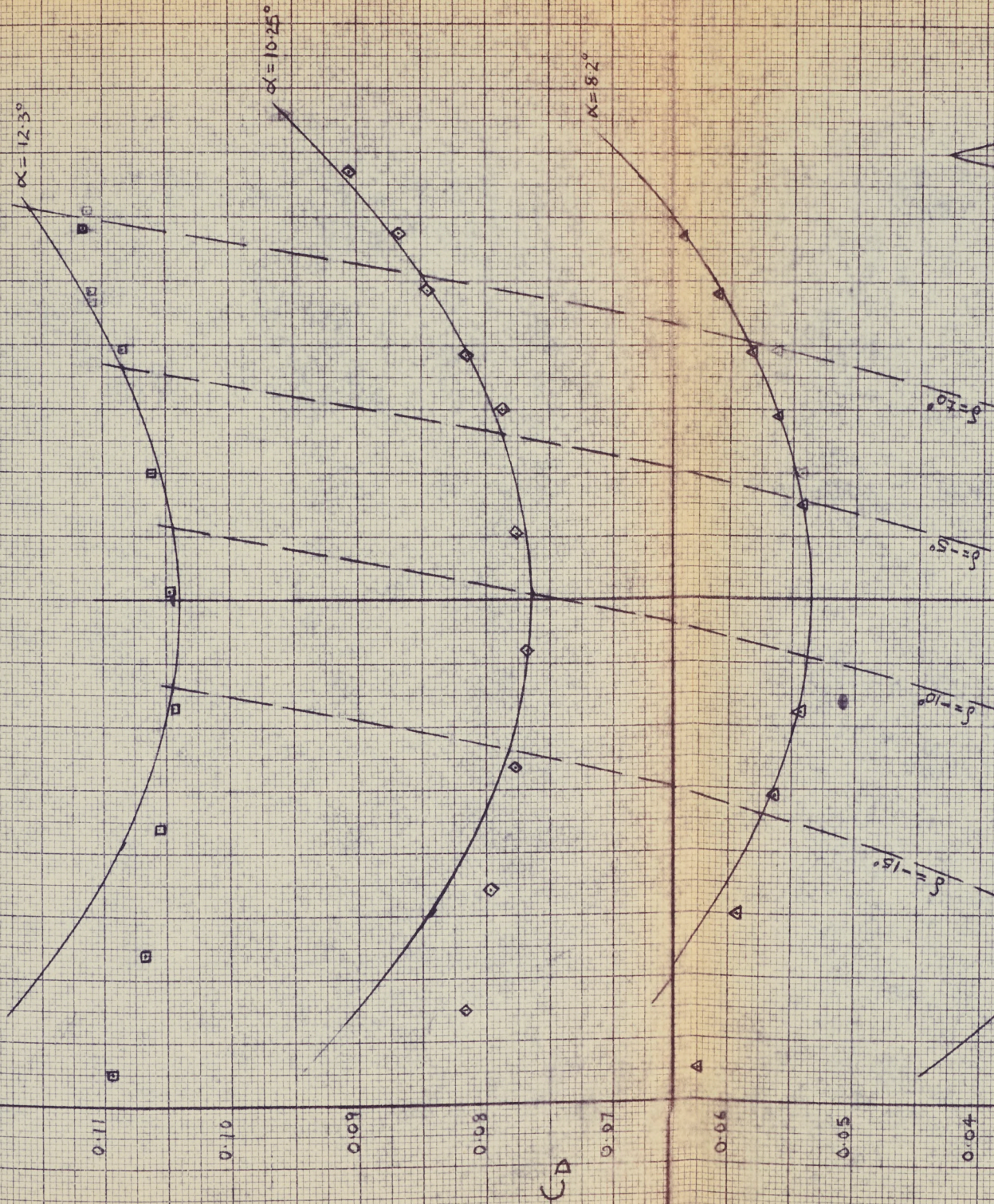
IDEAS OF DELTA WING IN M=1.5

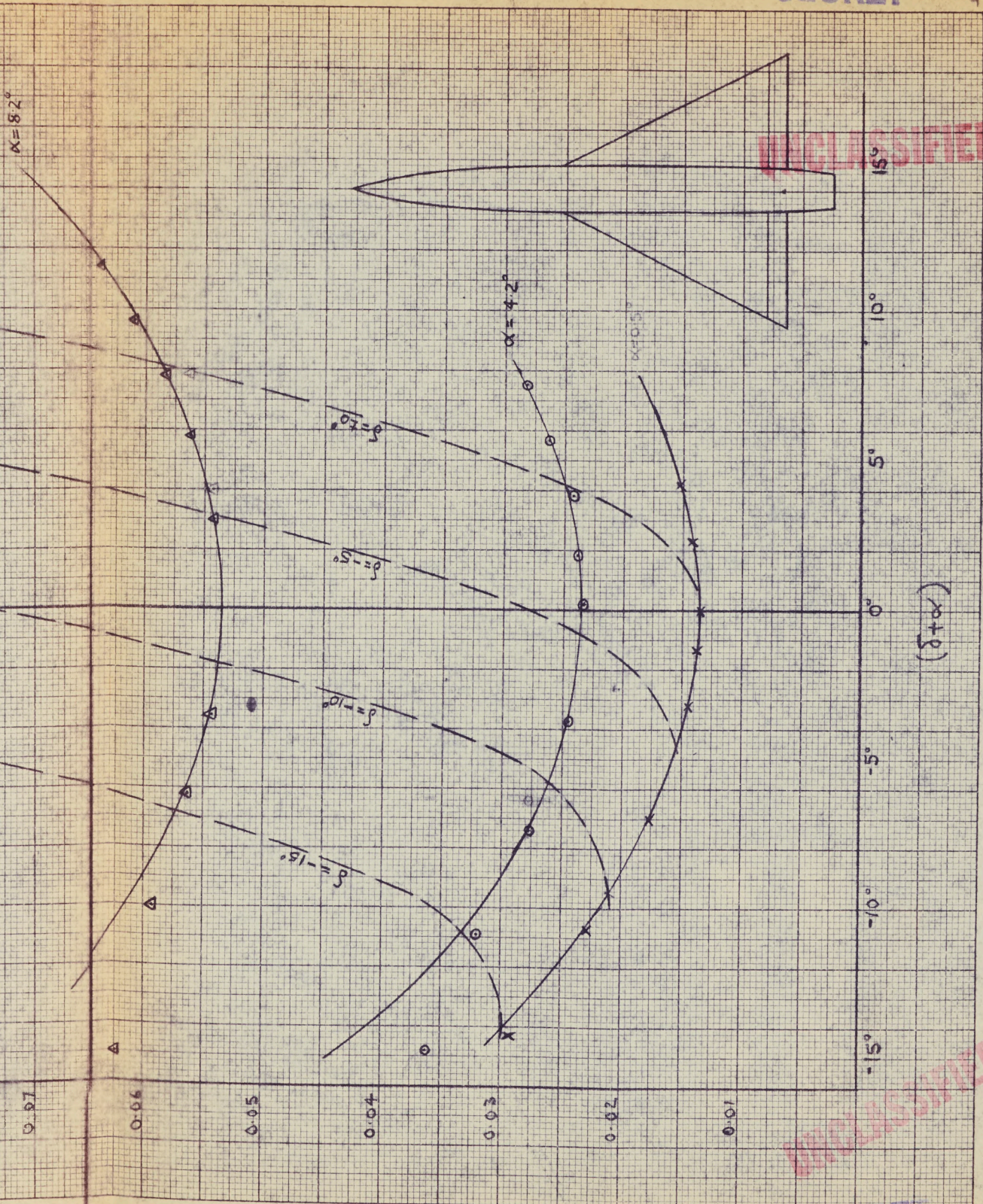
EXPERIMENTAL POINTS FROM LASER LOAD

CURVES FROM FORMULA $C_D = C_{D0} + \left(\frac{\partial C_D}{\partial \alpha}\right) \alpha^2 + \left(\frac{\partial C_D}{\partial \delta}\right) \delta^2 + \left(\frac{\partial C_D}{\partial \alpha}\right) \alpha + \left(\frac{\partial C_D}{\partial \delta}\right) \delta$

