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Issue 2

FLIGHT TEST REQUIRED FOR STABILITY AND CONTROL AND DAMPER DEVELOPMENT

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STABILITY AND CONTROL AND DAMPER

The attached report no. 71/FAR/23, issue 2, specifies the testing required on the above aircraft.

Instrumentation required for this work is as specified in I.D.M 7963/02A/J, sections 1 and 2. Instrumentation changes will be specified as and when required.

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NO. OF SHEETS 40

FLIGHT TESTS REQUIRED FOR STABILITY AND CONTROL AND DAMPER DEVELOPMENT

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SUMMARY

The following report presents the tests required to determine the basic Stability and Control qualities of the Arrow 1, with and without augmented Stability, and to effect development and evaluation of the Damper Systems. In this issue the manoeuvres and extent of flight conditions have been modified in the light of initial flight tests of the Arrow 1.

This is therefore a statement of what is required by way of flight tests, without suggesting the exact order in which these tests be performed.

Section 3 of this report includes those additional test requirements necessary to assess compliance of the Arrow 1 with U.S.A.F. MIL F-8785, as discussed in the applicable Avro Model Specifications and Report P/Aero Data/89.

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INTRODUCTION

In this Issue, which supersedes Issue 1, some of the manoeuvres and flight conditions have been modified, in the light of recent initial flight tests on the Arrow 1. Such modifications were made for reasons of flight safety, and for economy of test deemed possible from some quite promising comparisons of early test results with estimates. Slight changes have also been made to the methods of test analysis, due to developments in that field.

The report is in three Sections. Section 1 covers Damper Optimisation. Section 2 the basic Stability and Control tests, and Section 3 the additional tests required to demonstrate compliance with Mil. F-8785.

Damper Optimisation should be effected at the flight conditions (approx. 10) listed in the manner shown. In addition, the damper performance should be checked at the remaining flight conditions which cover the flight envelope, as outlined in Section 1.

Damper tests mentioned in 1/5, switching and limiting tests, will be phased in at a later stage of the flight test programme, along with structural integrity tests to comparable loads. (See Ref. 9)

To determine Stability and Control qualities of the basic Arrow 1 without damper system, and in order to permit optimisation of the damper, the basic Stability and Control tests of Section 2 should be conducted in conjunction with the Damper Development tests and suitably phased in with Structural Integrity Tests.

Section 3 of this report calls for tests which cover Stability and Control or handling of the Arrow 1 to satisfy fully the requirements of USAF Military specifications Mil. F-8785 with the minimum of flight tests. For this purpose the Arrow 1 will be tested using mainly two control systems, Normal and Emergency, while Alternate Emergency will also be tested. A good proportion of the tests outlined in Section 3, will be performed in the course of tests for Section 1 or vice versa.

Those additional tests which may be required to permit design of a fully representative Arrow flight simulator will be included in a later issue, to be requested when the need arises.

Flight conditions, quoted in coded form, are given as five number groups. The first two numbers represent the altitude in thousands of feet, the last three the Mach Number to two decimal places.
e.g. 20.070 represents 20000' M = 0.70

When referring to tests in this report the Section number will precede the Item number, separated by a "stroke".
e.g. 2/3.14 refers to Item 3.14 of Section 2.

Dampers, when engaged, will be in "Gear Up" mode unless it is specifically denoted "Gear Down".

SECTION 1

FLIGHT TESTS REQUIRED FOR DAMPER DEVELOPMENT

AND EVALUATION

1. GENERAL DISCUSSION

The objective of the flights on the development damper is to determine the "best" compromise of performance for the damper operation. The objective can be broken down into the following parts:

(a) Functioning of design damper features.

(b) Assessment of handling for all damper modes.

(c) Determination of gain margin

(d) Assessment of safety features

(e) Evaluation of damper changes

The damper development program is broken down into two phases consisting of:

(a) Preliminary adjustments and functioning in order to achieve a flyable damper configuration.

(b) Continous improvement and evaluation of the system until the design requirements have been met.

Flight test results from these two phases will be evaluated with respect to the results obtained on the Arrow Simulator. Before any changes are made to the aircraft damper configuration simulator investigations will be conducted. Flight tests will be conducted at standard flight conditions so that results can be correlated.

2. STANDARD FLIGHT TEST CONDITIONS

There are 52 standard flight conditions for which tabulated simulator data is available. Approximately ten of these conditions are used as reference points for detailed study.

The 52 flight conditions given as True Mach No. and altitude, at which tests may be made are:

Minimum * Safe Test Altitude	10000′	20000′	30000′	40000′	50000′	60000′
Low Speed Condition	0.4	0.4	0.4	0.6	0.8	1.0
0.400	0.7	0.7	0.6	0.8	1.0	1.03
0.500	1.0	0.9	0.8	1.0	1.4	1.15
0.600	1.15	1.15	1.0	1.15	1.6	1.4
0.70	1.3	1.40	1.15	1.4	1.8	1.6
0.95		1.60	1.4	1.6	2.0	1.8
1.0			1.6	1.8		2.0
1.03			1.8	2.0		
1.05			2.0			
1.075						
1.09						

* Simulator data available for Sea Level at these Mach No.

These flight conditions were chosen as representative of particular aerodynamic and system characteristics.

The reference points are:

10000′	20000′	30000′	40000′	50000′	60000′
1.15	Low Speed Condition	.80	.98	1.4	Unkown, depends on Performance.
	.7	1.60		1.8	
	1.0				
	1.4				

These reference points may be changed as further tests on the aircraft and simulator progress. (See Figure 1)

3. HANDLING OF AIRCRAFT

The handling of the aircraft can be divided into several aspects as follows, tests will be performed in order to assess each characteristic.

(a) Engage and disengage of damper.

(b) Transfer from gear up to gear down mode.

(Cont'd)

(c) Configuration and Power Effects

(i) Speed Brakes

(ii) Single Engine

(iii) Afterburner

(d) Ease of trimming for level flight and stick feel.

(e) Pull ups and accelerated turn.

(f) Partial rolls and continous rolls.

(g) Landing and Takeoff.

(h) Rolling Pullouts.

Handling tests for damper evaluation will be specified with respect to each flight as a result of prior testing on the simulator. A reasonable amount of testing associated with damper handling can be evaluated during normal flying without specific tests. (See tests of Section 3) Specific tests will only be required in order to establish and verify questionable results. Steps will be required in all axis (Δn command, rudder angle and p command) in order to determine damped aircraft frequency and damping.

4. GAIN MARGIN TESTS

The object of these tests is to determine the suitability of gain schedules and adjustments. Gain adjust knobs are provided so that gain changes can be made quickly and easily. Specific simulator checks will be made, taking into account all the avaialable information at the time of the test, in order to determine the expected allowable gain changes and the specific values to be tried. The general procedure will be to trim aircraft, apply step, observe result, increase gain, apply step observe result etc, until the information required is obtained. For the majority of the gain margin checks an observer will be required. The gain margin will be checked at the critical flight cases depending on the axis and the relationship between expected derivatives and actual derivatives. Approximately ten flight conditions will be chosen.

Gain margins will be determined on the following parameters:

Pitch axis	Δn	$\delta_e n$
	q	$\delta_e \int qH$
	$\delta_e \int n$	$\delta_e q$

4.0 (Cont'd)

Roll axis	$\delta_a p$
Yaw axis normal	$\delta_r a_y$
	$\delta_r r$
	$\delta_r \delta_{aq}$
	$\delta_r \delta_a$
Yaw axis emergency	$\delta_r a_y$
	$\delta_r r$
	$\delta_r \delta_a$

5.0 ASSESSMENT OF SAFETY FEATURES

The object of these tests is to develop and evaluate the safety features on the damper. These safety features are:

		Estimated Number of Flights
(a)	Ay roll rate limiting	5
(b)	Roll rate disengage	3
(c)	Rudder monitor	5
(d)	Auto-trim	3
(e)	Command limiters	2
(f)	G Limiter	10

In those cases where it is applicable the safety features will be evaluated by reducing the limit value to a safe level, and testing around this level. As more information becomes available these limits will be raised to their design values. In some cases the test associated with the safety features will produce high stresses and therefore these tests will not be detailed until structural integrity information becomes available. (See Ref. 9)

6.0 FLIGHT REQUIREMENT

The flight requirements are broken down into their respective objectives.

(a) Functioning of design damper features 10 flights

6.0 (Cont'd)

		10 flights
(b)	Assessment of Handling	
	Detailed investigation at twelve flight conditions	30
	Check evaluation at fifty flight conditions	10
(c)	Gain Margin Tests	10
(d)	Assessment of Safety Features	28
(e)	Evaluation of Damper Changes (Due to hyrdaulics etc.)	5
		93

The total number of flights should be reduced considerably by suitably combining more than one objective on each flight. On the other hand only one damper development objective may be scheduled with other flight requirements. Many of the tests of Section 3 can be performed in the course of those in this section, and vice versa.

