TL.114-53/03

PROJECT 'Y'

A Theoretical and Preliminary Numerical Study of Stability and Control

1. INTRODUCTION

The Project 'Y' design may be thought of as a very large conventional gas turbine engine laid out in an unconventional manner and essentially involving a large diameter engine rotor which flies edge-on to the wind instead of axially.

The polar moment of inertia of the rotor may be expected to be of the order of one-quarter of the polar moment of the rest of the aircraft in the gross weight condition. The gyroscopic reactions of this rotor - inherent to the design - have a dominant influence on the dynamic response to disturbances and on all the stability and control characteristics.

The coupling of the longitudinal and lateral equations of motion through precession is so powerful that the normal stability criteria such as static and manoeuvre margins lose their significance. For this reason, in view of the danger of being guided by pre-conceived ideas, this investigation has been pursued from first principles in an elementary manner.

2. SUMMARY

General equations of motion are first of all set up and then developed using wind axes. It is shown that the general complementary function can be obtained by multiplying out the 'normal' longitudinal and lateral equations and then adding the gyroscopic terms. Furthermore, it is shown that it is possible in some circumstances for the gyroscope to enforce a completely stable response on an aircraft with a so-called "negative static margin" by means of anhedral. This may be physically explained as a roll induced by a pitching couple leading to a "barrel downwards" motion with the precession providing counter action to the pitch; and presumably explains the flight of a clay pigeon. It also appears impossible for an aircraft which is "normally longitudinally unstable" to be fully stable unless it is also "normally laterally unstable".

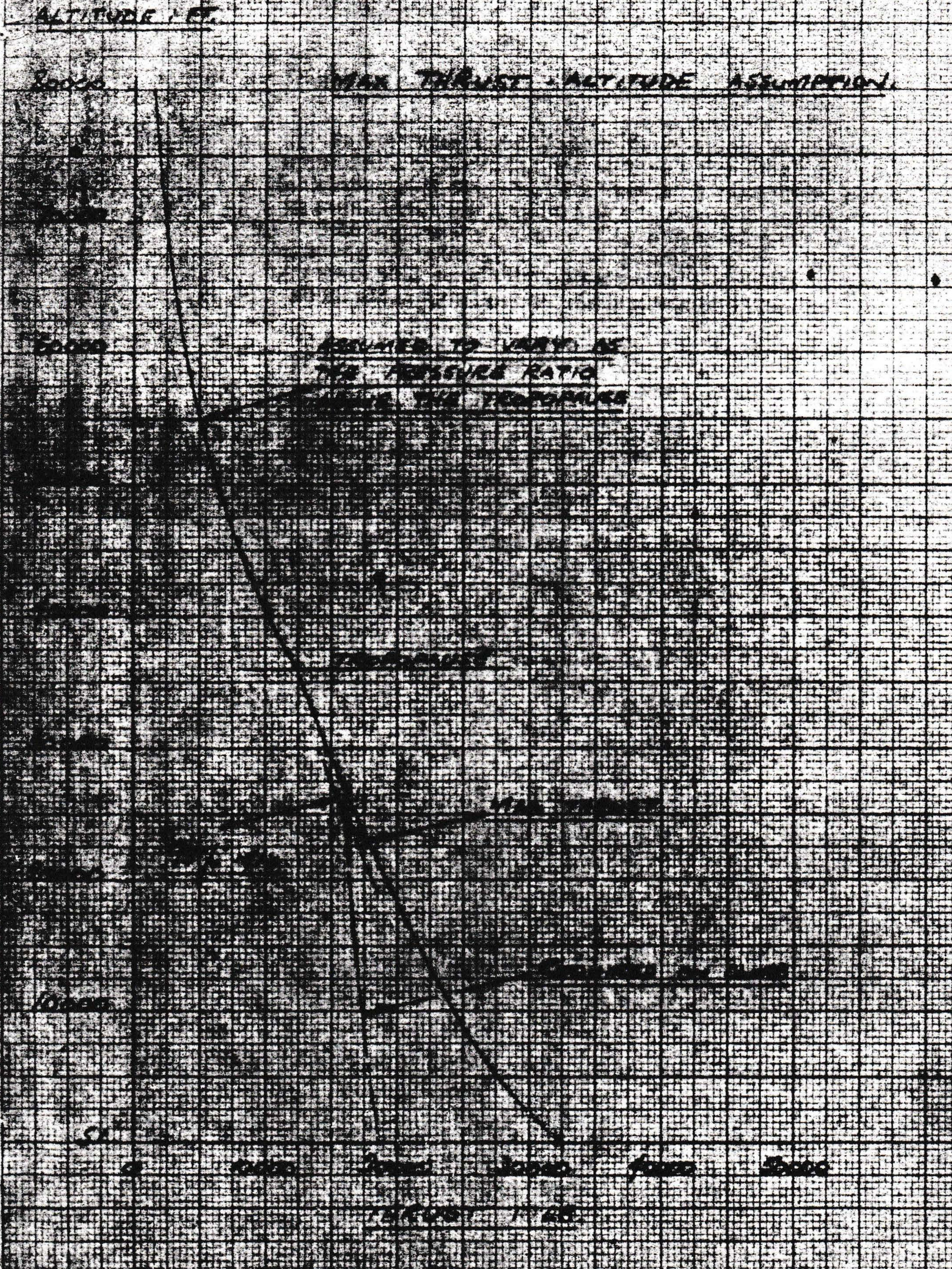
The equations are then set up for solving for given initial conditions for a typical gust case using Laplace transform notation.