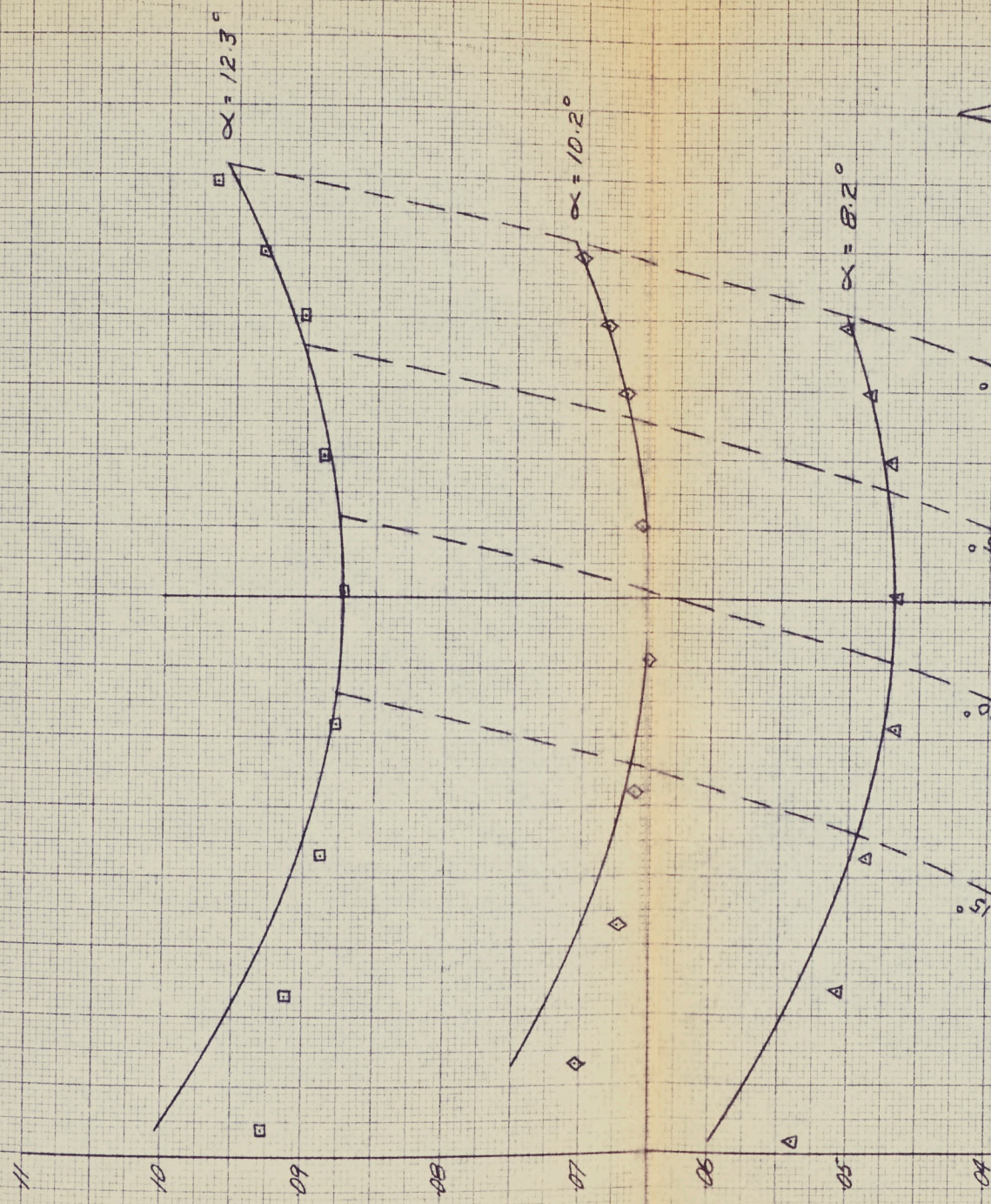
WERE OBTAINED FROM EXPERIMENTAL DATA

$$C_{D0}, \left(\frac{\partial C_D}{\partial \alpha}\right)_{\alpha=0}, \left(\frac{\partial C_D}{\partial \delta}\right)_{\delta=0}$$

