C-105 - A NOTE ON STABILITY

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SUMMARY

The altitude and speed range of the C-105 is so large that it has been found impossible to secure adequate stability by aerodynamic means alone. Accordingly, synthetic means are resorted to in order to augment the stability in certain modes of flight. While the aircraft should be flyable in most cases without these devices in operation, there are times when failure will be catastrophic. For this reason all possible measures including duplication are being resorted to, in order to secure as near perfect reliability of the synthetic stability system as possible.

DISCUSSION

The problems associated with the stability of the C-105 in general are caused by either high speed or high altitude or a combination of both. Thus, the take-off and landing should be quite exemplary as has been found on other delta aircraft. A gradual deterioration would be experienced as the further reaches of the flight envelope were explored, were it not for the use of synthetic stability, which will supply acceptable stability in all regimes.

(1) Longitudinal

The longitudinal stability and damping is quite satisfactory at low altitude, but deteriorates with altitude in the normal way so that above 40,000 ft. the damping requires augmentation. Due to the high speeds, the periods are much too short for the pilot to be able to control the response to a gust. Accordingly, it is virtually mandatory to augment the natural damping at high altitude by electrical means.

The characteristics of the clean aircraft are shown in Fig. 1. The damping derivatives used in this analysis have in part been verified by free flight model tests. It can be seen that the high altitude characteristics would be very unpleasant, but not necessarily dangerous in the event of failure of the damper.

The other peculiarity that may be experienced in the longitudinal motion of this type of aircraft is "pitch up". This effect was noted in wind tunnel tests at Mach number of about 9/10. To cure this, leading edge extensions and notches have been tried in the wind tunnel and seem to have been successful as shown in Fig. 2.

(2) Lateral Stability

At supersonic speeds the lift effectiveness of a fin falls off considerably. Also it is difficult not to suffer a large reduction in effectiveness at high indicated airspeeds without excessive weight, due to elastic deformation. Accordingly, it has been found to be virtually impossible to secure adequate directional stability at high Mach numbers and indicated airspeeds irrespective of the configuration. If the fin is enlarged, the nose must be lengthened to balance it, which requires still more fin to offset it, unless ballast is used. This is inefficient and reduces the performance.

In the face of this situation, it became obvious that the most practical solution was to try to make the aircraft marginal but flyable at subsonic speeds, and so to reap full advantage of the synthetic stability that must be resorted to for flight at very high speeds.

In attempting to achieve this result some difficulty has been experienced with a non-linearity of the weathercock stability for small angles on either side of the centre. This is shown in Fig. 3. The non-linearity increases in severity with Mach number for subsonic Mach numbers, but disappears at supersonic speeds.

The source of this effect has been investigated and it has been found to be almost entirely due to the intakes as shown by the curve identified by triangles on Fig. 3. Previously some effects had been noted which were attributed to the canopy. These were removed by a re-design of the canopy.

The nature and magnitude of the effects are given on Fig. 4, which shows the fin and body contributions separately. These effects are individually quite small and the main reason for their showing up in the weathercock stability,is that it is a small difference of two large quantities. Some modifications to the duct have been studied and proved ineffective in altering these results. Due to the smallness of the quantities under study,no great optimism is felt for the success of any further program for investigating the non-linearity.

Simulation work that has been carried on using non-linear derivatives represented by a photo former function generator has shown that the non-linearities are not difficult to deal with.

The basic values of the weathercock stability for the elastic airplane are shown on Fig. 5. The non-linearities are confined to the subsonic region. To achieve an adequate degree of positive stability at a Mach number of two would require a fin of area at least twice the present fin. This is clearly impossible. A further deterioration takes place in accelerated flight due to the effect of incidence.

To evaluate the seriousness of the lack of weathercock stability in the event of failure of the damping system simulation studies have been made. These indicate that in most cases the divergence will be slow enough to be controlled by the pilot, but at higher speeds this may not be true. An estimate of the dangerous regions is given on Fig. 6.

