71/FAR/54

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STRUCTURAL INTEGRITY PROGRAM

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ANALYZED

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AVRO AIRCRAFT LIMITED

MALTON - ONTARIO

TECHNICAL DEPARTMENT (Aircraft)

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AVRO AIRCRAFT LIMITED
MALTON – ONTARIO

TECHNICAL DEPARTMENT

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INDEX

LIST OF FIGURES

2. INSTRUMENTATION

The aircraft instrumentation for the structural integrity demonstration program will consist of the following parameters some of which will be presented on telemetry and others recorded on data tape and/or oscillographs:

2.1 General aircraft data:
Speed, altitude, control motions, accelerations and angular rates.

2.2 Elevator control box deflection indicator.

2.3 Strain-gauged control power jacks for control hinge moment measurements.

This instrumentation may be implemented for investigation of specific problems if and when required.

3. FLIGHT ENVELOPE

The combined flight envelope for altitudes up to 40,000 feet is shown on figure 1, for an aircraft weight of 60,000 lb. It can readily be seen that at Mach Numbers above approx. 1.2 the hinge moments limit the maximum available normal load factor to 4.25 "g" with minor exceptions. For the sake of ease of presenting of these limitations to service pilots, it is proposed that the flight envelopes be restricted by an identical straight line at 4.25 "g" or n W = 255000 whichever is smaller above M = 1.15 at all altitudes. Above 30,000 ft. at Mach Numbers greater than 1.15 the aircraft will be limited automatically to smaller values due to hinge moment and elevator deflections limit. The controllability considerations suggest a cut-off at 5 "g" or n W = 300000 whichever is smaller at Mach Numbers below 1.15. The combined envelope for structural integrity demonstrations will therefore be as indicated on fig. 1. Figs. 2 - 8 show individual flight envelopes for each altitude.

3. FLIGHT ENVELOPE (Continued)

Since the aeroplane will not be cleared for spinning and/or stalling for considerable time yet the low speed boundary will be $C_L = .7$ corresponding to angle of attack of approx. 15° to 17°. These limitations are also shown on individual envelopes. Shaded areas represent the difference between the structural design envelope and flight demonstration envelope.

4. TEST POINTS FOR NORMAL LOAD FACTORS

Nine test points have been selected and are shown on fig. 9. These are listed in order in which the tests will be carried out:

POINT	MACH NO.	ALT.	MAX "G"	KNOTS E.A.S.	MAX. α
1	.7	7500	5	400	11°
2	.9	10000	5	490	7°
3	1.15	12500	5	600	5°
4	1.25	40000	4.00	360	11°
5	1.25	30000	4.00	450	8°
6	1.25	20000	4.25	560	6°
7	1.6	35000	4.00	520	5°
8	1.15	4500	5	700	4°
9	2.00	40000	4	570	6°

want 1st envelope

COMMENTS

1. – Subsonic max load factor initial test point.

2. – Subsonic max "g" – critical case for "g" limiter since elevator effectiveness is the highest.

3. – Transonic max. "g" at high E.A.S.

4. – Max. elevator angle at high hinge moment and high "g".

5. – Max. elevator hinge moment, also critical point for elevator control box loads.

COMMENTS: (Continued)

6. - Max. elevator hinge moment at high E.A.S. and at max. "g".

7. - Max. hinge moment, high supersonic Mach Number.

8. - Max. "g" at maximum E.A.S.

9. - Max. "g" at highest Mach Number.

5. TEST PROCEDURE - Normal Load Factor

For extension of the flight envelope in normal load factors the following procedure will be adopted.

5.1 Complete static test aircraft tests (pull-up and check pitching manoeuvres).

5.2 Complete static test and/or B-1 rig tests for maximum hinge moments and jack stalling characteristics.

5.3 Obtain measurements of elevator hinge moments and control box deflections in flight at flight conditions resulting in relatively moderate hinge moments (50 - 70%).

5.4 Obtain from flight tests information on variation of aerodynamic derivatives with angle of attack.

5.5 Check all intended manoeuvres in excess of 4 "g" on flight simulator to establish the safest damper configuration.

5.6 Perform demonstrations in flight in steps starting at n W = 250000 subsonically and n W = 200000 supersonically (above M = 1.15) at points shown in paragraph 4.

5.7 Demonstration of maximum "g" will be combined with functional demonstration of the "g" limiter system.

6. OTHER TESTS

6.1 Roll rates of the order of 120° to 150°/sec. will be demonstrated in flight. To perform these manoeuvres it is necessary to activate ay-limiter and have a fully developed roll damper. Simulator studies will determine the exact maximum limits and conditions for these manoeuvres.

6.2 Fin loads will be demonstrated to approximately 60% of structural design limit load in the course of damper development. This will represent conditions of automatic change over from normal to emergency damper mode. Final assessment of conditions cannot be undertaken until dampers are fully developed.

6.3 Elevator hinge moments will be demonstrated to full design value of 60,000 lb.ft.

6.4 Rudder and aileron hinge moments will be flight tested to approximately 80% of design limits. In practice, it is extremely difficult to obtain steady states necessary to achieve maximum design limits on rudder and ailerons. The test will represent stalled jack conditions with finite rate of movement. To obtain the hinge moments on the rudder, rudder kicks and/or damper step switches will be used.

6.5 Rolling pull-outs.
The approximate limitations for rolling pull-out manoeuvres will be:- nW = 200,000 up to 90°/sec. Exact flight conditions will be determined on the flight simulator.

6.6 Checked pull-ups and push downs.
These manoeuvres will be demonstrated at conditions specified for steady pull-ups and push downs in Section 4.

