BM3-25-4-32

4 January 1955.

~~SECRET~~

Air Vice Marshal J. L. Plant,
Air Member for Technical Services,
Royal Canadian Air Force,
Department of National Defence,
Ottawa, Ontario.

Dear Air Vice Marshal Plant,

I enclose herewith some notes made during the recent discussions on the C-105 aircraft with the N.A.C.A. in Washington, and also a summary of my view of some things that might advantageously be done. I have not yet seen the final edition of Mr. Floyd's summing up of the discussion.

In view of the Company's evident desire to sell you the aircraft as it stands, in spite of shortage of inherent stability and of combat load factor, criticism by us seems to be strongly resented even when it proves to be correct or even understated (as in the case of the aircraft drag estimates).

If you think it worthwhile, I should like to have a chat with you concerning what could best be done now, because we are loath to extend our programme of work in a way which seems merely to irritate the firm rather than assist the R.C.A.F.

Yours sincerely,

J. H. Parkin
Director

NATIONAL RESEARCH COUNCIL

MEMORANDUM

TO:- Note:

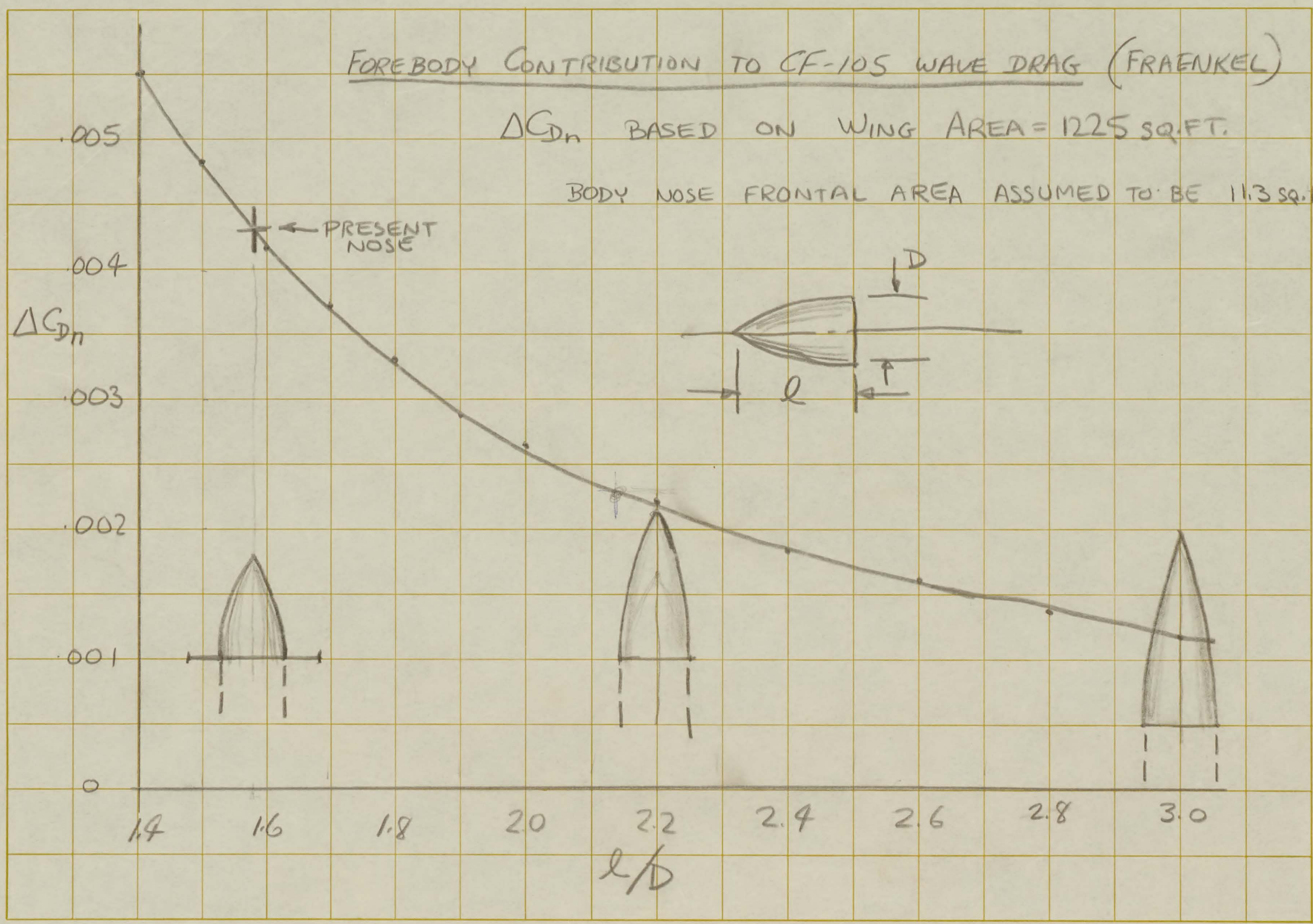
FILE NO.