From the above, it is obviously necessary to make the damping system as reliable as possible. The rudder channel must have virtually perfect reliability. To achieve this end, it is proposed to use conservative design with magnetic amplifiers, and to duplicate the complete rudder channel in all respects. With the elimination of vacuum tubes and the duplication of the power supply, gyros, amplifiers, miscellaneous circuitry, and the hydraulic servos in the rudder channel, it is hoped to secure a reliability at least comparable with that of the hydraulic boost system.

CONCLUSION

It is proposed to make the C-105 meet all the stability and control requirements under all conditions by the use of synthetic stability. These devices will be designed to an exceptionally high standard of reliability and will be duplicated where their failure would be catastrophic. All measures to secure this end are being vigorously pursued, and there is every reason to have confidence in their ultimate success.

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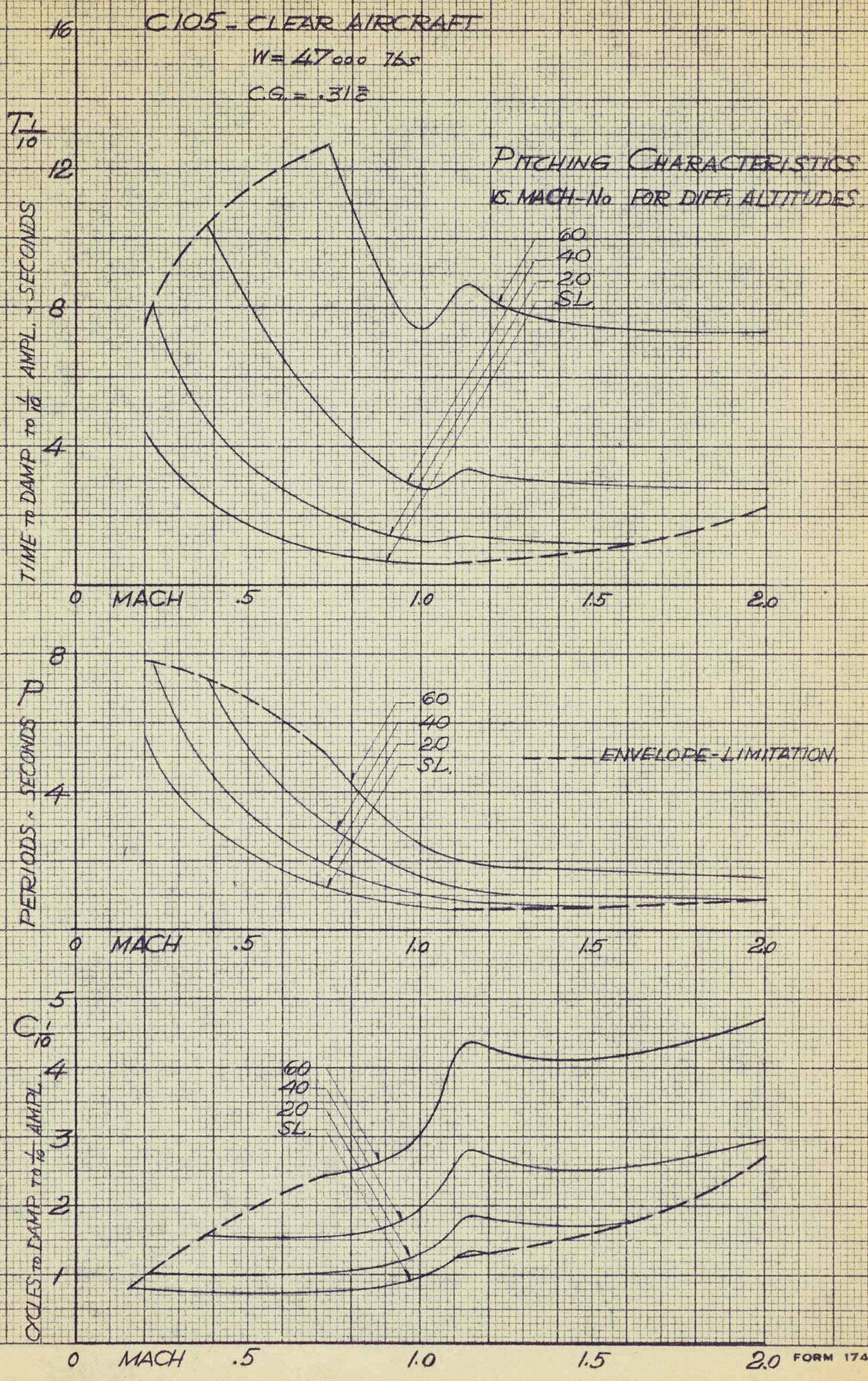
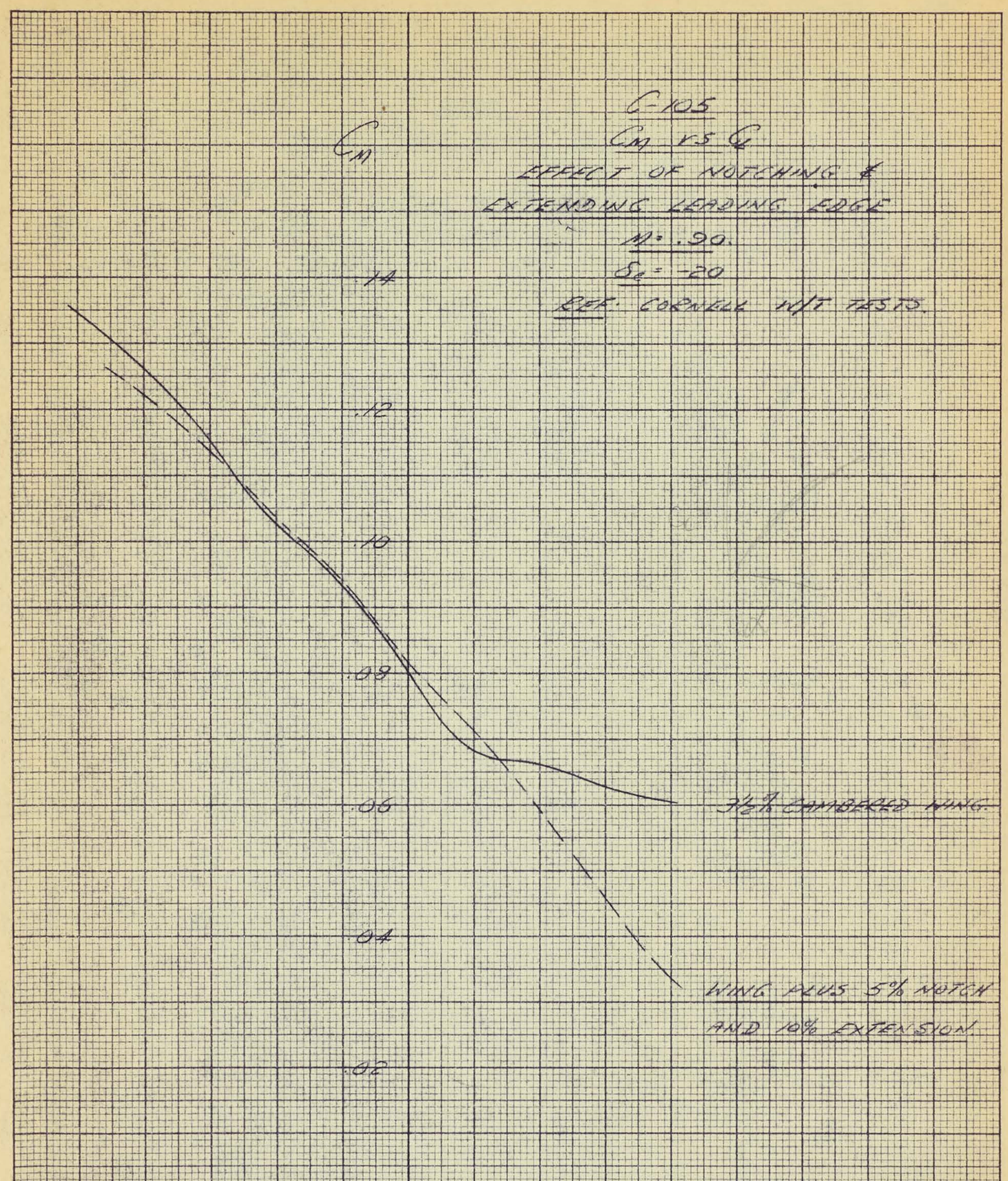


FORM 1746


C-105
CM VS CL
EFFECT OF NOTCHING &
EXTENDING LEADING EDGE
M = .90
δe = -20
REF: CORNELL W/T TESTS.
CM
.14
.12
.10
.08
.06
.04
.02
3½% CAMBERED WING.
WING PLUS 5% NOTCH
AND 10% EXTENSION.
-.4
-.2
0
.2
.4
.6
.8
CL

-4 ·3° 4·6° 6·9°

Jan 15 J.F.K.