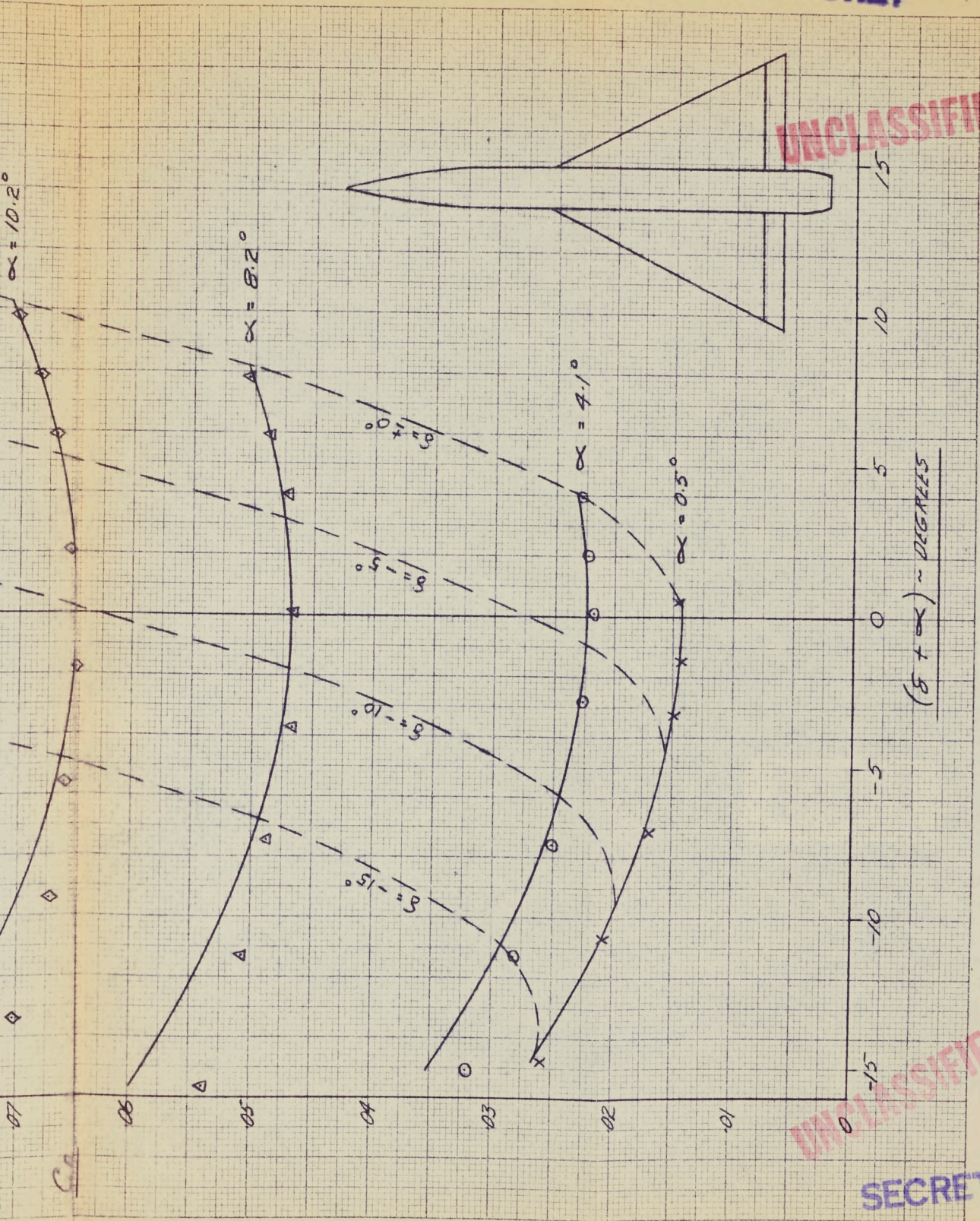




The curves are calculated for $\alpha = 10^\circ$ and 12.3° and compared with experimental curves from formula $C_D = C_{D0} + \left(\frac{\partial C_D}{\partial \alpha}\right)_{\alpha=0} \alpha + \left(\frac{\partial^2 C_D}{\partial \alpha^2}\right)_{\alpha=0} \alpha^2 + 2\alpha \delta$
 C_{D0} , $\left(\frac{\partial C_D}{\partial \alpha}\right)_{\alpha=0}$, $\left(\frac{\partial^2 C_D}{\partial \alpha^2}\right)_{\alpha=0}$ WERE OBTAINED FROM EXPERIMENTAL DATA



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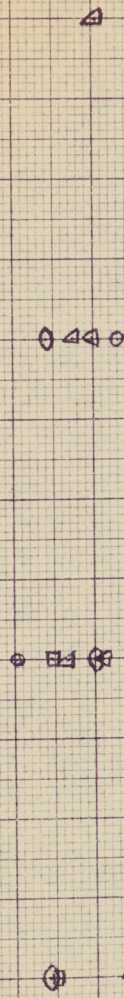