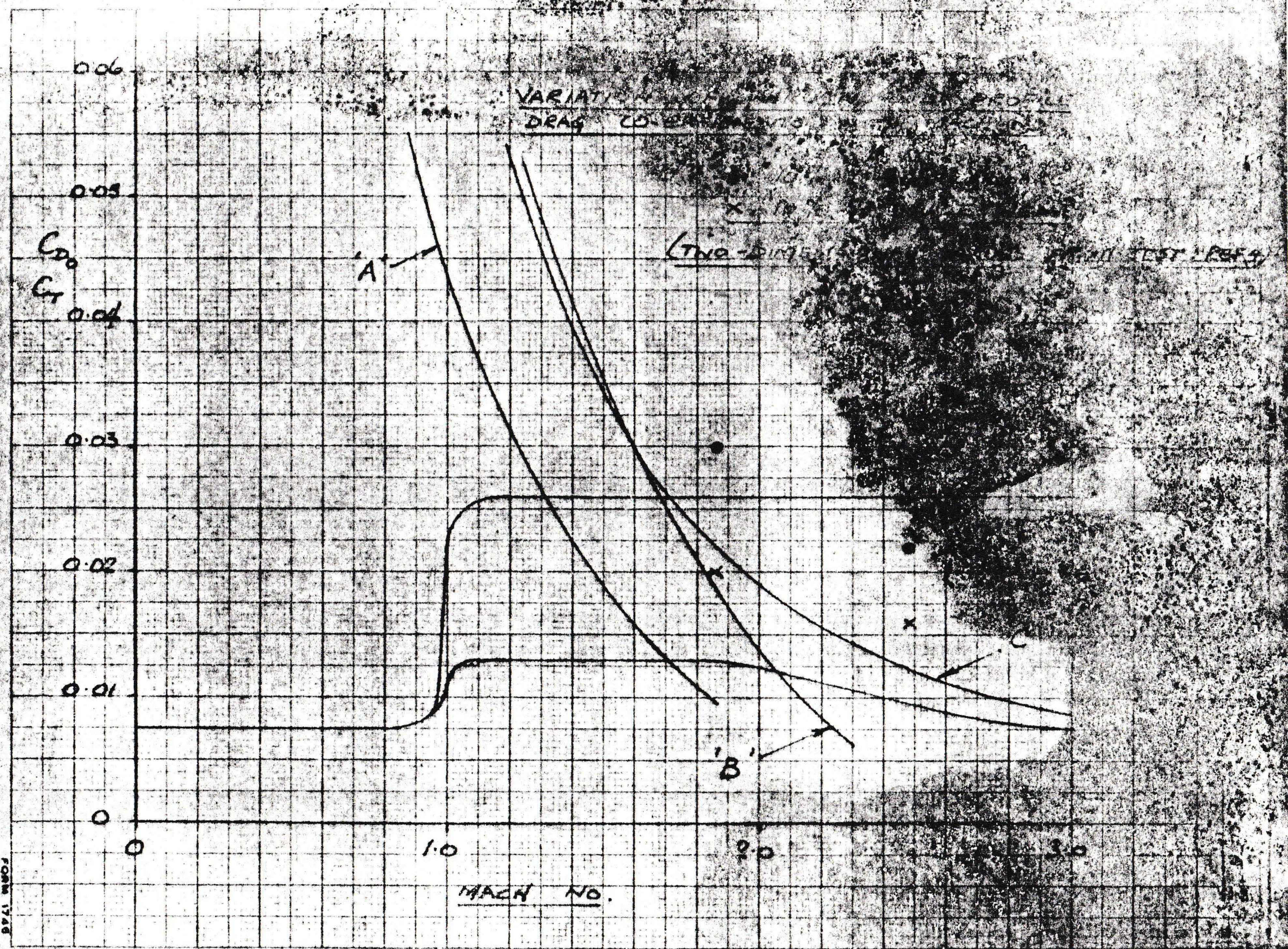
Finally the report includes some preliminary numerical analysis of selected cases using roughly estimated derivatives and varying the more important of these over a wide range. It appears that the two derivatives perhaps most easily under the designers control-of rolling moment due to sideslip or dihedral effect, (L_v) and yawing moment due to sideslip or weathercock stability (N_v) - have a very marked effect on response.