GENERAL NOTES

It is assumed that all the data required by Table 4 and Table 5 of 71/FAR/12 "Reduction of Flight Test Data for Stability and Control Analysis" will be supplied by Flight Test on compatible data tape to Digital Computing, together with necessary calibration data. Computed and corrected data of Table 4 and Table 5 of 71/FAR/12 will be analysed by the second stage Digital Stability Analysis programmes.

In general, it is more important to hold constant Mach Number in a test, and to climb or dive slightly to achieve this. Where constant I.A.S. is required this is specified.

When producing disturbed aircraft motions by movement of elevators or rudder, care should be taken to move only elevators or only rudder. With movement of ailerons however, it may be specified that rudder be moved to maintain zero sideslip. In this way, unless aerodynamic or inertia coupling is encountered, the disturbed motion should be in either longitudinal or lateral modes, without combinations of the two, thus simplifying analysis.

Where * appears beside a flight condition, this denotes that the condition is an intermediary one to check that the trend of stability is as estimated. At these conditions pilot to perform only the abrupt stick deflection (and return) of manoeuvre 1 (a), and manoeuvre 1 (d). Pilot to await request from Operation Room to proceed to higher Mach Number at this altitude; telemetry must be functioning to permit assessment of aircraft motion at these conditions.

Analysis of natural aircraft, lateral and longitudinal oscillatory response with the controls fixed will be made by the methods given in Ref. 2 and Ref. 3; where the controls are moving during the manoeuvre, analysis will be by the methods of Ref. 4 and Ref. 5. Data from steady state flight tests will be analysed for stability derivatives by Ref. 8 and Ref. 13 and for control hinge moment derivatives by Ref. 6 and Ref. 7. Hinge moment derivatives with controls moving should also be obtained from Refs. 6 and 7.

These are all digitally computed programmes, using digital input data which is corrected on the basis of instrument calibration then processed for data reduction (Ref. 1). Ref. 8 is also set up for hand computation in the initial stages of testing.

The analysis programmes of Refs. 2, and three are self checking. In addition, Refs. 4 and 5 can provide aircraft responses from the derivatives obtained, to compare directly with actual responses. (This facility also has application to analytical studies and prediction of response at other conditions) .

Comparisons with flight test will also be made directly with predicted stability and control qualities of the Arrow.

Natural aircraft stability derivatives obtained from these tests will be used by Analog Computing Section to obtain revised responses with dampers engaged, and to speed optimisation of the damper system.

1. NATURAL AIRCRAFT STABILITY, 1g FLIGHT

At each flight condition with aircraft trimmed for straight and level flight, pilot to determine response of aircraft to gentle control motions. Then to perform the following manoeuvres.

(a) Normal Damper engaged, Yaw axis only.

Deflect stick forward and backward to produce alternate 0.g and + 2g, for a period of approximately 5 seconds, ending with an abrupt stick deflection with abrupt return to neutral, producing an instantaneous 2g to 2.5g. Allow subsequent oscillation to decay, with stick in neutral position.

(b) Normal Damper engaged, Yaw Axis only.

(i) Roll from ϕ = + 30° to -30° and back to + 30° at 30°/sec. max. rate approximately.

(ii) Then from ϕ = + 30° to -30° and back to + 30° at approximately 45°/sec. max. roll rate.

(c) Dampers OFF

Perform either of the following, choice to be made in pre-flight briefings:

(i) Deflect rudder to produce positive sideslip and release pedals. (Do not exceed 40% of permissable β)

or, (ii) Deflect ailerons to produce a dutch rolling oscillation. Return controls to neutral and release.

In order not to exceed bank limits the manoeuvre should be started from a banked position. It is important that stick and pedals should be left free as the oscillation decays, or for at least three complete oscillations where this is possible, recovering earlier when the aircraft attains an undesirable attitude.

1.1 Performed Manoeuvres 1 (a) to 1 (c) at Flight Conditions-

10.070	(D)
30.095	(D)
50.115	(D)
10.100	
10.115	(D)
20.090	
20.115	
30.100	
30.115	

1.1 (Cont'd)

40.100
40.115
50.100
50.140

Note: (D) denotes condition at which damper is optimised

1.2 Perform Manoeuvres 1 (a) to 1 (c) at Flight Conditions:

10.040
20.040 (D)
20.070 (D)
30.045
30.060
40.060
40.070
50.070
50.080

1.3 Perform Manoeuvres 1 (a), 1 (b), and when specified by Technical Design, 1 (c)

* (50.150)
50.160 (D)
* (40.130)
40.140 (D)
* (40.150)
40.160
* (30.130)
30.140
* (30.150)
* (20.130) only if specifically requested by Technical Design

* ( ) Intermediary condition at which handling should be checked by small disturbance of controls by pilot, in the course of approaching the condition of higher speed at the same altitude.

1.A Rolls to 90° of Bank

At each of the following conditions, aircraft to be trimmed for straight and level flight, Normal Damper ON, then rolled the short way round to 90° bank, then back the short way to wings level.

10.070
10.100
10.115
20.040
40.115
40.140
40.160

1.B Gross-wind Landings

At 10,000 feet damper OFF perform simulated circuit for cross-wind landing, with overshoot. Note height lost during recovery action.

Perform landings in cross-winds of approximately 15k and 25k components normal to runway. Use Damper OFF.

Repeat using Emergency Damper Gear DOWN mode. Overshoot if necessary.

2. NATURAL AIRCRAFT STABILITY, 2g FLIGHT

At each of the following limited flight conditions, with aircraft trimmed into a steady 2g turn descending where necessary to maintain Mach Number, pilot to determine response of aircraft to gentle control motions. Then to perform the following manoeuvres:

(a) Normal Damper engaged, Yaw Axis only

Deflect stick forward and backward produce alternate 1g and 3g, for approximately 5 seconds ending with an abrupt stick deflection and abrupt return to trim position producing instantaneous 3g. Allow oscillations to decay with stick in trimmed position.

(b) Damper OFF

(i) Deflect rudder to produce 10% or less of maximum permissable β in a direction which tends to roll out of turn and release pedals. Leave both stick and rudder pedals free as oscillation decays.

(ii) Repeat (i) to 30% or less of maximum permissable β.

2.1 Perform Manoeuvres 2 (a), (b) except where shown at Flight Conditions

10.100	
10.115	
20.090	
20.115	2(a), 2(b)(i) only
30.095	
30.115	
40.100	
40.115	
40.140	2(a) only

2.2 Perform Manoeuvres 2a, 2b, except where shown, at Flight Conditions

10.070	
20.070	
30.060	2(b) only
30.080	
40.080	2(b) only

2.3 Perform Manoeuvres 2a, at Flight Conditions:

*	(20.130)
	20.140
*	(30.130)
	30.140
*	(30.150)
	30.160
	40.150
*	40.160
	(40.170)
	40.180

* ( ) Intermediary conditions as in 1.3

3. NATURAL AIRCRAFT STABILITY - LOW SPEED

3.1 Check low speed handling generally in decelerating flight at a convenient altitude below 20000' to determine Minimum Safe Flying Speed (vs) in knots I.A.S.

3.1.1 with L/G UP, approach power

3.1.2 with L/G UP, power idle

3.1.3 with L/G DOWN, approach power

3.1.4 with L/G DOWN, power idle

In each configuration assess onset of buffett or tendency for wing drop or other stall warning. Approach Vs cautiously.

At each flight condition, with aircraft trimmed for straight and level flight, pilot to determine response of aircraft to gentle control motions. Then to perform manoeuvres as shown.

3.2 Landing gear UP

3.2.1 Perform Manoeuvre 1(a), 1(c), and also operate δr_t:

3.2.1.1 At 160k E.A.S. but limiting incremental "g" to $\pm$.5g or onset of moderate buffet and sideslip to 20% max. permissable.

3.2.2 Perform Manoeuvres 1(a) to 1(c) and also operate δr_t, at

3.2.2.1 200k E.A.S.

3.2.2.2 245k E.A.S.

3.3 Landing gear DOWN

3.3.1 Perform Manoeuvres 1(a) 1(b)(i) at

3.3.1.1 160k E.A.S. limit incremental "g" to ± .5g and sideslip to 40% max. permiss.

3.3.2 Perform Manoeuvres 1(a) to 1(b)(i) at

3.3.3.1 180k E.A.S.

3.3.2.2 200k E.A.S.

3.3.2.3 245k E.A.S. - and manoeuvre 1(c)

4. NATURAL AIRCRAFT STABILITY - ENGINE EFFECTS; ASSYMETRIC POWER

Upon Technical Design approval, the following tests are to be performed

4.1 At Conditions:

20.090

250k E.A.S.

200k E.A.S.

180k E.A.S.