DATE 22.11.55

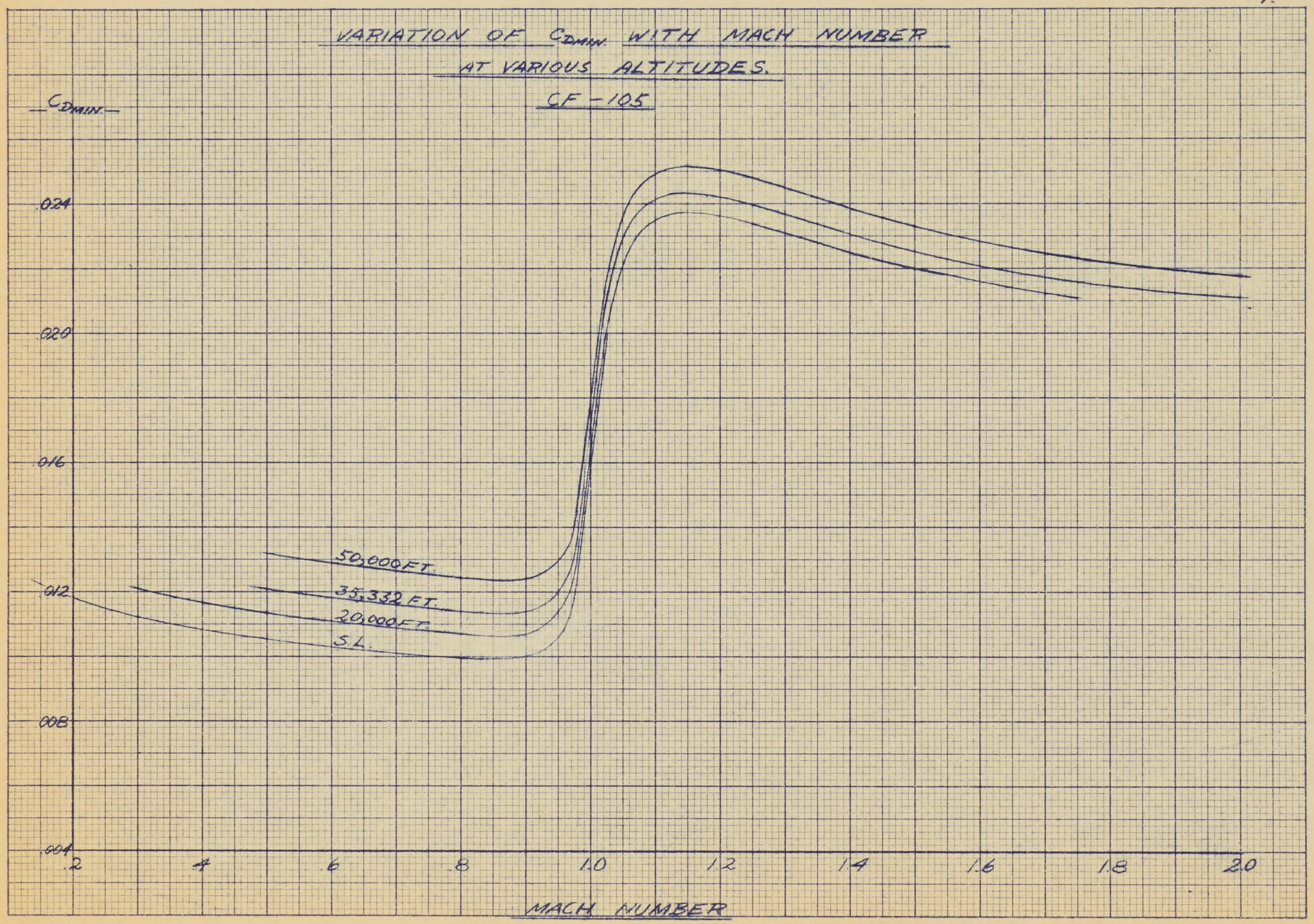
Attached graphs prepared by RJ Templin and OE Michaelsen for use at C105 Sub-committee meeting at Avro Aircraft Ltd. in Toronto on 22.11.55. 9 copies were run off:

FORM NRC 47B (REVISED 24.2.49)

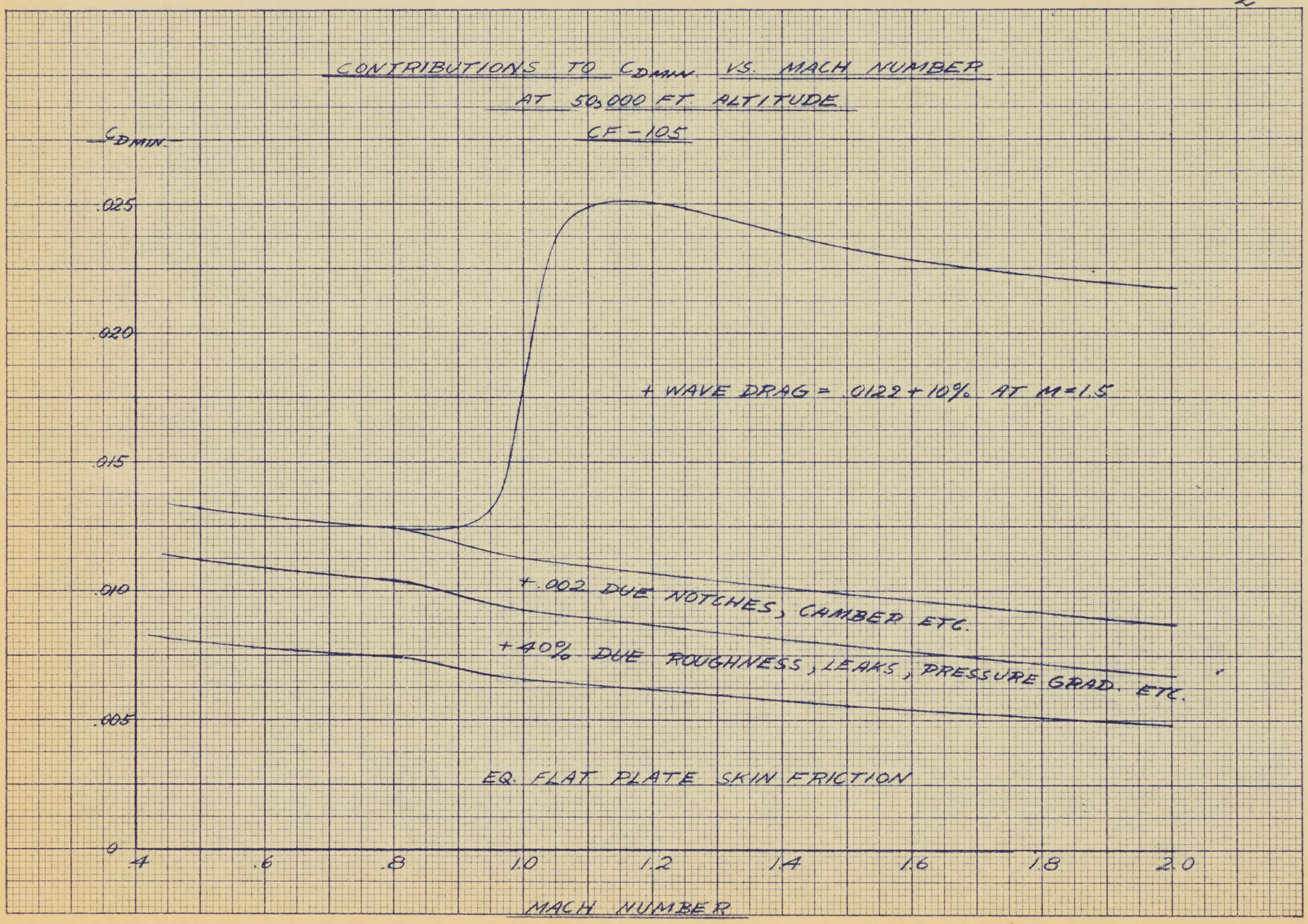
NO. 31,184. 2 DIVISIONS PER INCH BOTH WAYS. 14 BY 20 DIVISIONS. CODEX BOOK COMPANY, INC. NORWOOD, MASSACHUSETTS