The nutatory mode or "wobbling" motion which may be set up in the rotor and which was pointed out in an independent report by Dr. S. Z. Mack is, in general, adequately damped. This mode is undamped at zero forward speed, being a pure gyroscopic effect. As would be expected the influence of the gyroscope is more pronounced at slow speed and high altitude where the relative density of the aircraft and gyro (compared with the air) is

AIRPLANE COMPONENT SHEET NO. ______ REPORT NO. ______
DATE ______ PREP. BY ______

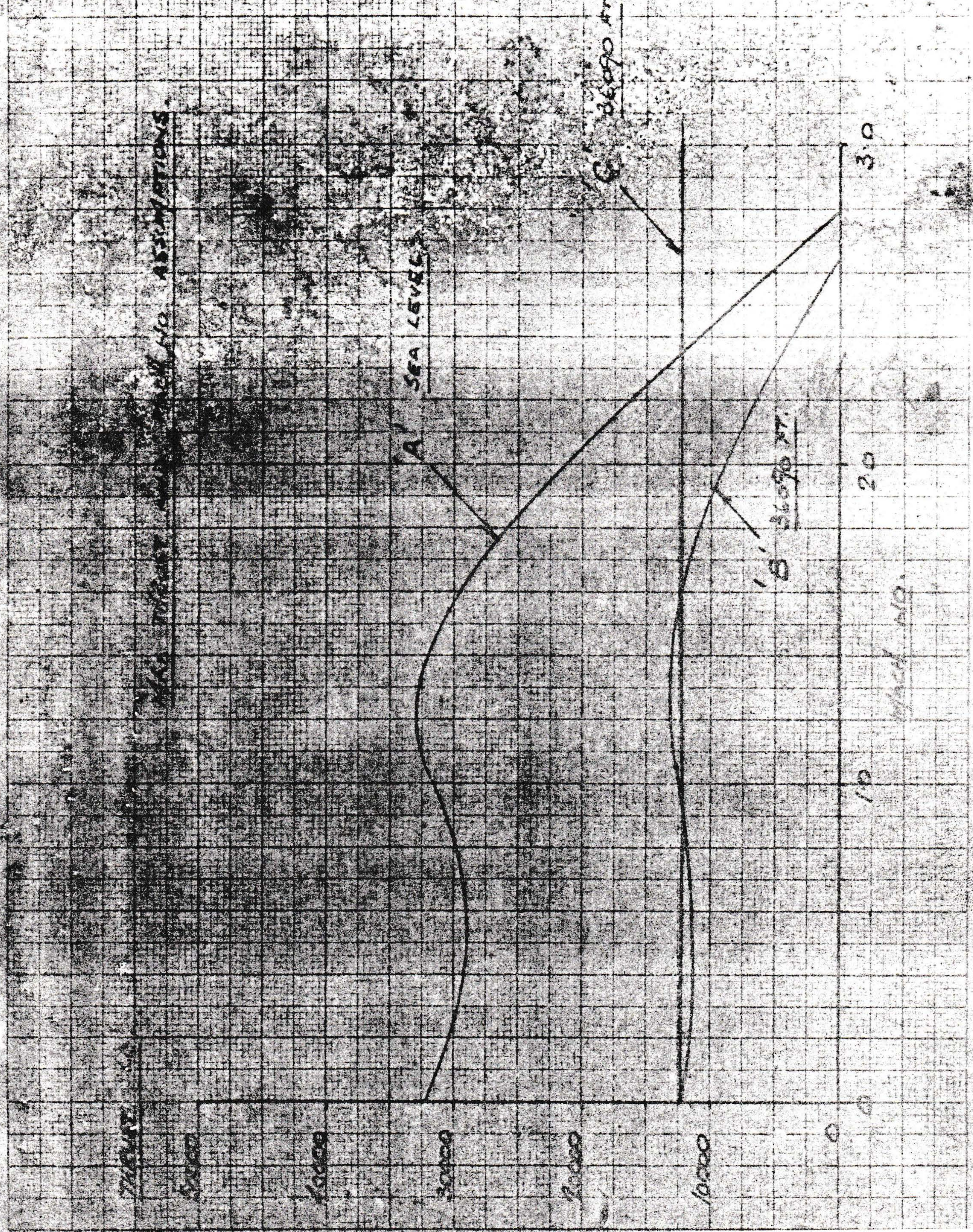
FIGURE 1.




VARIATI
DRAG CO-
(TWO-DIM
TEST · REF 4)
C_{D_0}
C_T
0.06
0.05
0.04
0.03
0.02
0.01
0
'A'
'B'
C
0
1.0
2.0
3.0
MACH NO.
FORM 1746