C105

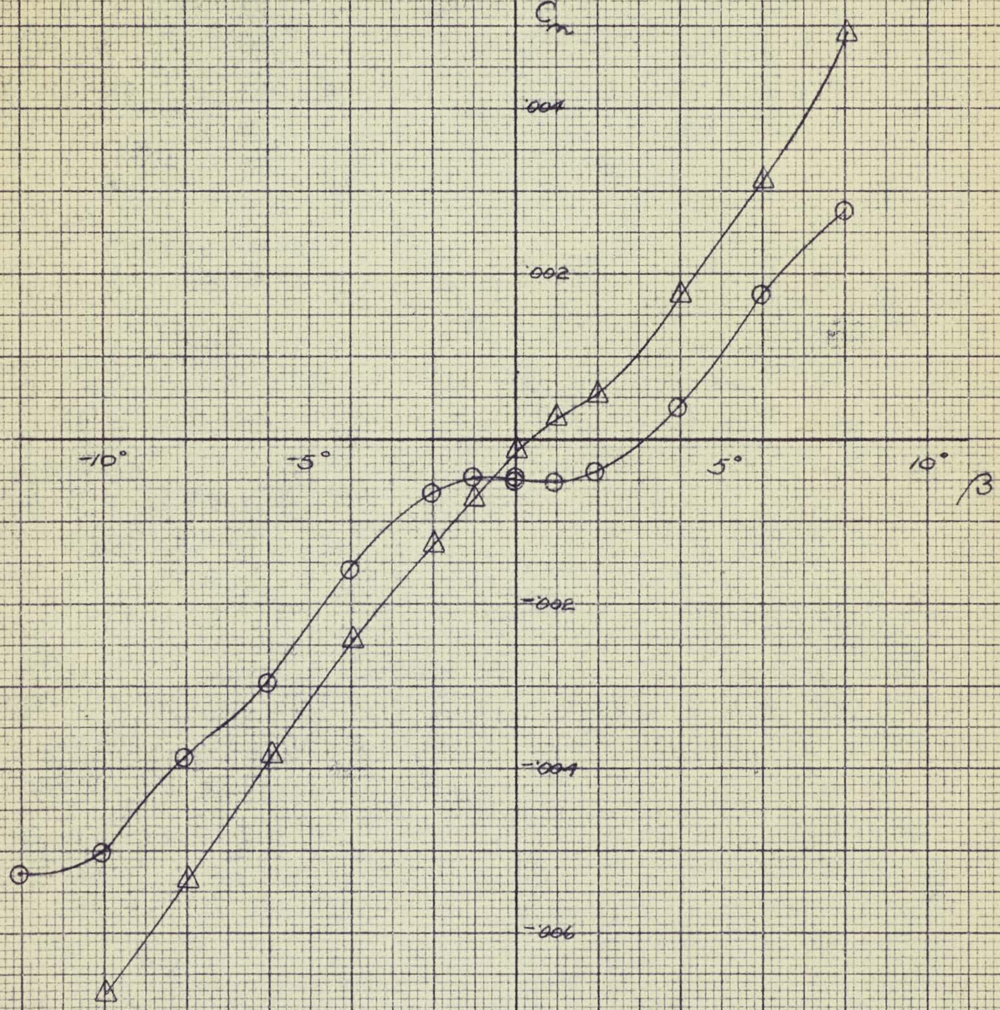
C.A.L. WIND TUNNEL TESTS

C_n vs β

$M = \cdot 9$