At altitudes of 20000' or below

4.1.1 With aircraft trimmed with power for level flight, one engine to be closed to idling gradually, and sidelsip maintained zero with pedal force. Then pedal force released gradually to determine sideslip, wings maintained level with ailerons up to a maximum of 60% maximum permissable sideslip. Then trim out rudder and aileron force with zero sideslip.

4.1.2 Repeat 4.1.1 using Military Rated Power, (No AB) starting trimmed into a climb at const I.A.S. slightly below 20000'.

4.1.3 Repeat 4.1.1 using Augmented Power (AB lit)

4.2.1 These tests (4.2) to be performed after analysis of tests 4.1 and upon approval by Technical Design. With aircraft trimmed with power for level flight, one engine to closed rapidly to idling, attempting to maintain zero sideslip, wings level, without trimming. Repeat without using rudder force, allowing aircraft to take up sideslip but maintaining wings level with aileron.

4.2.2 Repeat 4.2.1 starting from a trimmed climb condition using M.R.P.

4.2.3 Repeat 4.2.1 starting from a trimmed climb condition using augmented power.

5. NATURAL AIRCRAFT STABILITY - ENGINE EFFECTS, SYMMETRIC POWER

After performing Tests 1, 2, 3, 4 with analysis of test data, and with Technical Design approval, the following tests are to be performed.

(a) Dampers OFF

Deflect rudder to produce a steady sideslip of 20% of maximum permissable positive β and release pedals. Allow oscillations to subside, or for at least three complete oscillations, controls free.

(b) Normal Dampers Engaged, Yaw Axis Only

Deflect stick forward and back to produce alternate 0.g and + 2g for a period of approximately 5 seconds, ending with an abrupt stick deflection and abrupt return to trimmed position producing an instantaneous 2g to 2.5g. Allow subsequent oscillations to decay with stick in trimmed position.

5.1 With both engines idling the aircraft to be trimmed into a dive to maintain constant M or at least to reduce the rate of decrease of M as much as possible, starting at an altitude above specified altitude, -where this is possible - to allow for loss of height.

Perform Manoeuvre 5(a), 5(b) at Conditions:

20.070
20.090
40.115
40.080

5.2 With afterburners lit, the aircraft to be trimmed into a climb to maintain constant M, starting as an altitude below specified altitude to allow for increase in height.

Perform Manoeuvre 5(a), 5(b) at Conditions:

20.050
20.090
40.080
40.100

6. NATURAL AIRCRAFT STABILITY - CONTROL SYSTEM FAILURE

6.1 With at least Emergency damper engaged, simulate separately the loss of one system and of one pump at

30.045
30.095
10.115

6.1.1 with elevator stick force zero

6.1.2 with elevator stick force 10 lb.

6.1.3 with 20°/sec. roll rate on (not at 30.045) rolling from ϕ = -45° to +45°

6.1.4 with 20% max. permissable sideslip on, if this can be achieved with 180 lb. pedal force.

6.2 At the flight conditions of 6.1 with complete control hydraulic system operative; one system inoperative; one pump inoperative; - move elevator, aileron and rudder controls at rates up to max. rate to remain within 0g and 2g, 30% of max. permissable sideslip and 30°/sec. rate of roll.

7. NATURAL AIRCRAFT STABILITY - 3g FLIGHT

7.1 At each of the conditions below, with aircraft trimmed into a steady 3g turn descending where necessary to maintain constant Mach No. pilot to determine response to gentle control motions. Then perform manoeuvres 2(a), 2(b), but in 2(a) use between 2g and 4g and attain 4g in final abrupt stick deflections, and in 2(b) use 20% or less of max. permissable sideslip.

7.1.1 20.090
20.115
30.095
40.115

7.1.2 40.160 (Manoeuvre 2(a) only)

8. CALIBRATION OF ANGLE OF ATTACK

This should be performed in two stages

8.1 Subsonic Calibration

Normal Damper, Yaw Axis or all 3 Axis. Photographs should be taken from nearest safe distance of Arrow in side elevation with fuselage datum clearly marked against a background of the horizon, the aircraft in steady level flight. Pilot or observer to note fuel weight, speed, height and α where these are not otherwise recorded.

Conditions:

10000'	every 50k from 160k to M = .85
20000'	every 50k from 160k to M = .85
30000'	every .1 M from 160k to M = .85
40000'	every .1M from 160k to M = .85

8.2 Supersonic and Transonic

Normal Damper engaged. Repeat 8.1 at 20000, 30000, 40000, 50000, from M.9 up to limit of chase or Arrow in intervals of .1M.

9. ADDITIONAL TESTS

9.1 Chase plane to take 3/4 rear view of Arrow from as close a distance as possible and safe. Arrow to be in steady level flight at the following conditions: (Normal Damper, Yaw Axis or all 3 Axes)

10.030	30.045	40.060
10.050	30.060	40.070
10.070	30.070	40.080
10.080	30.080	

Chase pilot should announce when shot is taken, Arrow pilot should then call off airspeed, altitude, fuel, weight and angle of attack, before proceeding to next condition. The main purpose of this test is to obtain confirmation of elevator trim angles in the subsonic region, and serve as in-flight functional calibrate of this parameter.

SECTION 3

TESTS TO DEMONSTRATE COMPLIANCE WITH

U.S.A.F. MIL. SPEC. F-8785

GENERAL NOTES

The methods by which tests with the dampers engaged will be analysed have not yet been finalised.

Dependent upon the conditioning of test responses to suitable inputs or disturbances, it should be possible to consider the aircraft with damper engaged as a very stable natural aircraft, and apply the analysis programmes of Ref. 2 and 3, treating the aircraft as having controls fixed (The pilots controls could be maintained fixed during damping). This would allow expression of effective derivatives for the total response comparable with classical aerodynamic derivatives. (A sub-programme exists for determining optimum shape and size of control disturbance for such an analysis).

The programmes of Refs. 4 and 5 will be used to obtain natural aircraft derivatives, including control derivatives at all parts of the flight envelope, dampers in or out, but particularly in those parts of the envelope where it is considered unsafe to fly without dampers.

Steady state programme Ref. 8, utilizing corrected trim data from Ref. 13, together with hinge moment programmes Ref. 6, and 7, will be used to analyse tests with dampers in just as with dampers out.

Again it should be noted that the programmes of Ref. 2, 3, are self checking while those of Refs. 4, 5, compare response for obtained derivatives with actual response.

Tests specified in this section are essentially in the form of demonstrations that the aircraft can comply with the handling requirements of the U.S.A.F. Military Specification F-8785, as discussed in the applicable Avro Model Specifications and P/Aero Data/89, or to indicate the deviation where the requirement cannot be met. However, when adequate data has been obtained from flight tests, concerning free aircraft Stability and augmented Stability, it should be possible to replace some of the demonstrations in flight by simulation on the ground. If this method proves acceptable, some economy in flight test time will be realized.

1. AUGMENTED STABILITY, LEVEL FLIGHT

1.1 To be performed at flight conditions of Figure 2, with dampers in Normal Mode, then Emergency Mode. Aircraft to be trimmed at constant speed and altitude at each flight condition.

Pilot first to determine response of aircraft to gentle control motion, then:

1.1.1 Abrupt elevator deflection and release to produce approximately a momentary $\ddot{Z}$ of 1g, or up to buffet whichever reached first. Abrupt aileron deflection and release to produce up to 30° of bank. Abrupt rudder displacement and release, to produce up to 30° bank.

1.1.2 Abrupt aileron deflection to produce approximately 40°/sec then 60°/sec of roll rate within the limits ± 60° of bank. Abrupt rudder displacement and release to produce within 40% of limiting sideslip, with result and bank angle within ± 60°. Manoeuvre may be started with initial opposite bank to achieve this. After movement of aileron or rudder all controls should be released until oscillation have damped out, or for at lease three oscillations.

1.1.3 Increasing deflection of rudder manually within 40% of limiting sideslip or within 150 lb pedal force, whichever attained first, while keeping wings level with ailerons, and release force on both controls. This manoeuvre should be made in two stages, using increasing rudder angle, to maintain subsequent roll within 60° of wings level.

Step input as in Section 1, item 4(a), (i) (ii) (iii)

1.2 To determine trimmability, δt_e δt_a δt_r to be operated to produce aircraft responses within ± 1g, ± 30°/sec, ± 40% of limit β subsonically, ± 20% supersonically.

1.2.1 With Normal Damper, at the flight conditions of Figure 3, but excluding 20000' conditions.

1.2.2 With Emergency Damper, at the flight conditions of Figure 3, but excluding 20000' conditions.

1.2.3 With Alternate Emergency in operation, in flight conditions:

50.080
50.160
10.040
10.115
180k L/G Down Mode (20000' or below)

1.2.4 With Normal Damper engaged, at 1.2 V_S 10000', 180k E.A.S. apply N.R.P., climb to maintain speed, and trim. (V_S taken as minimum safe flying speed 150k E.A.S.)