DATE ____________ PREP BY ____________

FIGURE 3

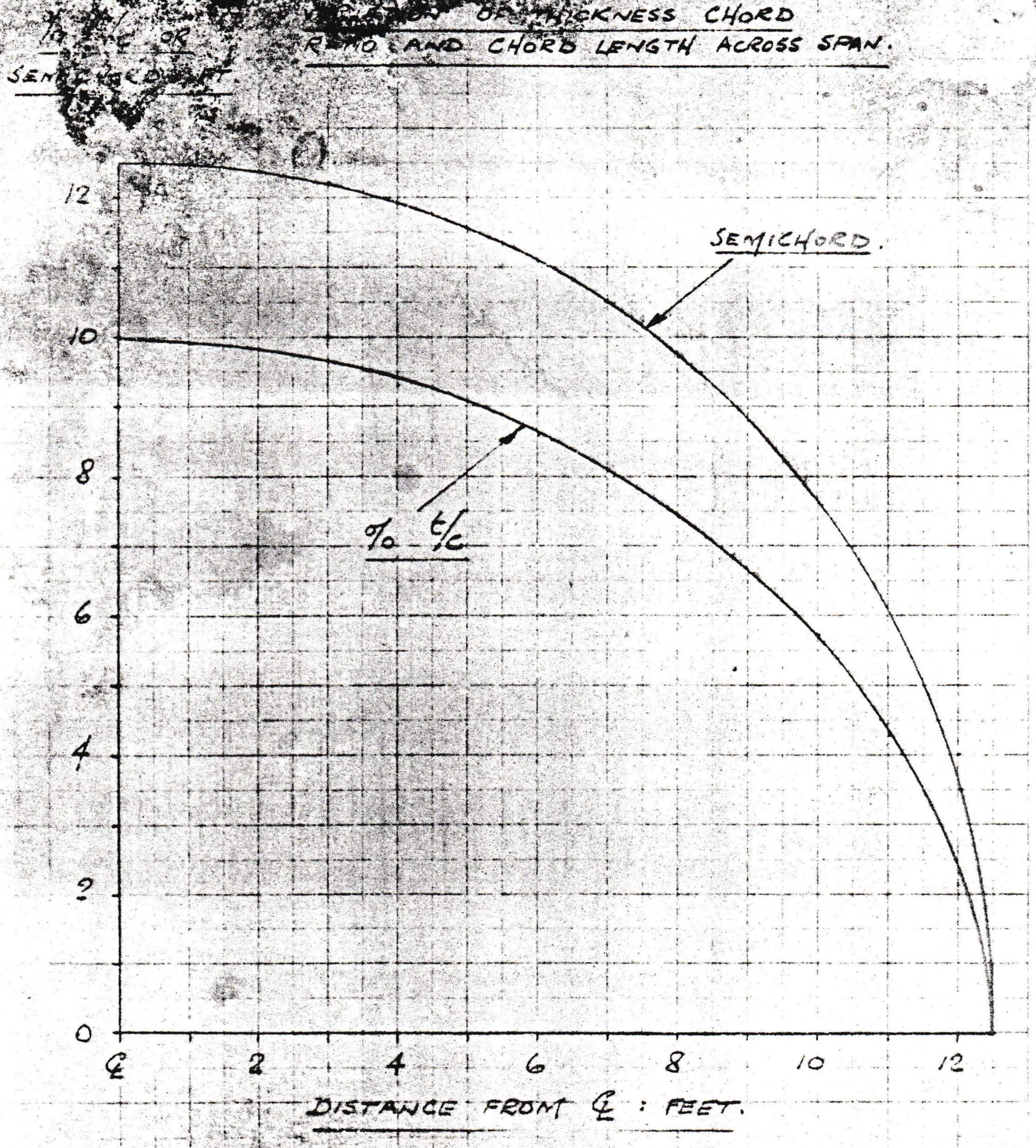


AIRCRAFT U.W. COMPONENT SHEET NO. DATE REPORT NO. PREP. BY

FIGURE 4

10% CIRCULAR ARC BICONVEX AIROFOIL OF CIRCULAR PLAN FORM

VARIATION OF THICKNESS CHORD RATIO AND CHORD LENGTH ACROSS SPAN.