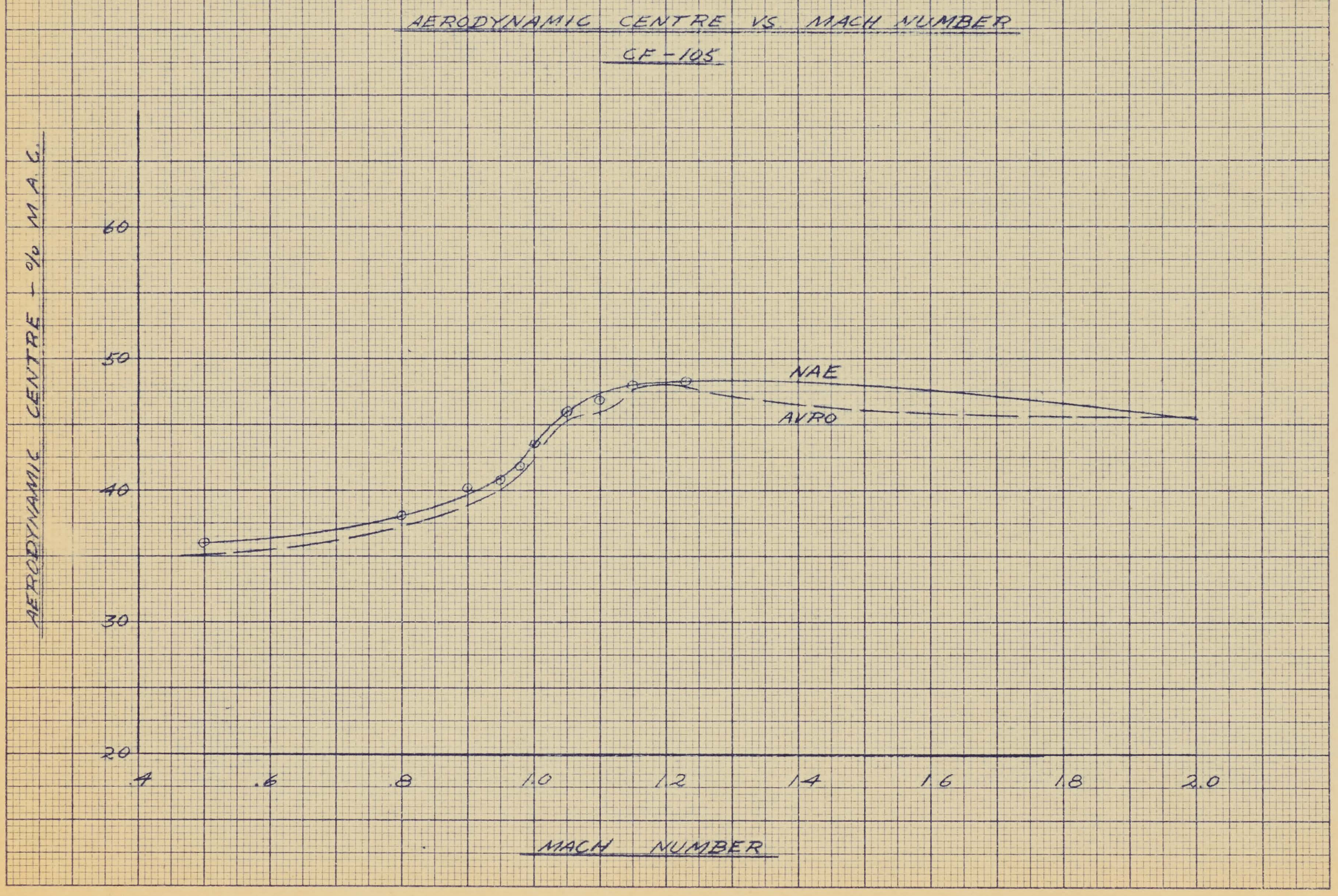
\# 1.