6. OTHER TESTS (Continued)

6.7 All remaining manoeuvres specified by MIL - S - 5711 either do not apply to Arrow configuration or do not produce loads not covered by the cases listed above.

6.8 Limitations of the manoeuvres described above are not final and result mainly from an inadequate information on crosscoupling effects, variations of derivatives with angle of attack, damper performance, control system behaviour etc. and not from Structural considerations.

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7. REMARKS

a/c should be annotated now

7.1 Due to differences in performance, minor structural details and weight and c.g. balance it is planned to conduct a suitable demonstration program on an Arrow 2 aircraft at a later date.

7.2 The tests will be performed with the c.g. range available e.g. it will not be possible to cover the full nominal c.g. range at each flight condition because fuel requirements will not permit the necessary ballasting.

7.3 The "g" limiter action can result in loads in excess of demonstration limit but inside of the structural limit. The cases exceeding demonstration limit will be kept to a minimum.

7.4 It should be noted that the apparent reduction in the rolling pull-out manoeuvre is compatible with the reduction in subsonic normal load factor. It is expected that this limit will be extended at least in some regions of the flight envelope as soon as rudder monitor and a_y limiter are finalised.

7.5 Figure 10 shows a typical "g" response to a ramp input in stick force. To exceed the command limit by pilot's effort requires a minimum stick force of 70 lb. The exact value of stick force necessary to overpower the servo and the rate of "g" build up afterwards will be different in each flight condition and will also depend on the magnitude and rate of stick force application. It should be noted that overpowering of the servo is a dangerous procedure since the "g" limiter may be tripped and this will result in a sudden lightening of the stick force and a corresponding increase in "g's".
Figure 10 shows also the elevator motion corresponding to a ramp stick force input. The elevator motion definitely stops when the command limit is reached and further increase in force (up to approximately 70 lb.) will not produce any response. This fact will provide to the pilot a very definite indication of reaching the command limit.