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VARIATION OF EXPERIMENTAL TO THEORETICAL K_2 WITH MACH N°

K_{2EXP}
 $K_{2THEORY}$

1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2



SYMBOLS
 CONSTANT CHORD - TRUE CONTOUR Δ
 CONSTANT CHORD - BLUNT CONTOUR \square
 CONSTANT CHORDS - TRUE CONTOUR \circ
 CONSTANT CHORDS - BLUNT CONTOUR \diamond

REFERENCE
 RM A52104
 RM A52101C

MACH N°

1.8

1.7

1.6

1.5

1.4

1.3

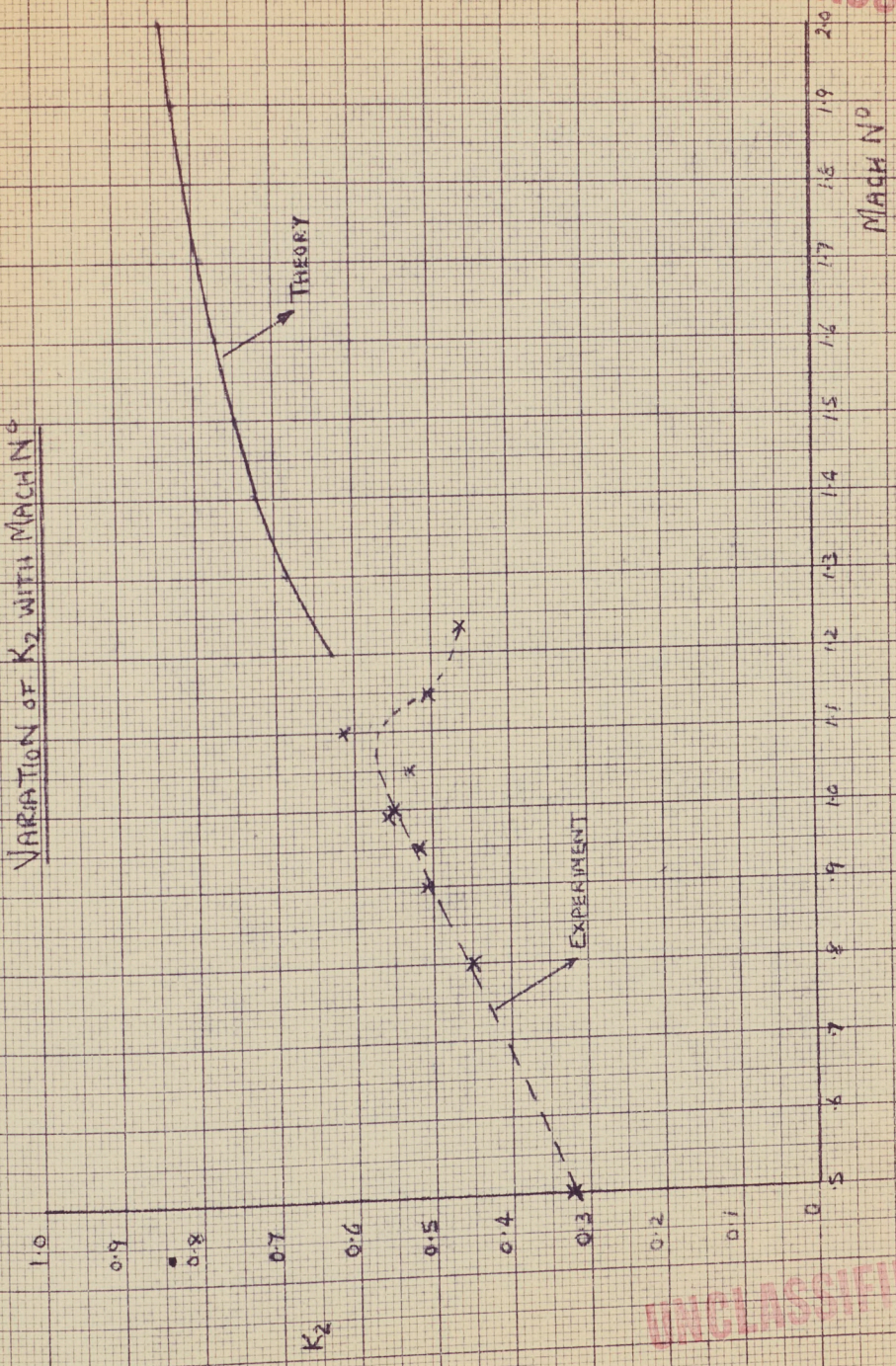
1.2

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C105
VARIATION OF K_2 WITH MACH N²