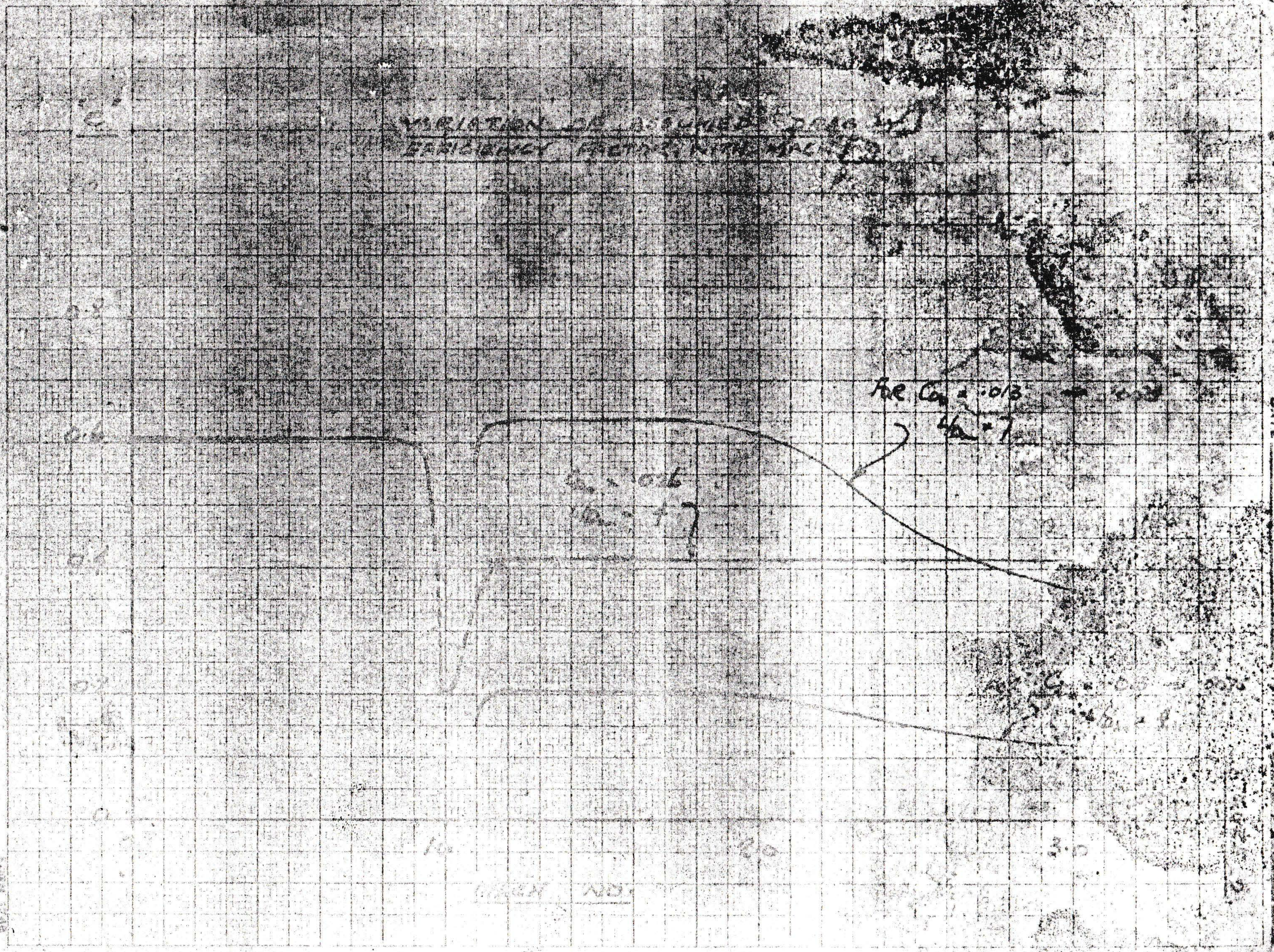
FORM 1746