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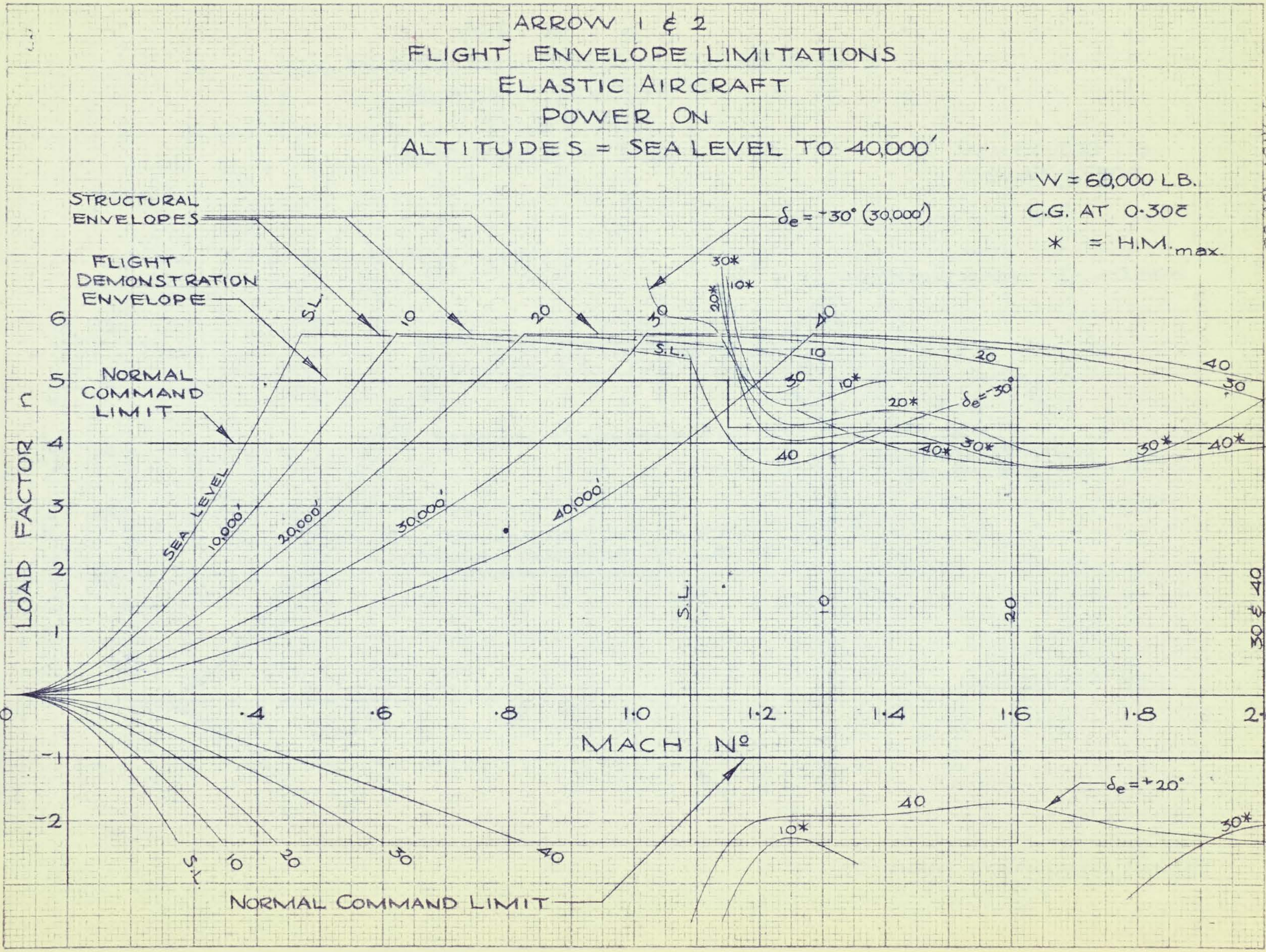
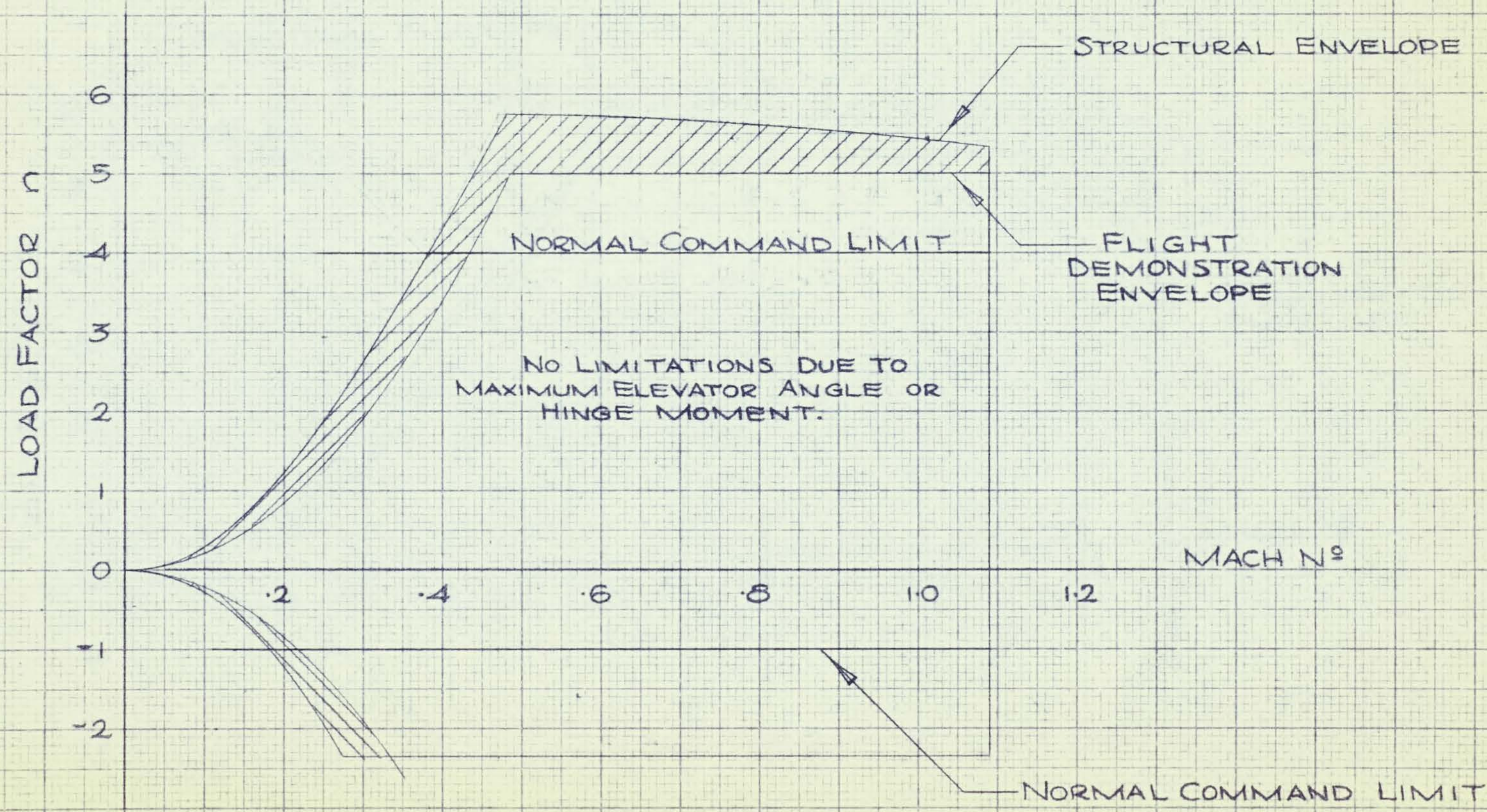