2. AUGMENTED STABILITY IN 2g TURNING FLIGHT

2.1 While trimmed into a steady 2g turn, descending if necessary to maintain Mach No. , and at as near to constant altitude as power allows, pilot to determine response of aircraft to gentle control motion, at conditions of Figure 3, except 50.080, 50.100, 30.045, 10.040 and 20000' points. With Normal Damper then Emergency Damper:

2.1.1 Repeat 1.1.1, (rolling within 0° and 75° ϕ)

2.1.2 Repeat 1.1.2, ($\Delta \ddot{y}$ to 20%)

2.1.3 Repeat 1.1.4 (ϕ 0° to 90°)

3. FURTHER LEVEL FLIGHT TESTS

At the flight conditions of Figure 4 for 3.1 and 3.2, initially trimmed with power for level flight.

3.1 With Normal Damper

3.1.1 Elevator step to give $\Delta \ddot{z}$ = 2 "g", or to moderate buffet, whichever lower.

3.1.2 Abrupt aileron movement to give 70°/sec. checking roll rate limiter set to 60% ($\phi \pm 60°$ to $\pm 60°$).

3.1.3 Abrupt rudder movement to 60% $\ddot{y}$ limit (given as β limit) or to 180 lb. pedal force whichever is reached first, if resultant roll is within 60° of wing level.

3.1.4 Extend airbrakes, stick free.
Trim out subsequent steady "g"
Retract airbrakes stick free and re-trim.

3.2 With Emergency Damper

3.2.1 Abrupt elevator movement to give $\Delta \ddot{z}$ = 2 "g" or to moderate buffet, whichever lower.

3.2.2 Abrupt rudder movement to 60% $\ddot{y}$ limit (a β limit) or 180 lb. pedal force whichever is reached first, if resultant roll is within 60° of wings level.

3.2.3 Extend airbrakes, stick free.
Trim out subsequent steady "g"
Retract airbrakes stick free and repeat.

NOTE: For all manoeuvres except 3.1.4, 3.2.3, release controls after disturbance and allow oscillation to subside.

4. DETERMINATION OF MANOEUVRE OR "g" ENVELOPE *

4.1 Pull steady "g" in turns up to envelope* or moderate buffet, or limits defined by Technical Design, at flight conditions of Figure 5, increasing the "g" in turns and descending where necessary to maintain constant Mach No.

4.1.1 With Normal Damper engaged, check "g" limiter.

4.1.2 Repeat with Emergency Damper, (No "g" limiter).

4.2 Straight push downs to negative "g" limit, * as defined by Technical Design, at conditions of Figure 5.

4.2.1 With Normal Damper

4.2.2 With Emergency Damper

4.3 Rolling pull-out. Trim into turn in one direction, then roll through upright position to turn in the opposite direction. (See Figure 5).

4.3.1 Normal Damper engaged. Perform rolling pull-outs at 3.0 "g" with roll rates as defined by Technical Design.

4.3.2 Normal Damper engaged. Perform rolling pull-outs to limits of Ref. 9

4.3.3 Emergency Damper engaged. Perform mild rolling pull-outs within limits defined by Technical Design.

4.4 Further limiter tests. Limiters to be set to limits lower than design values when necessary for safety reasons. Each manoeuvre to be investigated in detail on flight simulator where actual flight test data are available. Start with Normal Damper engaged

4.4.1 Check roll rate limiter (p) set to 120°/sec and lateral acceleration limiter (A_y), set to 60% of design, at conditions shown on Figure 5.

4.4.2 At 30,060, check switching at maximum permissable sideslip (6° β)

NOTE:

This group of tests will not repeat those limiter tests performed under Item 5 of Section 1, during assessment of safety features.

* These tests should be performed after Structural Integrity tests to the same or greater loadings. For Phase 1 Flight Testing limit loads will be as outlined in Ref. 9. Thus Item 4 of Section 3 should be repeated to full maximum permissable loads after Strucutral Integrity tests to the same loads

Items 4.1.1, 4.2.1, 4.3.1, 4.3.2, may be covered partially by some points of the Structural Integrity Tests.

5. CLIMBS AND DIVES

5.1 With aircraft trimmed at start of Climb, Climb at Climb Power (Suggest M.R.P. or A.B. lit) at recommended climb speeds up to Service Ceiling 50000'. Use Normal Damper and repeat with Emergency Damper.

5.2 At 25% N.R.P. or Minimum Power available, whichever less, dive at an angle of 45° or less, Use Normal Damper and repeat with Emergency Damper.

5.2.1 From trimmed flight at M = .92, 50000', to 20000' to remain below M = 1.6. Airbrakes OUT. Repeat with Airbrakes IN.

5.2.2 From trimmed flight at M = 1.5, 50000', to 30000' to remain below M = 2.0. Airbrakes OUT. Repeat with airbrakes IN.

Pull-outs to remain with "g" limits.

6. TRANSFER TO AND PERFORMANCE WITH, THE VARIOUS FLYING CONTROL AND DAMPER SYSTEM

While trimmed and with power for straight and level flight at the flight conditions listed below, perform following tests:

6.1 Check manual transfer from Normal to Emergency and auto switching to Alternate Emergency (Both to "A" and to "B" alone); and with one pump out, in Emergency Damper.

At 30.045 - Approach Thrust and shallow dive
30.095
30.160
10.115

with

6.1.1 Elevator stick force zero

6.1.2 Elevator stick force approximately 10 lb.

6.1.3 With 20°/sec. (approx) roll rate on, rolling from 45° bank one way to 45° bank the other.

6.1.4 With 20% max. permissable sideslip on if this can be achieved with 180 lb pedal force. This manoeuvre to be performed at 30.045 and 30.095, but at conditions 30.160 and 10.115 only on confirmation from Technical Design.

6.2 At the above flight conditions, with Normal Emergency, Alternate Emergency (A or B Systems) and with one pump inoperative, move elevator, aileron and rudder controls at rates up to max. rate of control movement, and to keep within 0g and 2g, 30% of limiting sideslip and 30°/sec. rate of roll.

7. CROSS WIND LANDING

Perform Natural 1B (Section 2) with Normal Damper Gear Down Mode.

8. ENGINE EFFECTS - SYMMETRIC POWER

8.1 Perform Natural A/C No. 5 (Section 2) at conditions given there but with Damper Normal also:

40.180 (apply step δe δr as well)

8.2 Perform Natural A/C No. 5 (Section 2), manoeuvre 5(a) only, at the conditions given there but with Emergency Damper Engaged.

9. ENGINE EFFECTS - ASSYMETRIC POWER

9.1 Perform Natural A/C No. 4 (Section 2) with Damper Normal. Perform 4.1.1 of Section 2 also at following conditions; limit β to 40% max., also step δe δr, as well as manual

\# (10.080)
\# (10.090)
10.100
10.115 # See note to 1.3 Section 2
40.080
40.115
40.160

Limiting power on live engine first to original power for level flight (2 engines) and then power for level flight (one engine) where possible, and test δ_e, δ_a, δ_r, δ_{et}, δ_{at}, δ_{rt}, one engine.

9.2 Repeat 9.1 Emergency Damper

9.3 With normal damper, at M.R.P. and V_{NRP} 40000' trimmed, apply afterburner, Note Change of trim 20000'

10. LOW SPEED TESTS

10.1 Determination of V_S, taken as minimum safe flying speed, in gear up mode, landing gear up; and gear down mode landing gear down.

10.1.1 Normal Dampers, at conditions of Natural No. 3.1 Section (2). in gear up mode, landing gear up; and gear down mode, landing gear down.

10.1.2 Emergency Dampers at conditions of Natural No. 3.1 Section (2).

10.2 Stability and Control at Low Speed, in gear up mode, landing gear up; and gear down mode, landing gear down.

10.2.1 Normal Damper perform tests at conditions of Natural 3.2, 3.3 Operate δ_{et}, δ_{at}, δ_{rt}.

10.3.1 At 160k, 200k, 250k } E.A.S. (At 20000' or below) L/G Up then Down. Trimming at all speeds. Normal damper gear gear up (landing gear up); Gear down mode (landing gear down)

10.3.1.1 Apply graded "step" δ_e δ_r δ_a
Apply δ_r, δ_a up to sideslip limit (6°) or 180 lb whichever less.

10.3.1.2 Apply δ_a to give up to 60°/sec; (at 200k, 250k only)

10.3.2 Emergency, repeat 10.3.1 Gear up mode (landing gear up) and gear down mode (landing gear down)

10.3.3 Repeat 200k and 160k of 10.3.1

With

10.3.4.1 Power at idle
10.3.4.2 Power at approach

Use a shallow dive through the nominal altitude, where necessary. Here check the trim at 1.4 V_S, (210k,) power idle and approach.