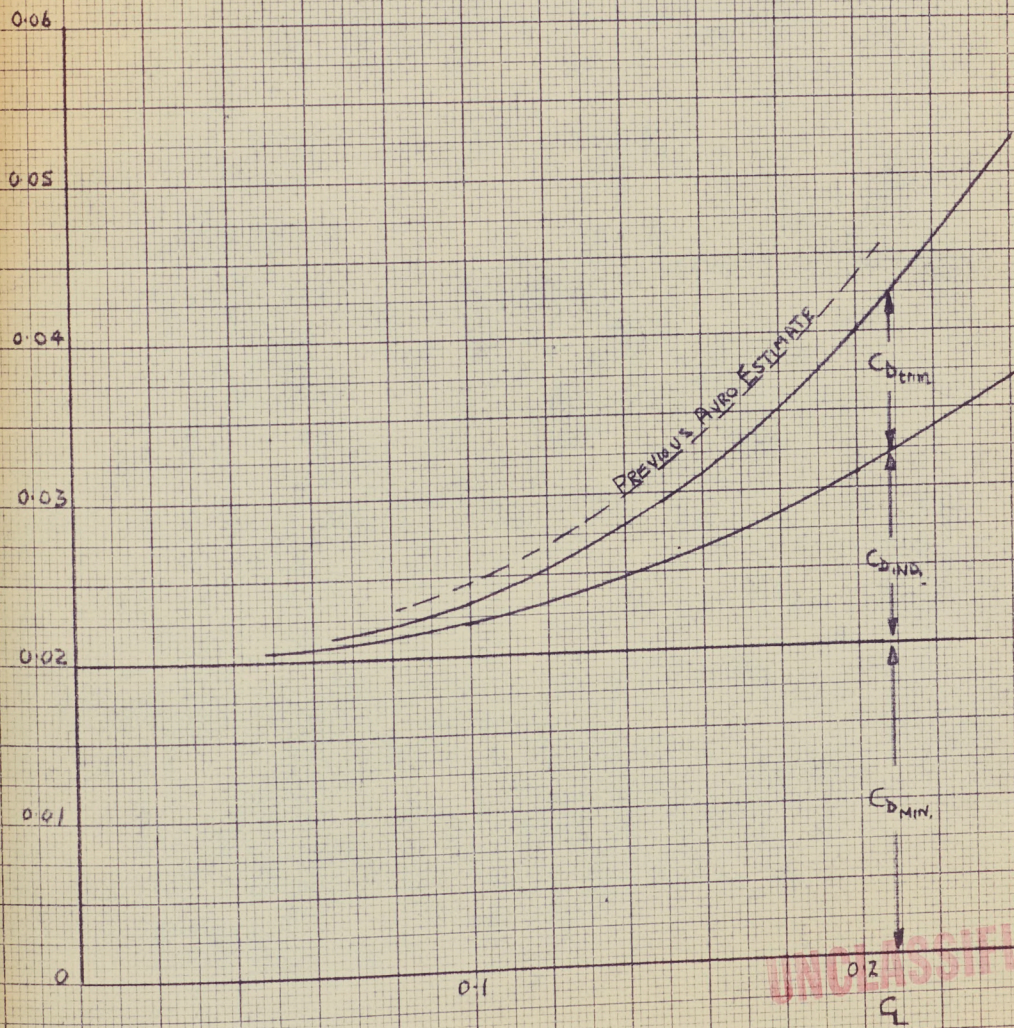


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C105
ESTIMATED C_D vs Q AT $M=1.5$ ($h=0.24$)

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January 1956.

3. CF-105 INSTALLED ENGINE DATA

The methods of estimating installed engine data (extract P/Power/51) has been presented in section 3 of CF-105 Monthly Report No. 1, with minor revisions noted in Report No. 2 and 3.

No further revisions have been made to the J-75.

The Orenda PS 13 maximum thrust in the stratosphere has been re-estimated (P/Power/56) based on the latest Orenda non-dimensional data - curves 12907 to 12916.

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BRISTOL
1850
MADE IN U.S.A.