71/FAR/54 FIG. 1

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

ARROW 1 & 2
FLIGHT ENVELOPE LIMITATIONS
ELASTIC AIRCRAFT
POWER ON
ALTITUDE = SEA LEVEL

W = 60,000 LB.
C.G. AT 0·30 $\bar{c}$

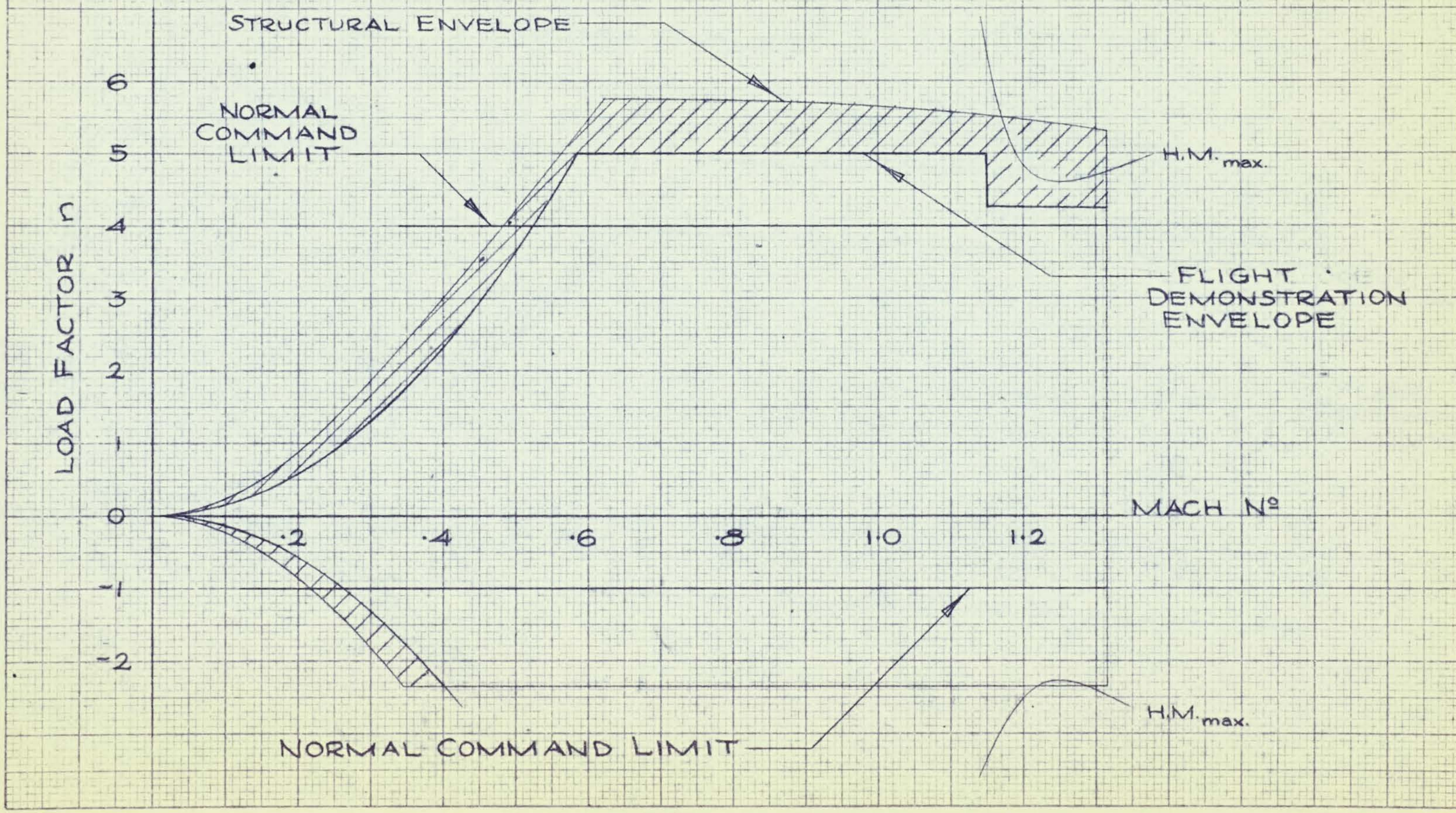


H.H.S. Nov/58

71/FAR/54 FIG. 2

ARROW 1 & 2
FLIGHT ENVELOPE LIMITATIONS
ELASTIC AIRCRAFT
POWER ON
ALTITUDE = 10,000 FT.