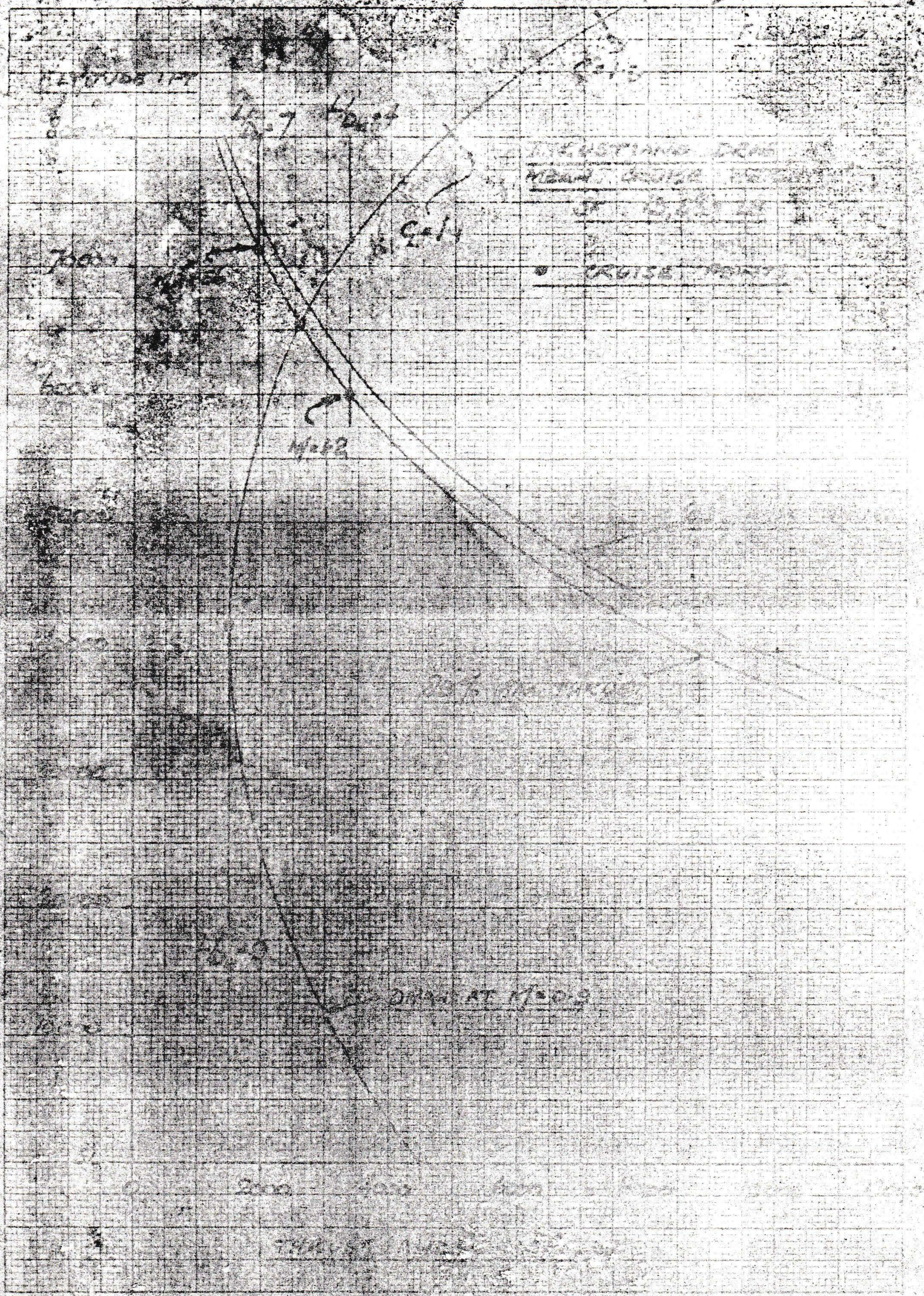
AIRCRAFT

COMPONENT

SHEET No.