10.3.4 Alternate Emergency in operation, repeat 10.3.1

10.4 Trim changes at Low Speeds

10.4.1 Normal Damper, gear down mode, landing gear down and gear up mode, landing gear up

10.4.1.1 Accelerate from 160k to 250k E.A.S. (280k L/G up) use M.R.P.

10.4.1.2 Decelerate from 250k to 160k power idle.

10.4.1.3 Accelerate from 160k to 250k (280k L/G up) Augmented Power

10.4.1.4 Decelerate from 250k to 160k power idle, airbrakes Out

Maintain constant altitude. Start from trimmed condition Rudder step inputs while slowing.

10.4.2 Emergency Damper gear down mode (L/G down) and gear up mode (L/G up) Repeat 10.4.1

10.4.3 At 155 - 160k, 10000' or below Normal Damper gear down (L/G down) Power for Level Flight (P.L.F.)

10.4.4.1 Apply M.R.P. and maintaining const. rate of climb raise L/G, speed const.

10.4.4.2 Apply Augmented Power and repeat 10.4.4.1

11. LONG PERIOD LONGITUDINAL OSCILLATION OR "PHUGOID", TESTS

At:
10.070
10.100
10.115
40.090
50.115
50.160

11.1 Normal Damper

Trim with power for straight and level flight and allow aircraft to fly "hands off" in the longitudinal sense for at least 3 minutes being careful when correcting roll to do so gently and without causing manual movements of elevators.

11.2 Emergency Damper - Repeat 11.1 with emergency damper engaged.

12. EFFECT OF RATE OF CONTROL MOVEMENT ON AVAILABLE HINGE MOMENT

Perform after Structural Integrity Tests to Ref. 9. Normal Damper, only Yaw Axis engaged.

12.1 At the following flight conditions confirm with caution that the stick full back, moving stick gradually, does not achieve the max. permissible "g". Then increase rate of stick movement in three stages up to maximum rate at which it can be moved backwards manually, remaining within permissible "g" limits.

In these regions it is estimated that there are hinge moment limitations which may become more severe with increased rate of control movement.

30.160
30.140
30.180
40.160
40.140
40.180

Normal Damper Engaged:

12.2 At the following conditions, check with caution that full aileron produces a rate of roll less than 120°/sec. Then in three stages increase rate at which aileron control is moved up to maximum rate for manual movement.

40.160
30.140
20.120 } On confirmation from Technical Design

In these regions it is estimated that rate of roll is limited by full aileron travel and for structural reasons. It is possible that high hinge moments will further limit the rate at which this roll rate can be built up.

13. SPINS AND RECOVERY

Sufficient information is not available yet to establish that spins are possible and that recovery is satisfactory from established spins. Further tests and evaulation will be necessary to establish the extent of demonstration of spins.

14. ARMAMENT TESTS

At the following conditions

10.090
10.115
30.095
30.160

14. ARMAMENT TESTS (cont'd)

50.115
50.160

basically one sub or trans-sonic condition, one supersonic condition, at each altitude.

14.1 Normal Damper Engaged. With missiles down, or with missile bay doors open depending upon final configuration, δ_r step within $\pm$ 40% of permissible β, to produce resultant roll within 45° of wings level.

14.2 Repeat 14.1 with emergency damper.

14.3 At conditions below, dampers off

10.090
10.115
30.095
30.115
50.115

apply steady sideslip and release; (sideslip within 20% sideslip to produce resultant roll within 45° of wings level).

14.4 Check trim changes with Normal Damper engaged, during lowering, or bay door opening, on launcher, during firing and during jettison, preferably at all the flight conditions at which such tests are carried out, but at least at the conditions for 14.1 and 14.2. Check at a minimum of three flight conditions with Emergency Damper.

1.5 EXTERNAL STORES - (ARROW 2)

With drop tank on determine effect on handling generally, particularly at take-off and climb conditions and cruise conditions, Dampers Normal and Emergency Damper.

15.1 Normal Damper, Gear Down mode

at

L/G UP and DOWN	160k E.A.S.	40.090 L/G up
	200k	at 20000' or below
	250k	

produce steady sideslip with rudder within 40% of max. permissible β and release. Steady sideslip should be such that resultant roll on release of rudder is within 45° of wings level.

15.2 Emergency Damper, Gear Down mode (Repeat 15.1)

15.3 Repeat 15.1 with Dampers OFF at conditions

L/G UP	40.090 200k	250k(20000' or below)
L/G UP and DOWN		250k (20000' or below)

16. FORWARD CRITICAL LOADING

It is assumed that most of the flight tests will be performed at c.g. positions near to the aft limit. Where the level flight tests have not been performed at c.g.'s near this limit, at least 16.1 and 16.2 should be repeated at the c.g. for Aft critical loading (31% M.A.C.)

The following tests should be made at the Forward Critical Loading (c.g. 28% M.A.C.)

16.1 With Dampers OFF, at the flight conditions of Figure 3 shown at 10000', 20000' and 50000', (but not at 10.130, 10.115, 50.180, nor 50.160) perform manoeuvres 1 (a), 1 (c) of Section 2.

16.2 At the flight condition of Figure 3, shown at 10000', 20000', 50000', perform manoeuvres of 1.1.1 of Section 3 in Normal Mode and Emergency Mode.

16.3 At the condition of Figure 5 at 10000' and 50000' levels only, repeat 4.1, 4.2 of Section 3.

16.4 Repeat 4.1 and 4.2 at

60.120
60.140
60.160

By "zooming" to altitude if necessary and allowing speed to fall while pulling increasing "g" to full stick back or to envelope, at constant altitude.

REFERENCES

1.	71/FAR/12	-	Reduction of Flight Tests Data for Stability and Control
2.	71/STAB/5	-	Digital Computer determination of Lateral Derivatives from Oscillatory Flight Tests.
3.	71/STAB/6	-	Digital Computer determination of Longitudinal Derivatives from Oscillatory Flight Tests
4.	71/STAB/31	-	Digital Computation Method of Analysis of Lateral Motion with Moving Lateral controls
5.	71/STAB/17	-	Digital Computation and Analysis of Arrow Longitudinal Resonse in Emergency Mode
6.	71/FAR/4	-	Control Mass Contribution to Hinge Moment
7.	71/FAR/5	-	Control Surface Hinge Moment Derivatives from Flight Test.
8.	71/FAR/13	-	Stability Derivatives from Steady State Tests (Section 2)
9.	RFT.5034	-	Arrow 1 - Structural Integrity Programme
10.	71/FAR/23 Issue 1	-	Flight Test Requirements for Stability and Control and Damper Optimisation
11.	71/STAB/37	-	Digital Computation of Response in Seven Degrees of Freedom (Digital Programme B-11)
12.	71/FAR/30	-	Flight Test Programme, Arrow 1 A/C 25201, -202, -203, Phase I and II
13.	71/FAR/56	-	Digital Correction of α_{TRIM} and δe_{TRIM} to Standard Conditions of 1g, 60000 lb, 30% M.A.C., and Nominal Altitudes.
14.	70/STAB/51	-	Digital Prediction of Control Angle with Dampers Engaged, using Test Values of Pilot Control Forces and Airframe Response as Inputs
15.	70/STAB/52	-	Digital Prediction of Control Angles and Airframe Response with Dampers Engaged, using only Test Values of Pilot Control Forces as Inputs