W = 60,000 LB.
C.G. AT 0·30 c̄



N.H.J. Nov/58

71/FAR/54 FIG. 3

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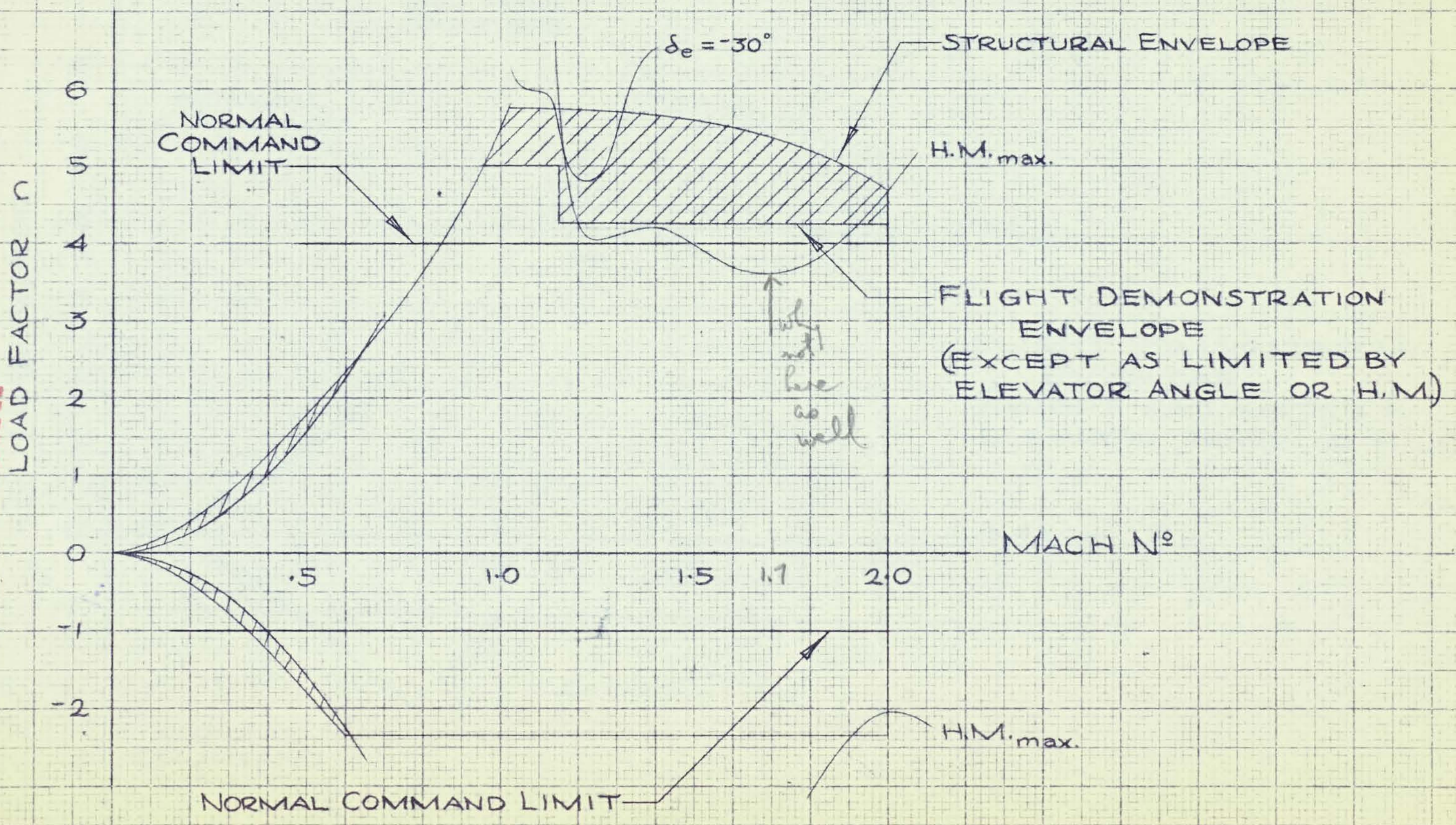
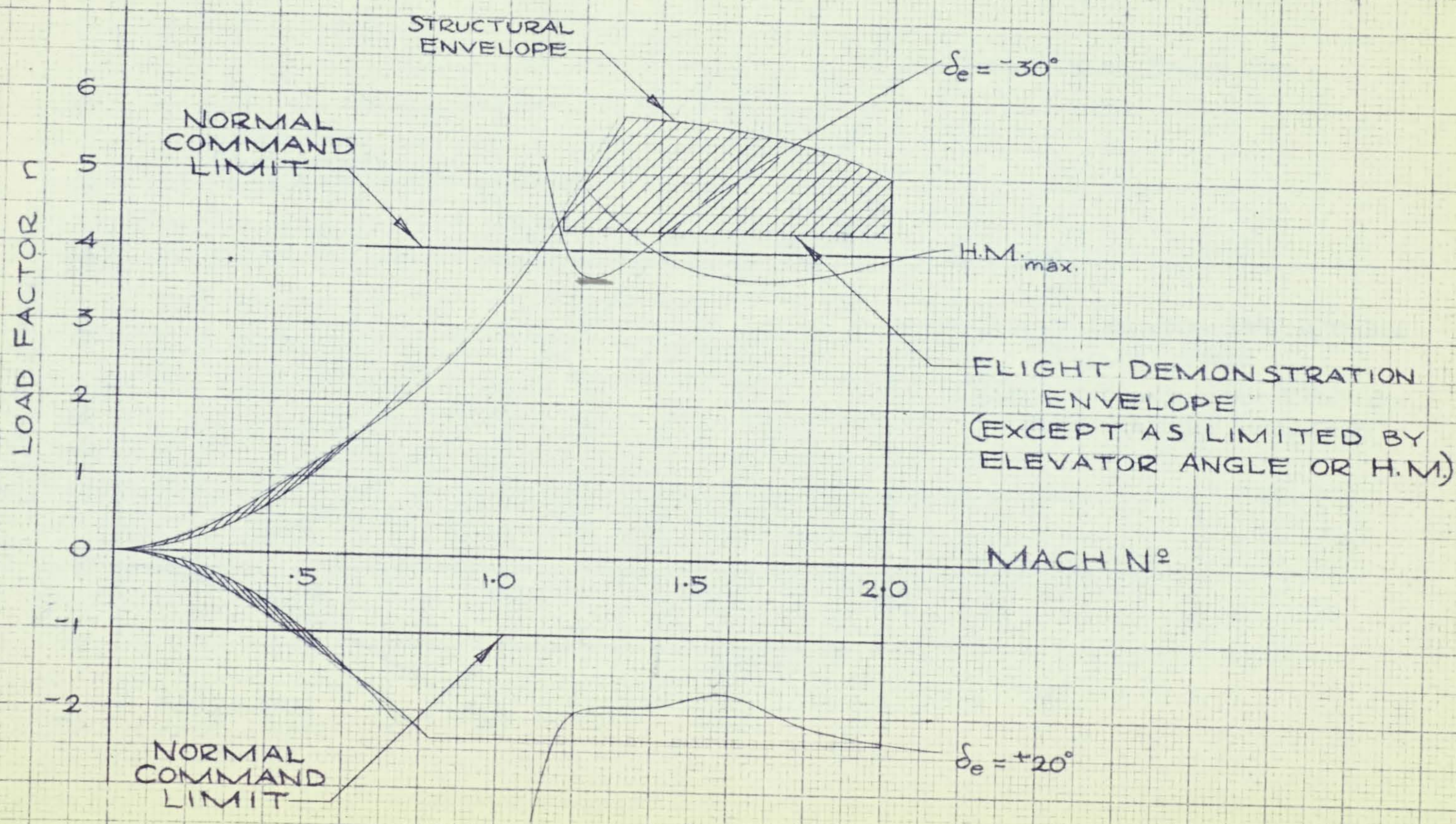
ARROW 1 & 2
FLIGHT ENVELOPE LIMITATIONS
ELASTIC AIRCRAFT
POWER ON
ALTITUDE = 30,000 FT.