DATE



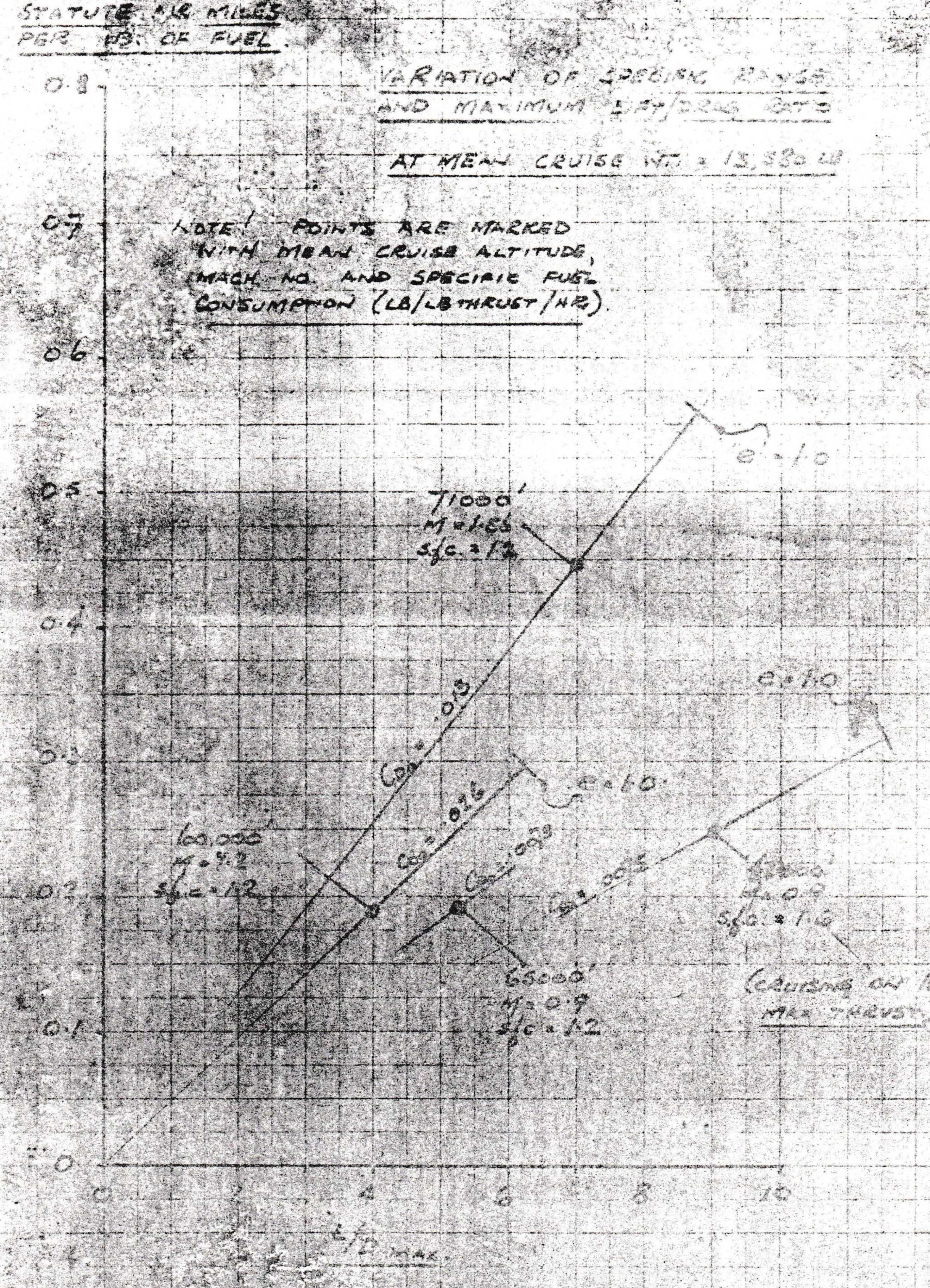


ALTITUDE FT
CRUISE POINTS
DRAG AT M=0.9
0
2000
4000
6000
THRUST LBS

DATE ______ PREP BY ______

FIGURE 7

VARIATION OF SPECIFIC RANGE AND MAXIMUM LIFT/DRAG RATIO AT MEAN CRUISE WT = 13,380 LB



AIRCRAFT F.A.U.W. | COMPONENT | SHEET No. | REPORT No. | DATE | PREP BY

FIGURE 8.