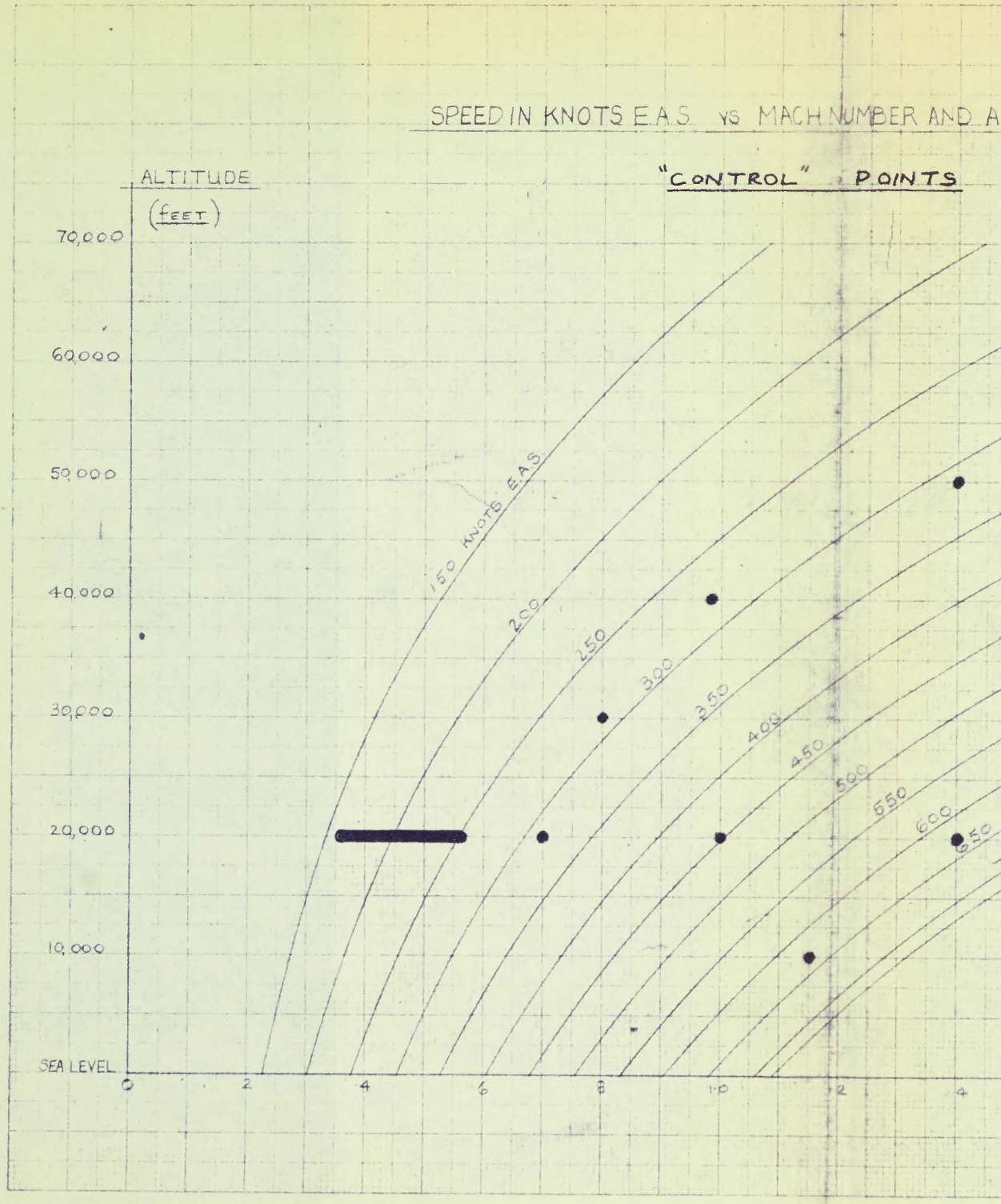
(Cont'd)

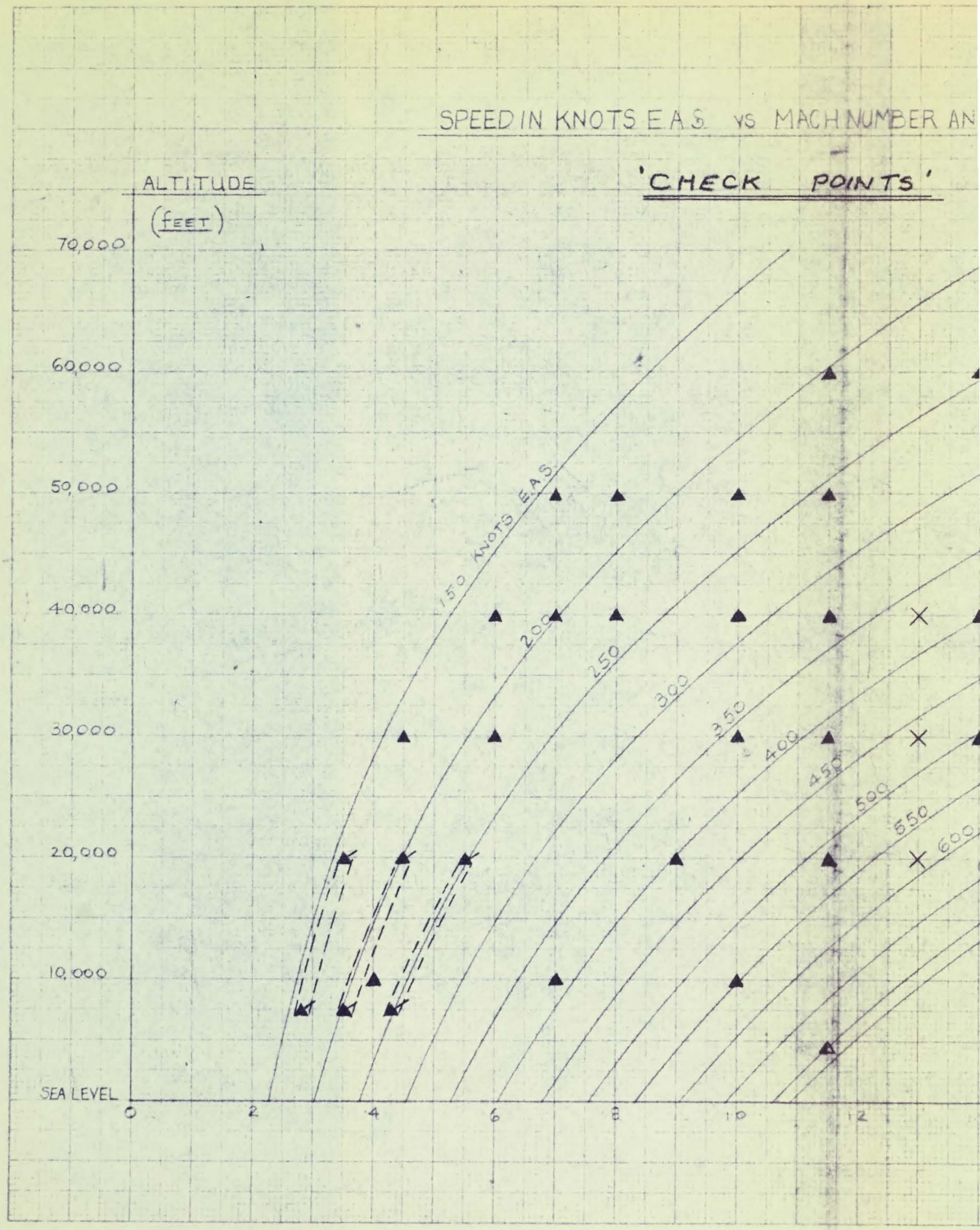
REFERENCES

16. 71/COMP/A8 - Evaluation of Damper Performance during Flight Test

17. 70/FAR/37 - Proposed Methods for Correction and Presentation of Arrow Flight Test Stability and Control Data

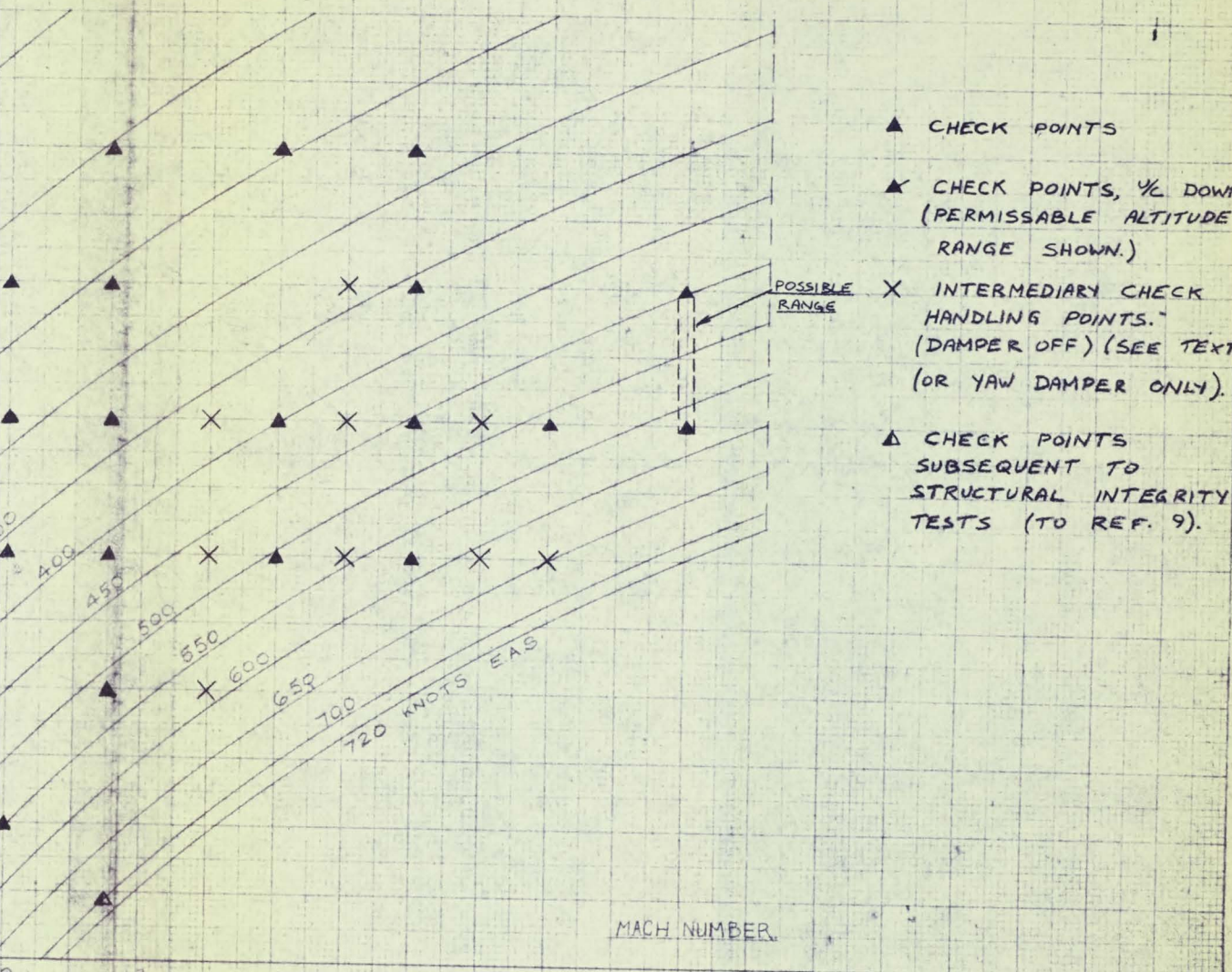
SPEED IN KNOTS E.A.S. VS MACH NUMBER AND A