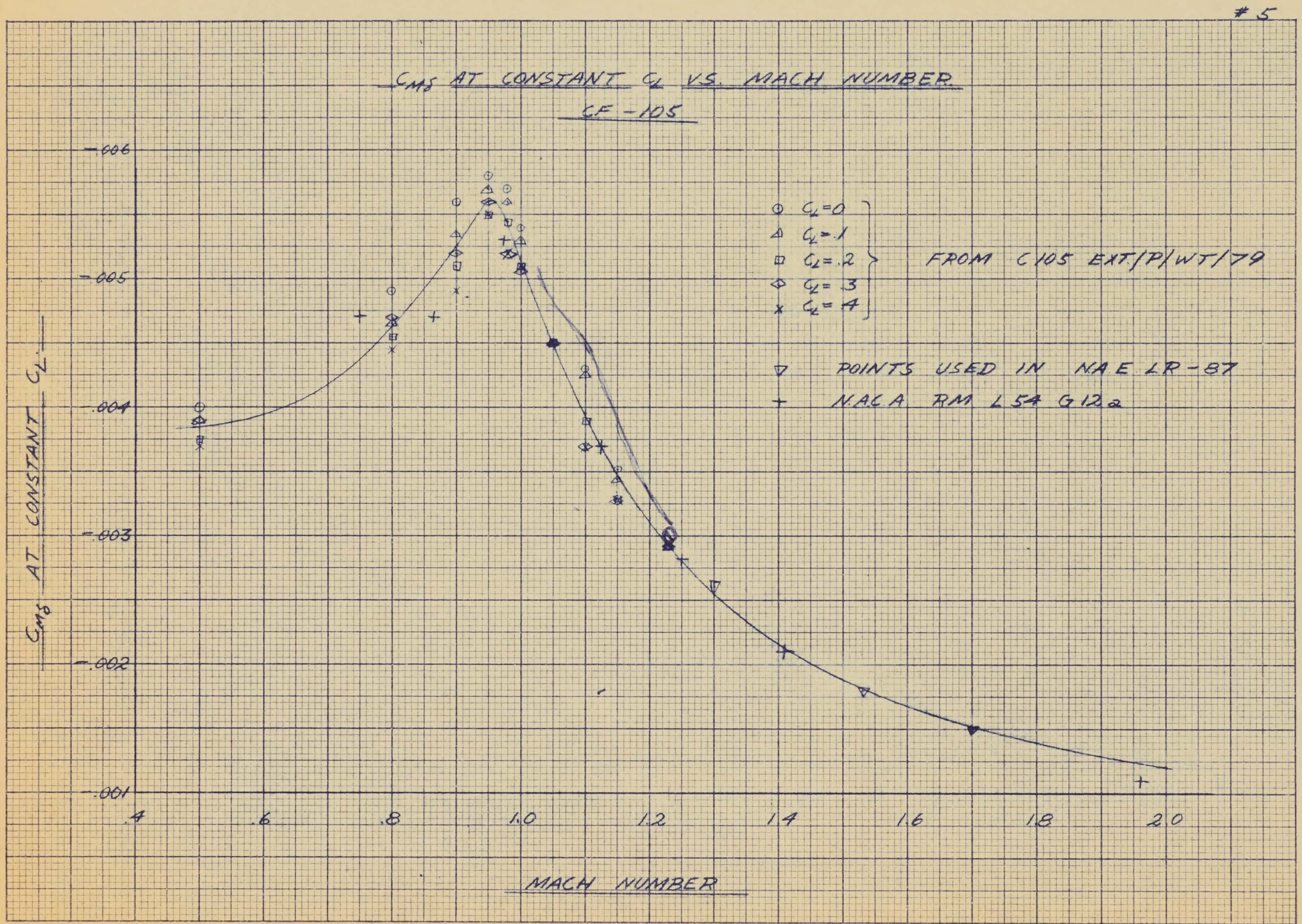

VARIATION OF $C_{D_{MIN.}}$ WITH MACH NUMBER
AT VARIOUS ALTITUDES.
CF-105
$C_{D_{MIN.}}$
.024
.020
.016
.012
.008
.004
50,000 FT.
35,332 FT.
20,000 FT.
S.L.
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER

#2

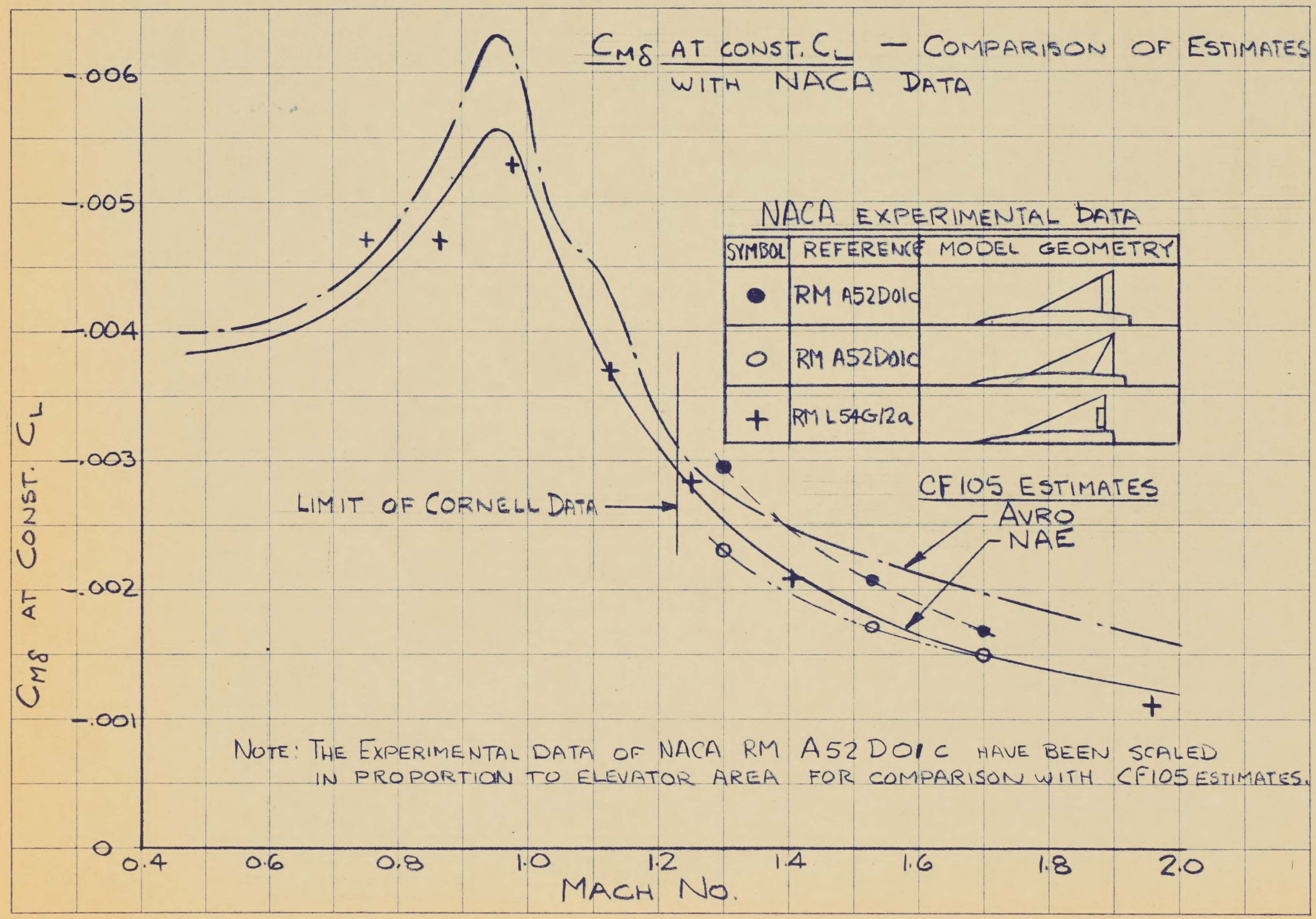

CONTRIBUTIONS TO C_DMIN. VS. MACH NUMBER
AT 50,000 FT. ALTITUDE
CF-105
C_DMIN.
.025
.020
.015
.010
.005
0
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
+ WAVE DRAG = .0122 + 10% AT M=1.5
+.002 DUE NOTCHES, CAMBER ETC.
+40% DUE ROUGHNESS, LEAKS, PRESSURE GRAD. ETC.
EQ. FLAT PLATE SKIN FRICTION
MACH NUMBER

#4.


AERODYNAMIC CENTRE VS MACH NUMBER
CF-105
AERODYNAMIC CENTRE - % M.A.C.
60
50
40
30
20
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER
NAE
AVRO