○ OPEN INTAKES RUN 718

△ FAIRED INTAKES RUN 914



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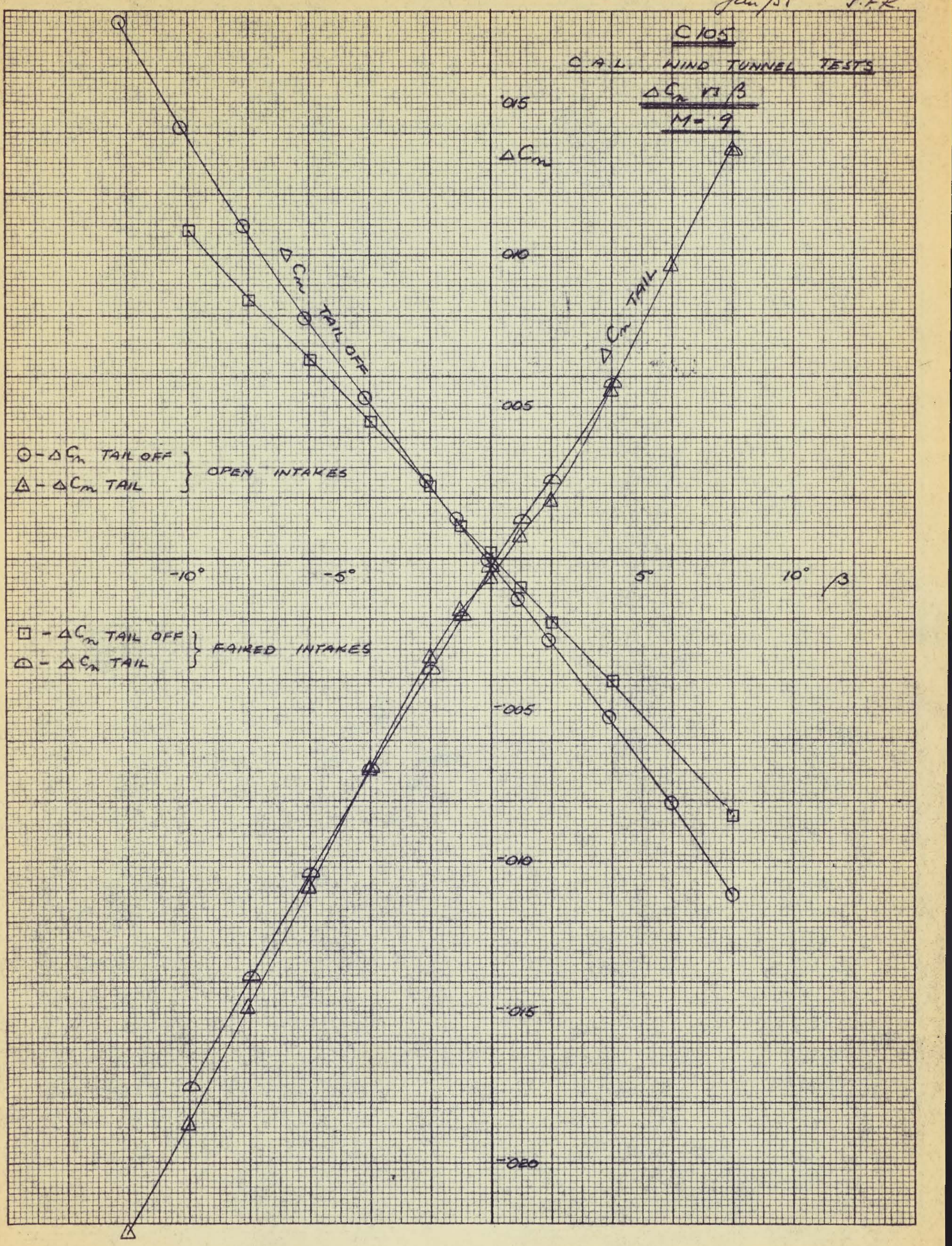
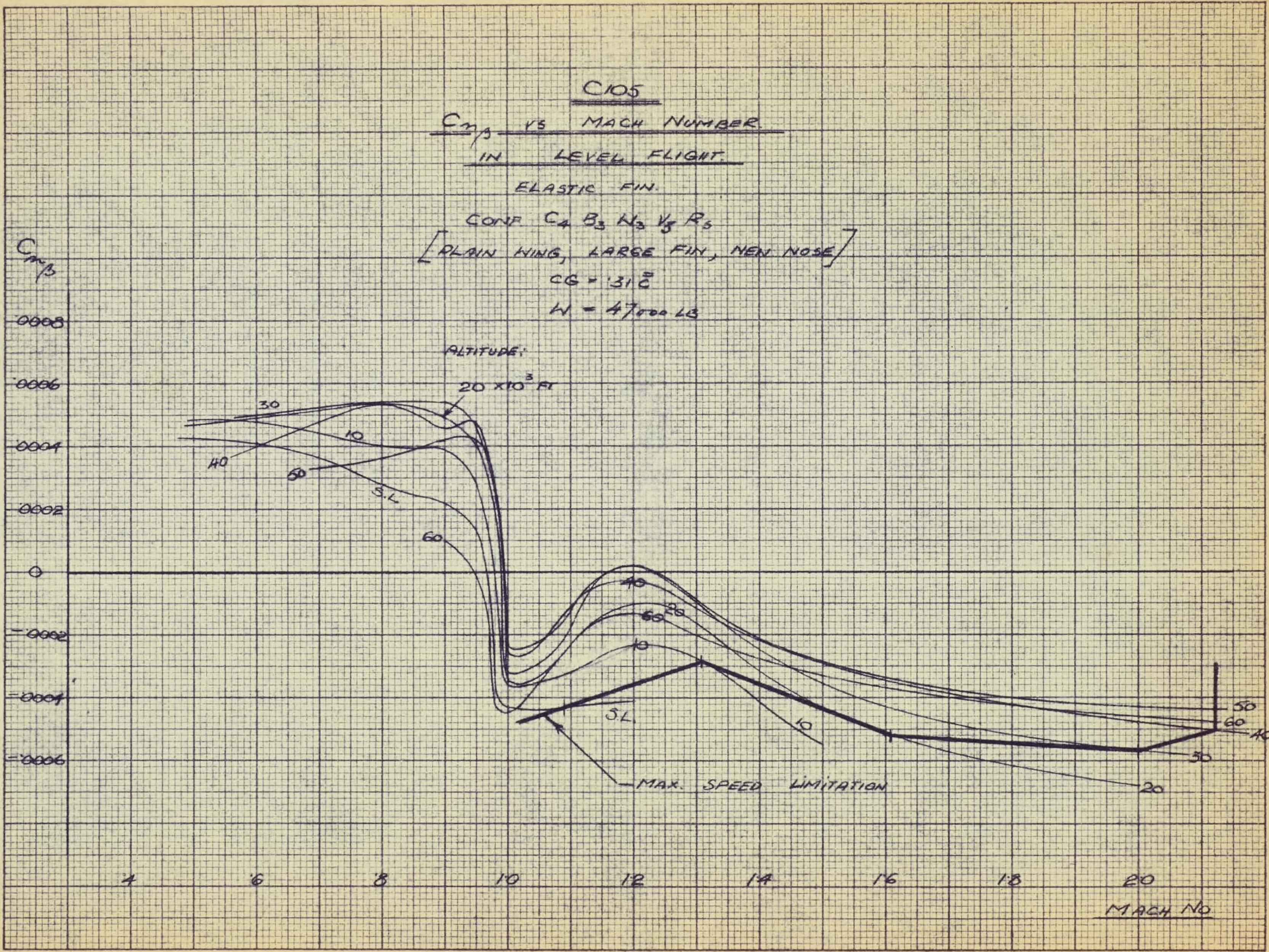