SPEED IN KNOTS E.A.S. VS MACH NUMBER AN
'CHECK POINTS'
ALTITUDE
(FEET)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
SEA LEVEL
150 KNOTS E.A.S.
200
250
300
350
400
450
500
550
600
0
2
4
6
8
10
12

VS MACH NUMBER AND ALTITUDE

CK POINTS'



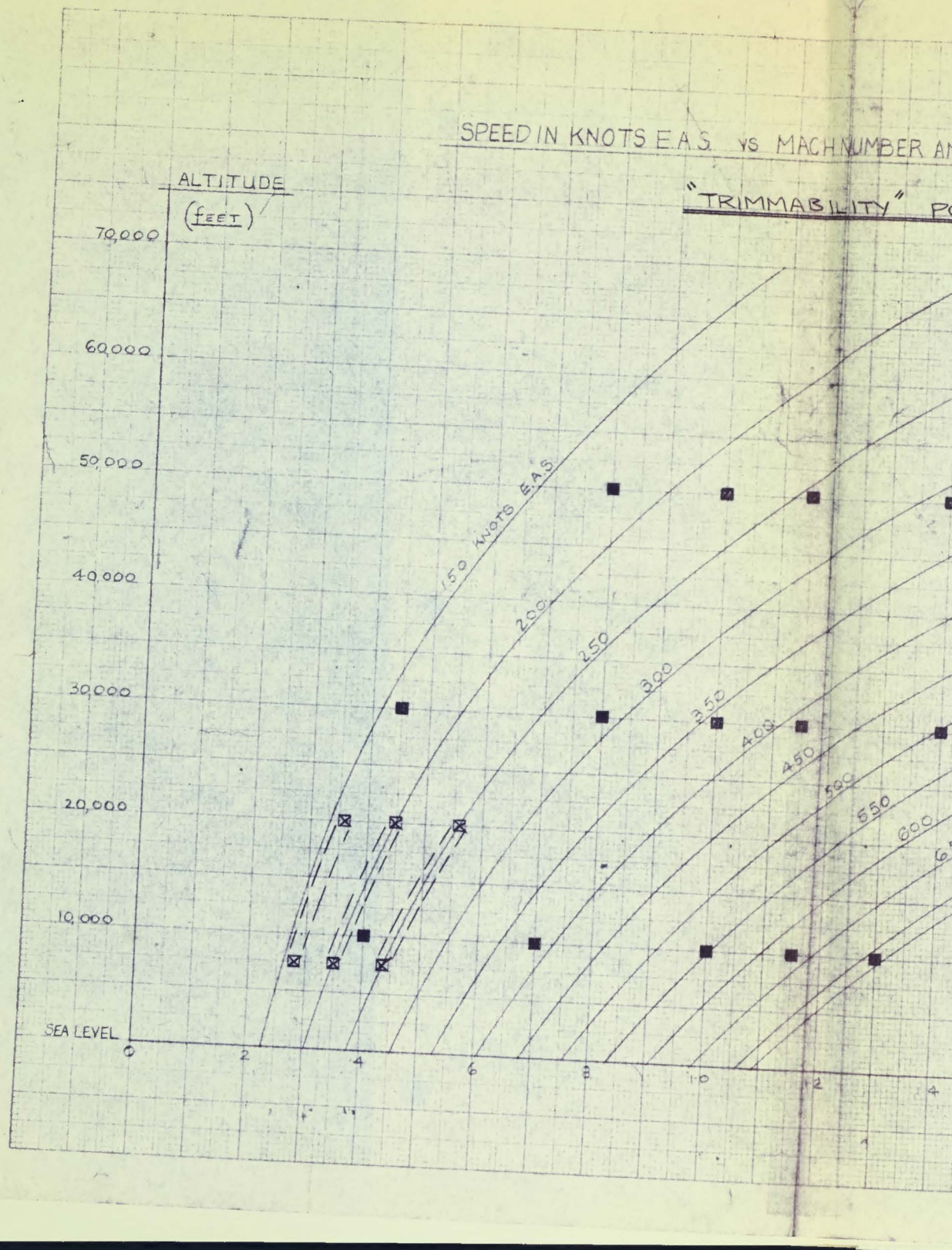
▲ CHECK POINTS

▲ CHECK POINTS, ½ DOWN. (PERMISSABLE ALTITUDE RANGE SHOWN.)

X INTERMEDIARY CHECK HANDLING POINTS." (DAMPER OFF) (SEE TEXT). (OR YAW DAMPER ONLY).

△ CHECK POINTS SUBSEQUENT TO STRUCTURAL INTEGRITY TESTS (TO REF. 9).

FIG. 2


SPEED IN KNOTS E.A.S. VS MACH NUMBER AN
"TRIMMABILITY" PO
ALTITUDE
(FEET)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
SEA LEVEL
150 KNOTS E.A.S.
200
250
300
350
400
450
500
550
600
0
2
4
6
8
1.0
2
4