W = 60,000 LB.
C.G. AT 0·30 $\bar{c}$



ARROW 1 & 2
FLIGHT ENVELOPE LIMITATIONS
ELASTIC AIRCRAFT
POWER ON
ALTITUDE = 40,000 FT.

WT. = 60,000 LB.
C.G. AT 0·30 c̄



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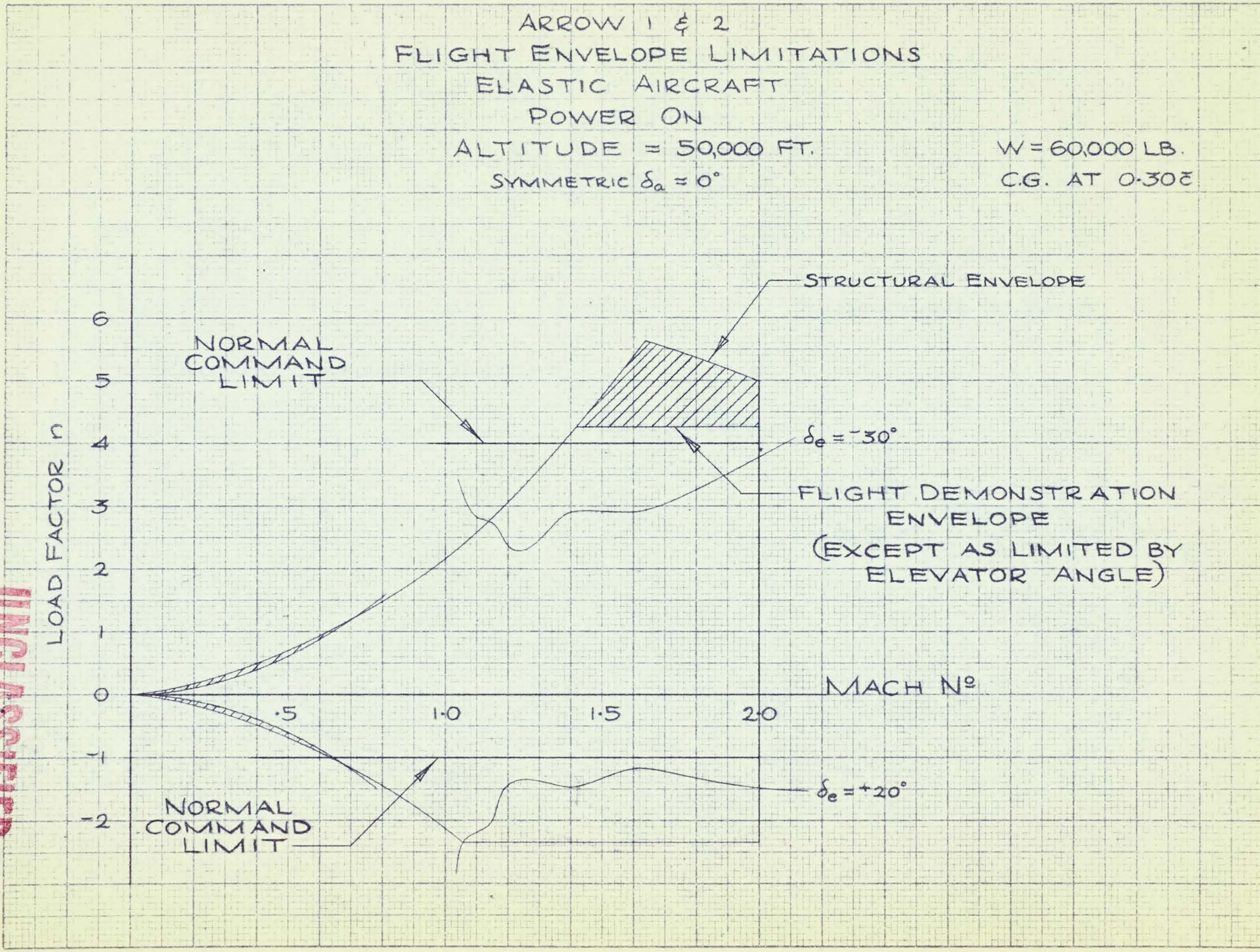
71/FAR/54 FIG. 6