C 105
C.A.L. WIND TUNNEL TESTS
ΔCn vs β
M = .9
.015
ΔCn
.010
.005
-.005
-.010
-.015
-.020
-10°
-5°
5°
10°
β
ΔCn TAIL OFF
ΔCn TAIL
⊙ - ΔCn TAIL OFF
Δ - ΔCn TAIL
OPEN INTAKES
⊡ - ΔCn TAIL OFF
⊖ - ΔCn TAIL
FAIRED INTAKES



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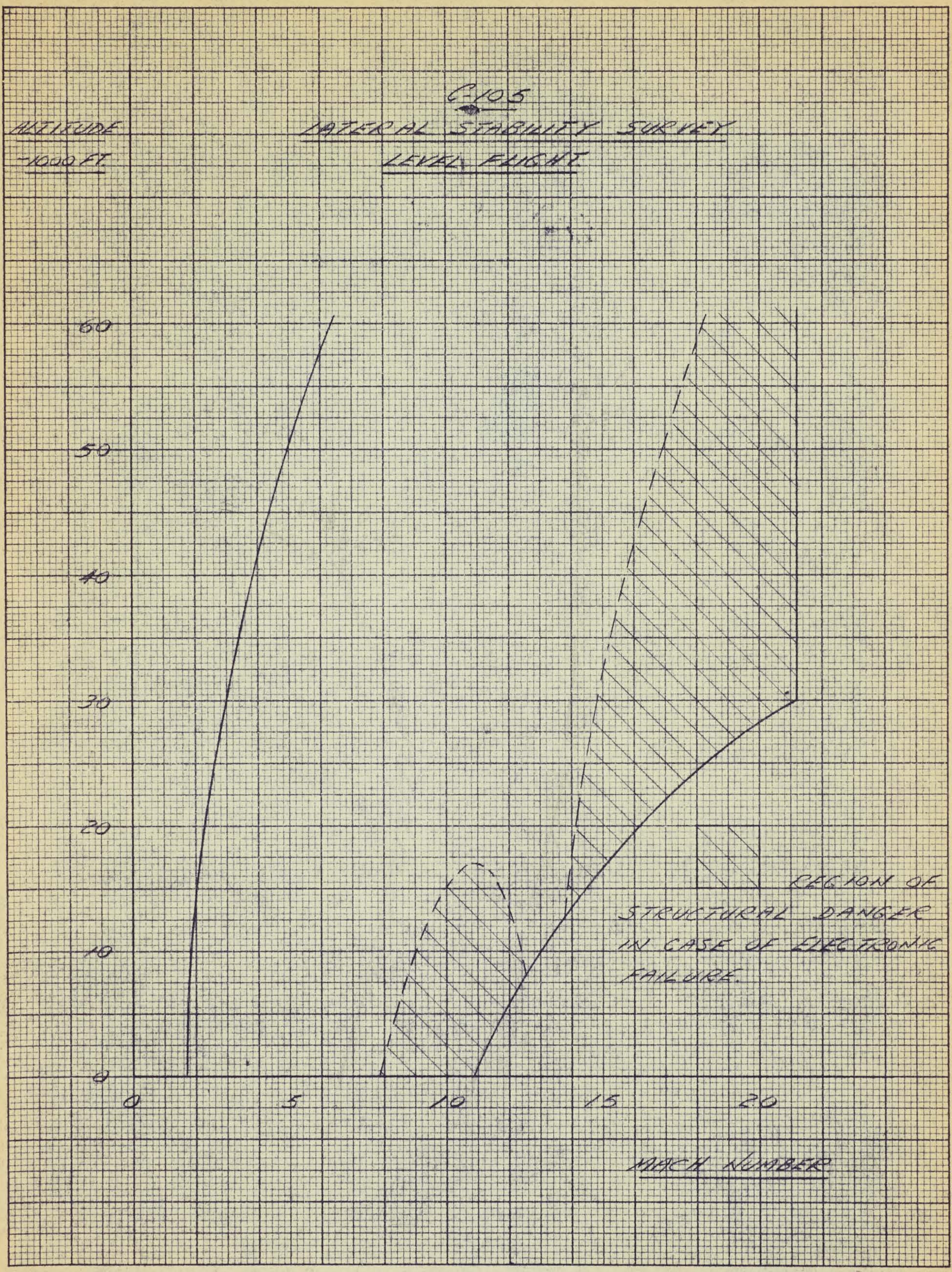
C-105
LATERAL STABILITY SURVEY
LEVEL FLIGHT
ALTITUDE
-1000 FT
60
50
40
30
20
10
0
0
5
10
15
20
REGION OF
STRUCTURAL DANGER
IN CASE OF ELECTRONIC
FAILURE.
MACH NUMBER