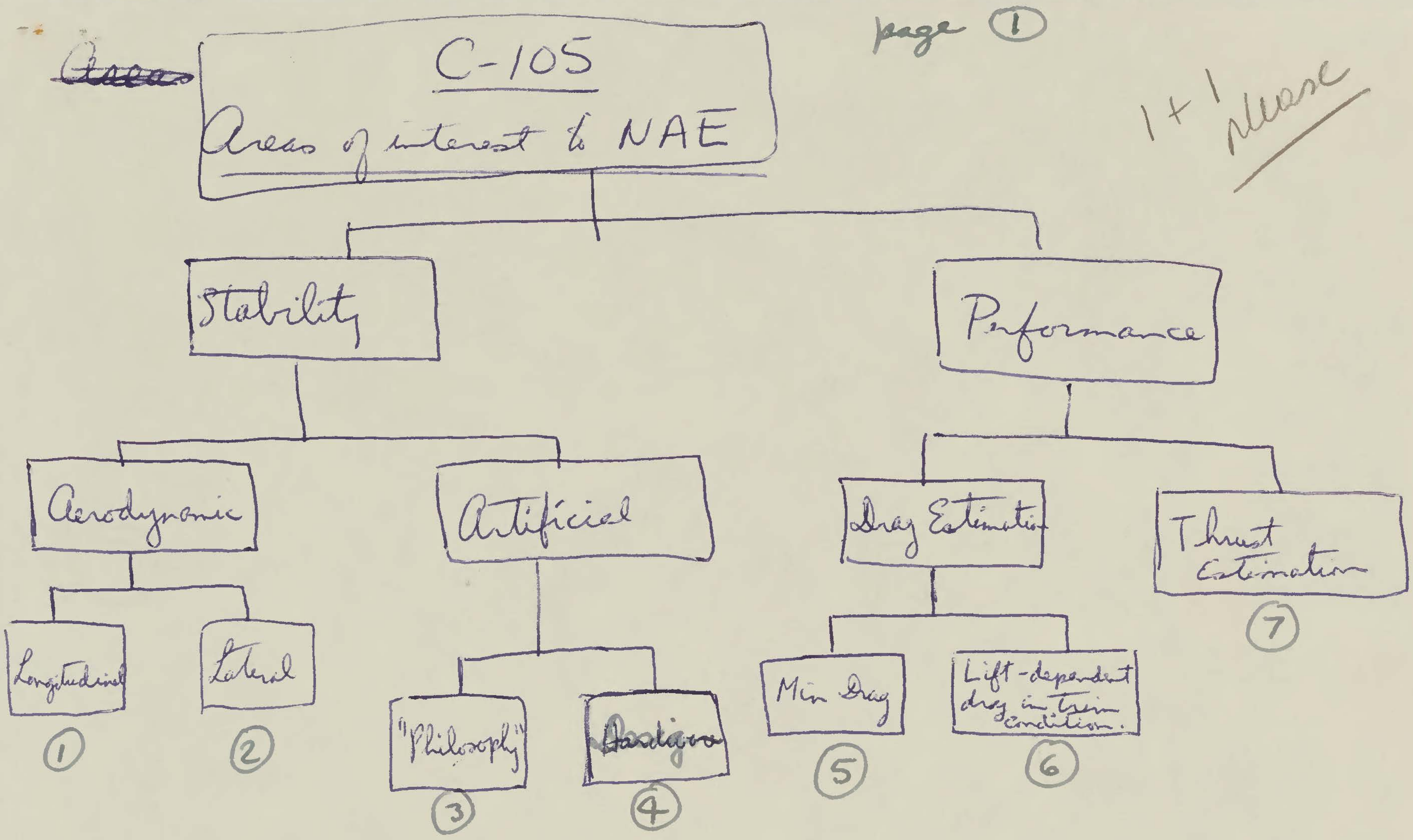

#5
$C_{M\delta}$ AT CONSTANT C_L VS. MACH NUMBER
CF-105
C_L=0
C_L=.1
C_L=.2
C_L=.3
C_L=.4
FROM C105 EXT/P/WT/79
POINTS USED IN NAE LR-87
N.A.C.A RM L54 G12a
-.006
-.005
-.004
-.003
-.002
-.001
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NUMBER
$C_{M\delta}$ AT CONSTANT C_L

5a



Cmδ AT CONST. CL — COMPARISON OF ESTIMATES WITH NACA DATA
NACA EXPERIMENTAL DATA
SYMBOL | REFERENCE | MODEL GEOMETRY
● | RM A52D01c
○ | RM A52D01c
+ | RM L54G12a
CF105 ESTIMATES
AVRO
NAE
LIMIT OF CORNELL DATA
NOTE: THE EXPERIMENTAL DATA OF NACA RM A52D01c HAVE BEEN SCALED IN PROPORTION TO ELEVATOR AREA FOR COMPARISON WITH CF105 ESTIMATES.
Cmδ AT CONST. CL
-.006
-.005
-.004
-.003
-.002
-.001
0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
MACH NO.

1+1 please



The above is a breakdown of the technical subject matter on the CF-105, in which the NAE are interested. The following notes refer to the numbered items in the diagram above. Items ① to ④ refer to dynamic stability, and items ⑤ to ⑦ refer to performance. Other main areas, such as structural design, ~~we have paid~~ armament and fire control, we have paid very little attention to.

① <u>Longitudinal Stability</u>: We are not sure that the problem of pitch-up has been satisfactorily cured by the company. They have, of course, made considerable improvement by the use of fixes (leading edge extension, notch and droop) but the $C_m - C_L$ curve is still not completely ~~stable~~ straight.