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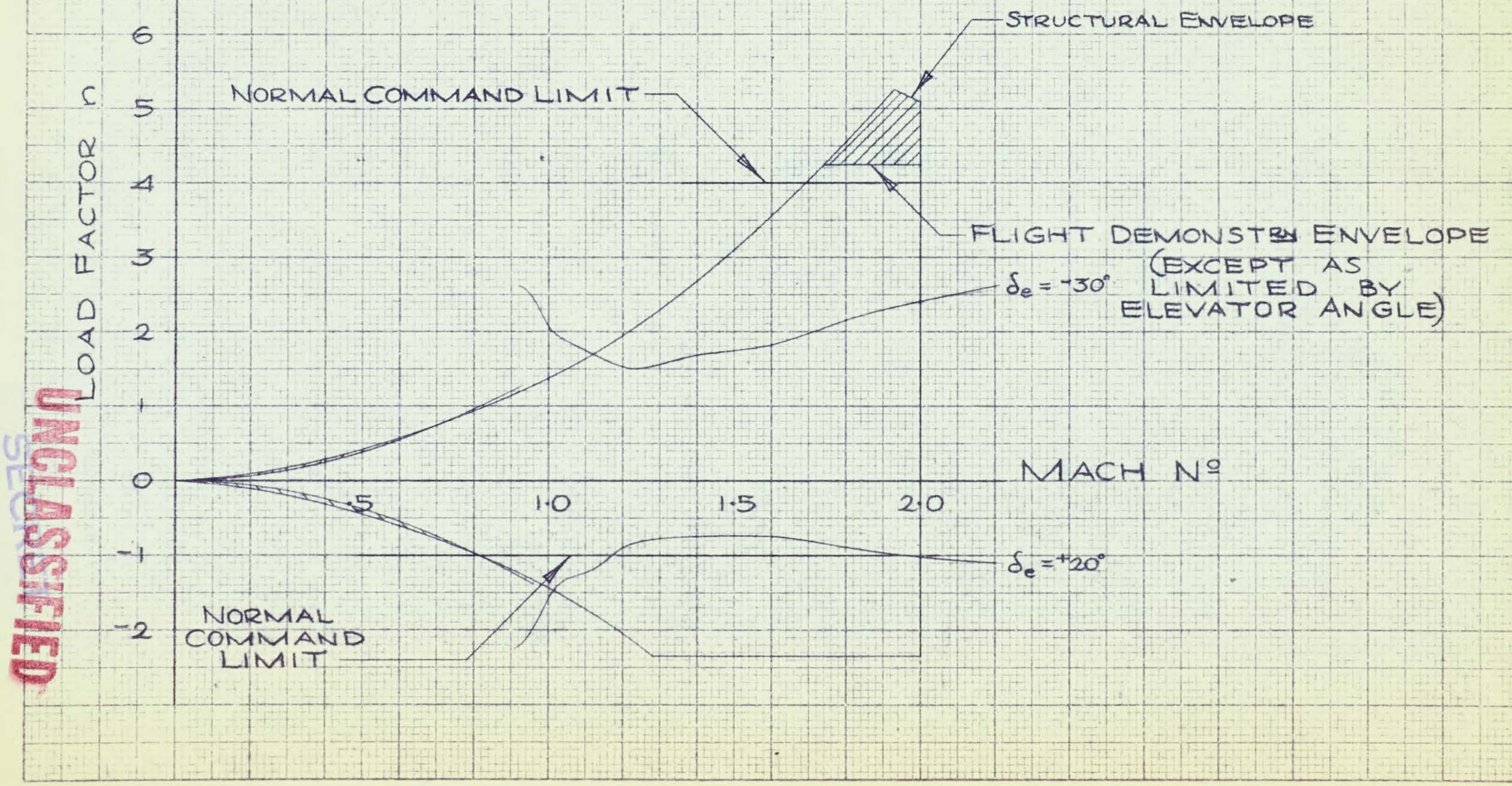
71/FAR/54 FIG. 7

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

ARROW 1 & 2
FLIGHT ENVELOPE LIMITATIONS
ELASTIC AIRCRAFT
POWER ON

ALTITUDE = 60,000 FT. W = 60,000 LB.
SYMMETRIC $\delta_a = 0°$ C.G. AT $0{\cdot}30\bar{c}$



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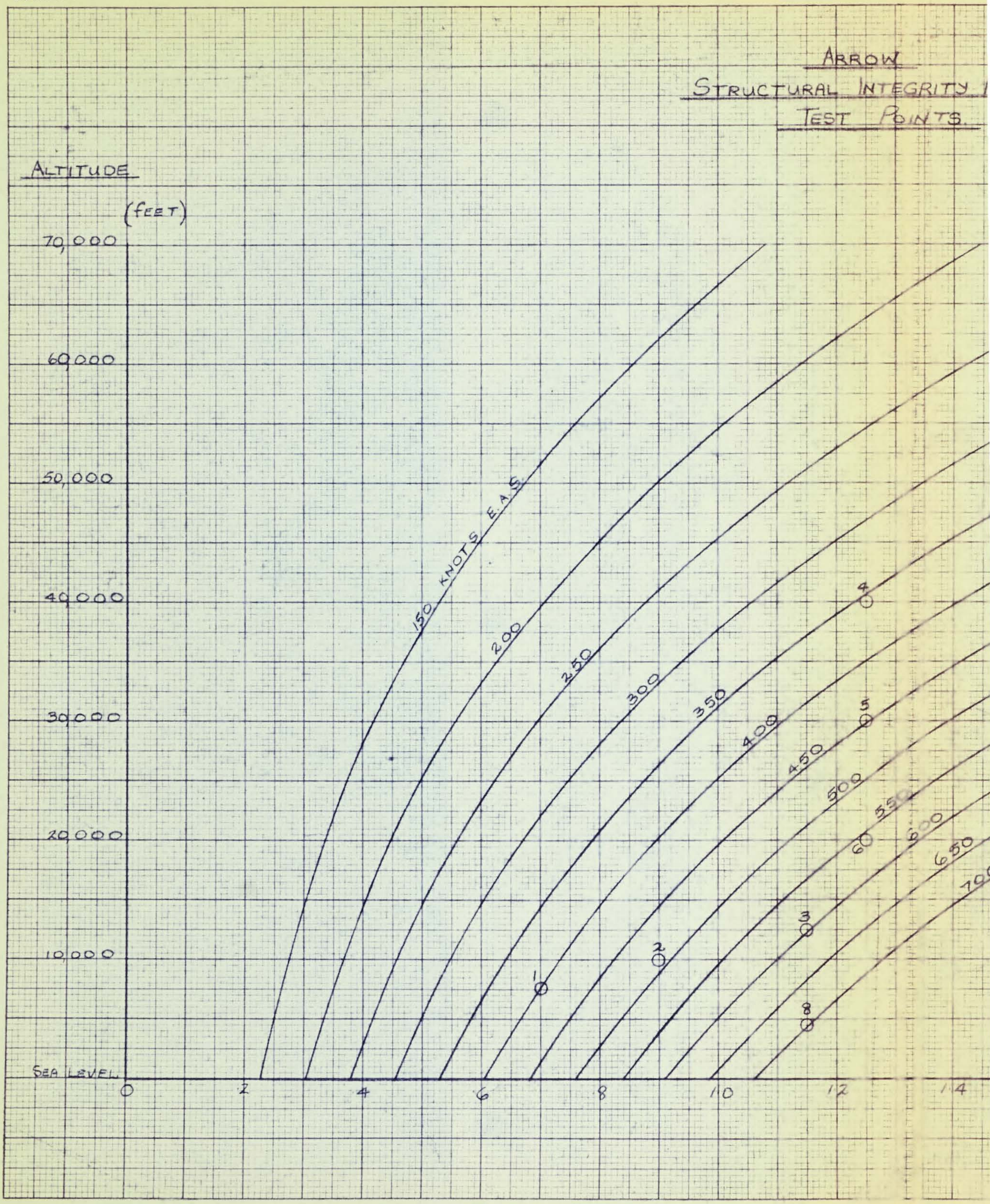
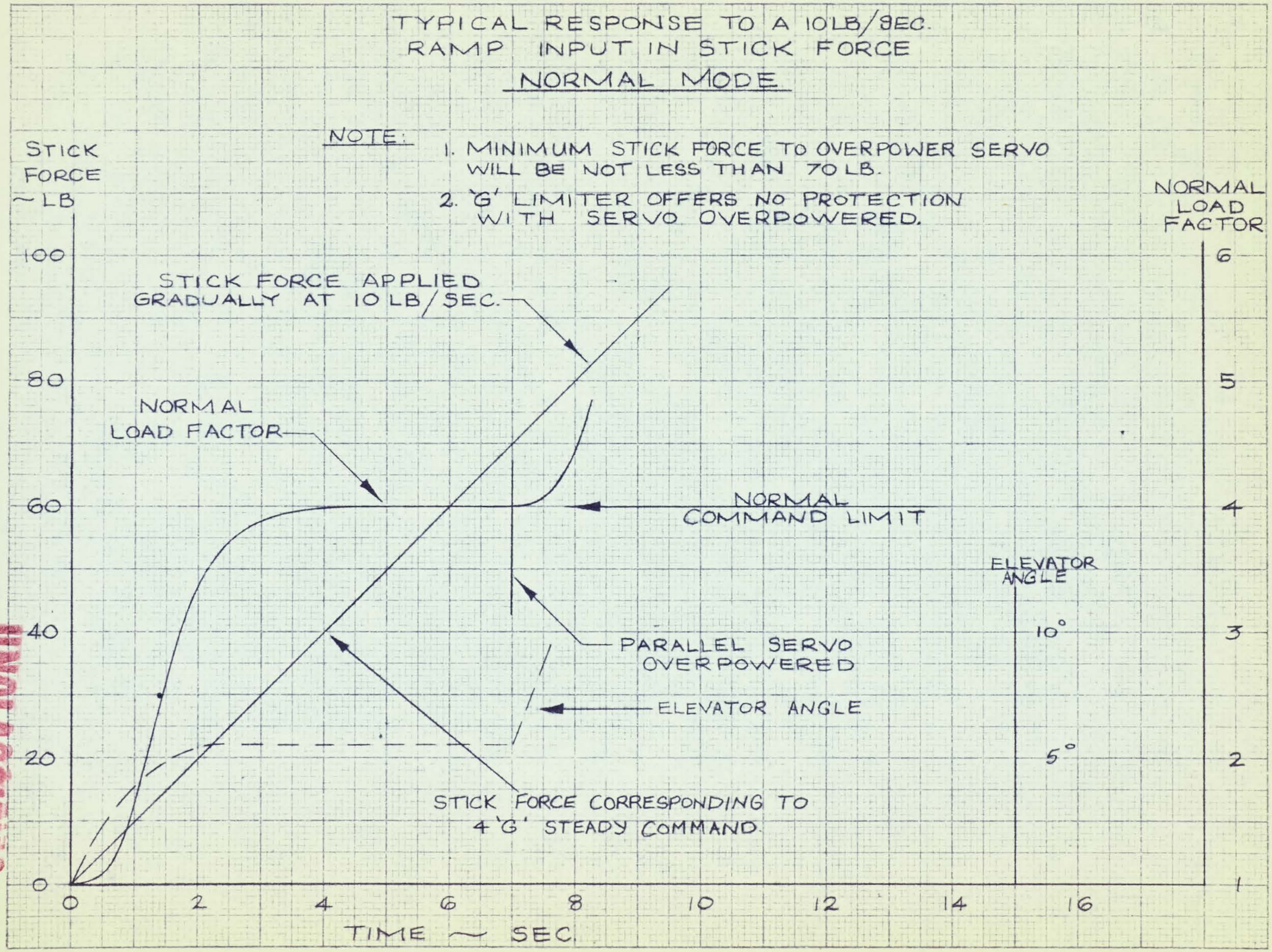
71/FAR/54 FIG. 8


ARROW
STRUCTURAL INTEGRITY
TEST POINTS.
ALTITUDE
(FEET)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
SEA LEVEL
0
2
4
6
8
10
12
14
150 KNOTS E.A.S.
200
250
300
350
400
450
500
550
600
650
1
2
3
4
5
6
8



71/FAR/54 FIG. 10