② <u>Lateral Stability</u>: The aerodynamic lateral stability of the aircraft is such that the aircraft can not be flown over part of its flight envelope without a very sophisticated type of artificial stability system.

(4) <u>Artificial Stability System Design</u>: We do not seem to have had much success in obtaining ~~the~~ clear answer on some questions relating to the basic design of the artificial "damping" system. In order to ensure maximum reliability, there are actually two systems in the aircraft. The ~~actual~~ hydraulic servos which operate the controls are not duplicated, but the damping system itself consists of a "normal" and a "standby" system. It would appear, however, that the standby system comes into operation in some cases when the <u>normal</u> system has <u>not</u> failed. This is as yet not clear to us. These other cases include any situation (such as one engine failure) which puts asymmetric forces on the aircraft. The switch-over to standby system is done automatically, although the pilot always has the choice of reselecting the normal system. In such cases, however, it would appear that the choice of reselecting would be academic because if the cause of automatic switch-over is not removed, the system would apparently continue to switch to standby. Hence it seems that double emergencies can occur. For example an engine failure may cause the normal stability system to go out of action. The standby, or emergency system is apparently not to be designed ~~—~~ to give completely adequate flying characteristics.

Another point here is that the timing of the artificial damping system seems to be lagging considerably. We feel that the design of the system is a very big job indeed, and that it has not progressed far as yet.

(5) <u>Minimum Drag</u>: A year or more ago this was the area of "hottest" disagreement between Avro and NAE. At that time the Company estimated $C_{D0} \approx .014$ at $M = 1.5$. Since that time the aircraft has been modified ~~by the~~ in accordance with the supersonic area rule, while at the same time their drag estimation has gone up to 0.022.

Our own estimate is not less than .023 and it is because of the similarity of the two estimates that this argument has died down. We still think that both estimates are optimistic, but no great purpose is served in further discussion. $C_{D_{min}}$ never will be known, probably.

⑥ Lift-dependent Drag in Trimmed Flight: At the moment this is the "hot" issue. We do not disagree too much with Avro on drag due to lift at zero elevator angle, and we apparently also agree with them on the drag due to elevator deflection, but where we disagree is on the elevator angle required to trim. The main reason is that we disagree on the value of C_{m_δ} at constant C_L, for Mach numbers above about 1.3. We seem to disagree by about 20% at M=1.5 and by even larger percentage at higher M. The two methods of estimation are basically different, although both are ~~essentially~~ to some extent empirical. Avro's method is to calculate C_{m_δ} (or C_{L_δ}) by linearized theory, which is then corrected theoretically for the finite trailing edge angle of the control. They have compared this method with available NACA data and find that it ~~agrees~~ seems to agree with experiment provided the Mach number is greater than 1.4 or 1.5. They use the method to calculate elevator effectiveness for the CF-105 in the range $1.5 < M < 2.0$ and fair the calculation into the Cornell results which do not go above M=1.23. Their method does not agree with NACA data in the mach number range up to about 1.5 but it always disagrees in the same direction. It always underestimates C_{m_δ} or C_{L_δ} in this range.

Our own method is concerned not so much with absolute values but with the *shape* of the curves of $C_{m\delta}$ versus Mach number over the range $1.2 < M < 2.0$. We find that ~~the~~ $C_{m\delta}$ (or $C_{L\delta}$) in general varies ~~at faster~~ with M at least as rapidly as $\frac{1}{\sqrt{M^2-1}}$.

Hence our method depends on knowing an end point, and this we have taken to be given by the Cornell data at 1.2. Our method is thus not nearly as sophisticated as Avro's but we feel that theirs does neglect certain factors, such as boundary layer effects and carryover effects on to that part of the body behind the wing trailing edge. There is, as a matter of fact, at least one possibility of bringing the two methods nearly into coincidence. This would occur if the Cornell data in the range ~~[illegible]~~ M = 1.1 to 1.2 were too low by about 20%. If this were the case, both methods would give the same result at M = 1.5, and this would ~~do so~~ result by changing the NAE estimate, not the Avro estimate.

It is somewhat academic to discuss this matter at the present time, since tunnel results will soon be available in the supersonic ~~range~~ speed range.

(7) Thrust Estimation: There is no difference of opinion here. The NAE has not made what could be called an independent estimate. ~~Cornell tunnel results~~ Cleveland tunnel results appear to bear out the Company estimate of pressure recovery, at least.