A.S VS MACH NUMBER AND ALTITUDE

"TRIMMABILITY" POINTS

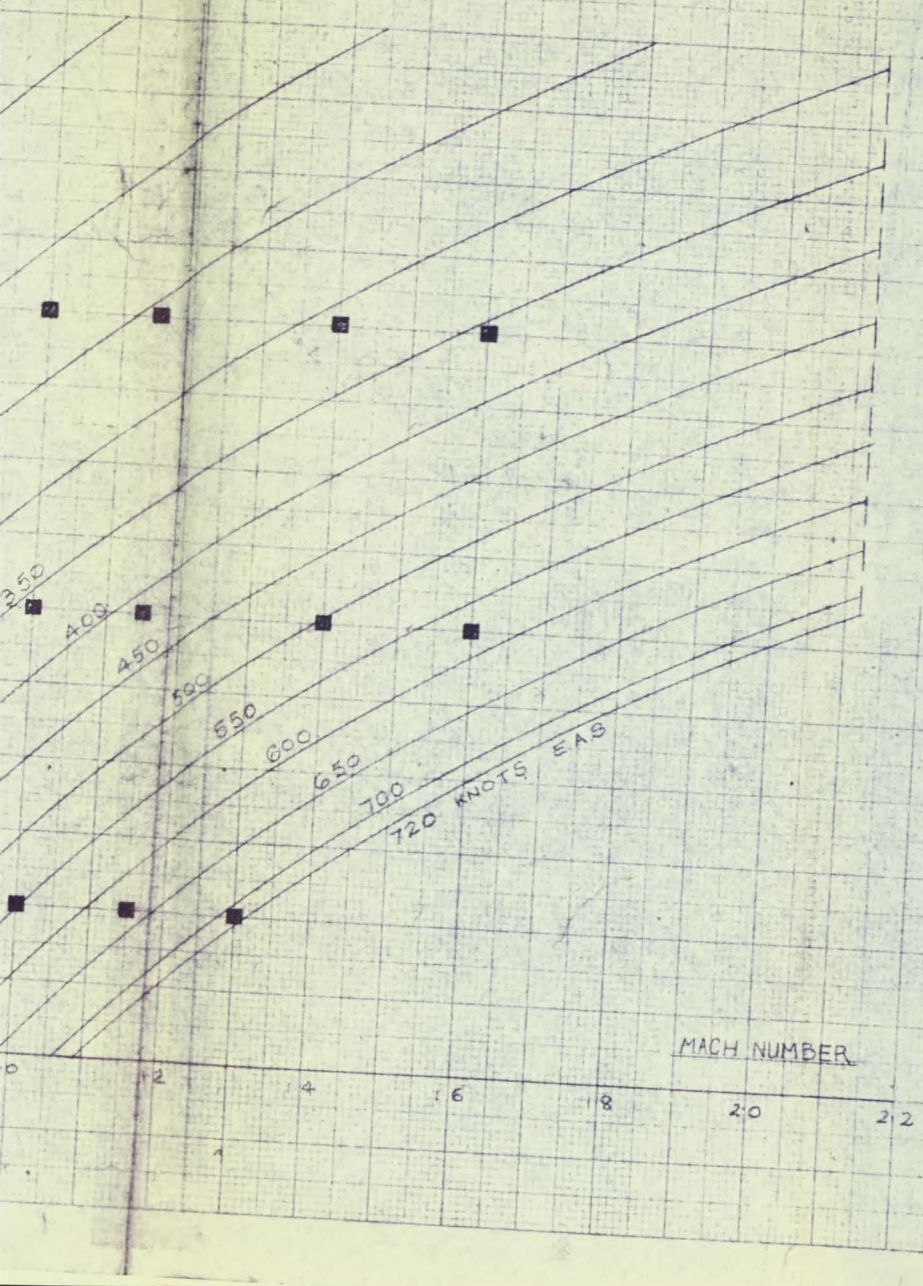
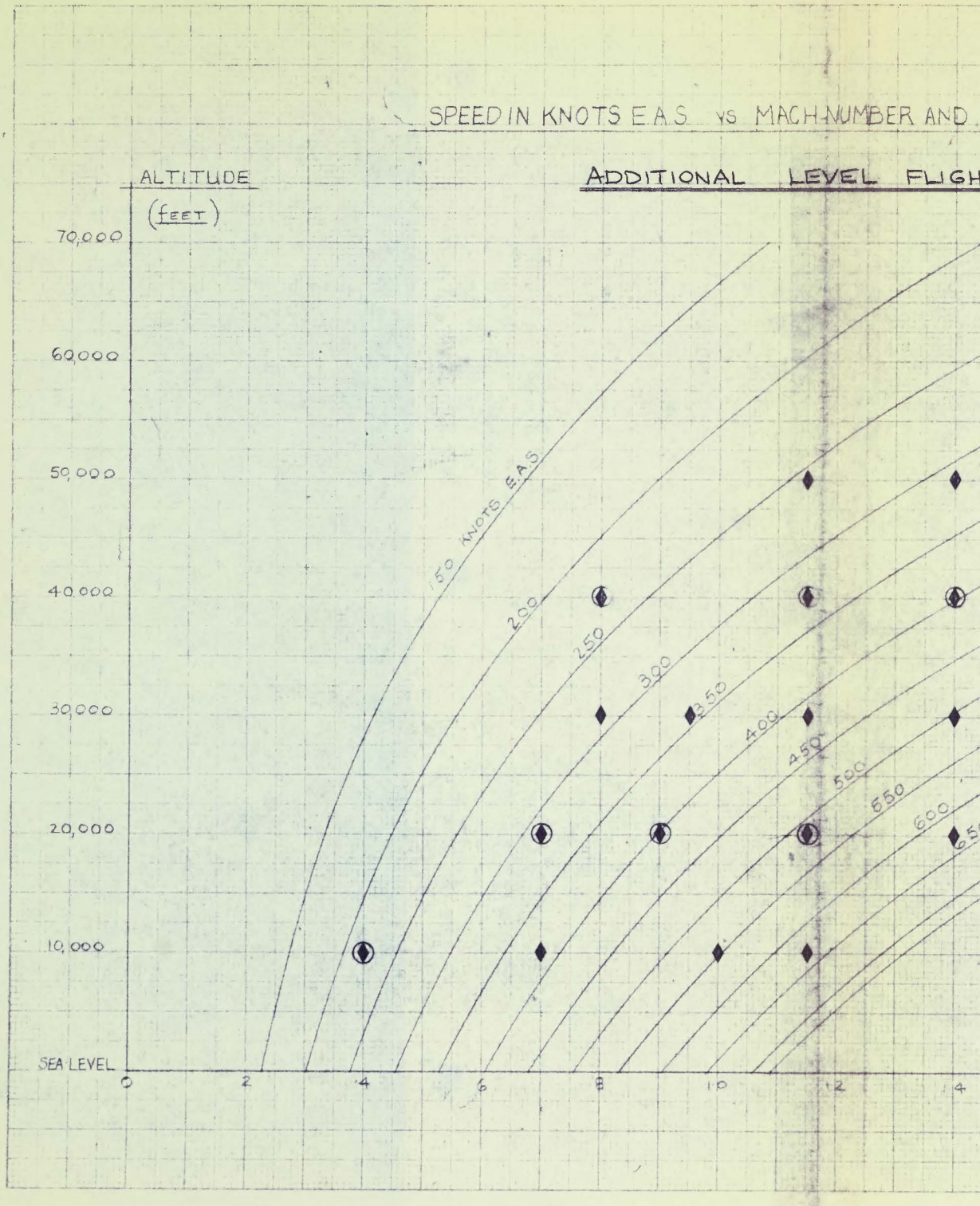


FIG. 3.

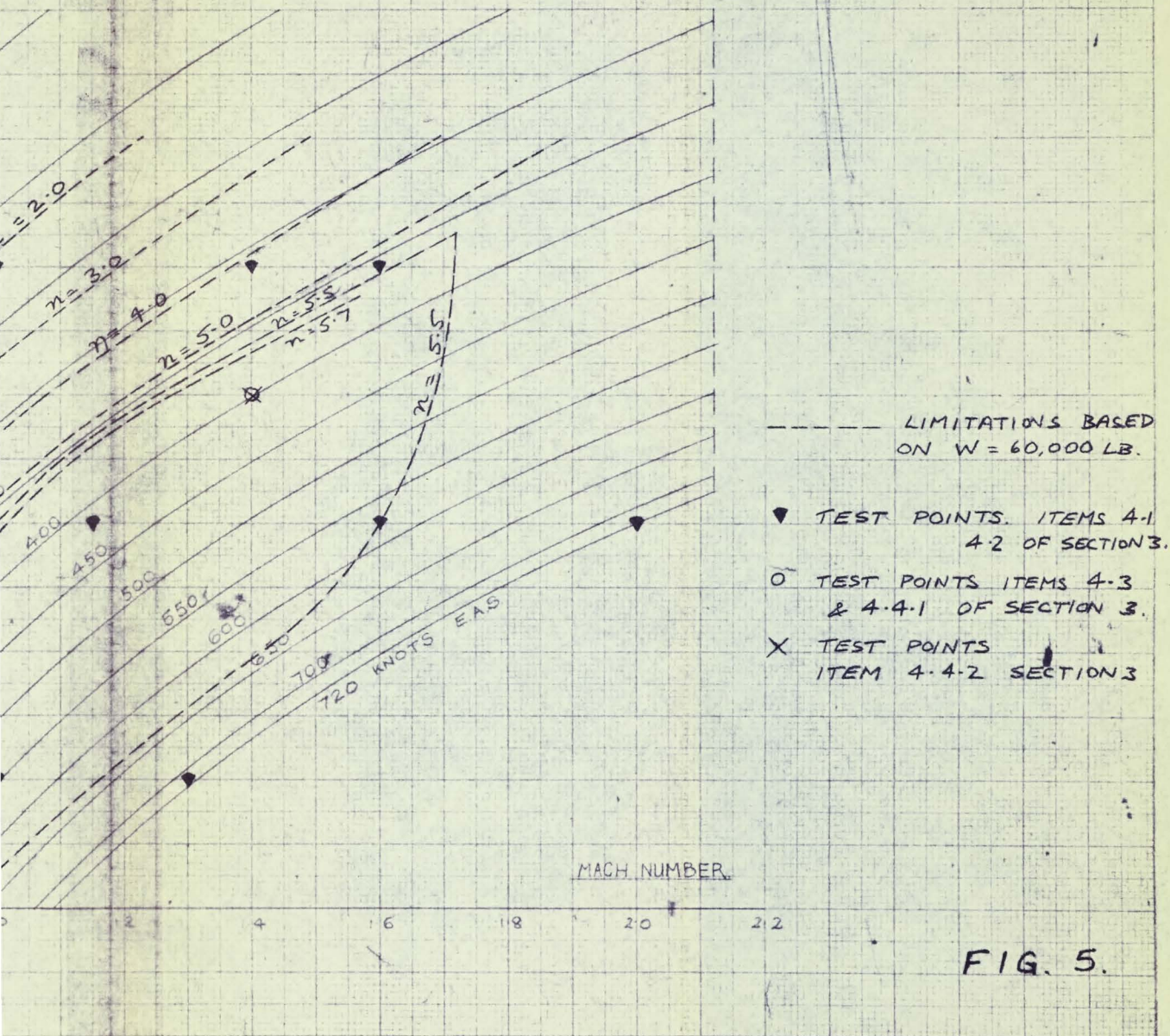
SPEED IN KNOTS E.A.S. vs MACH NUMBER AND

ADDITIONAL LEVEL FLIGH



s MACH NUMBER AND ALTITUDE

PE & LIMITER TESTS.



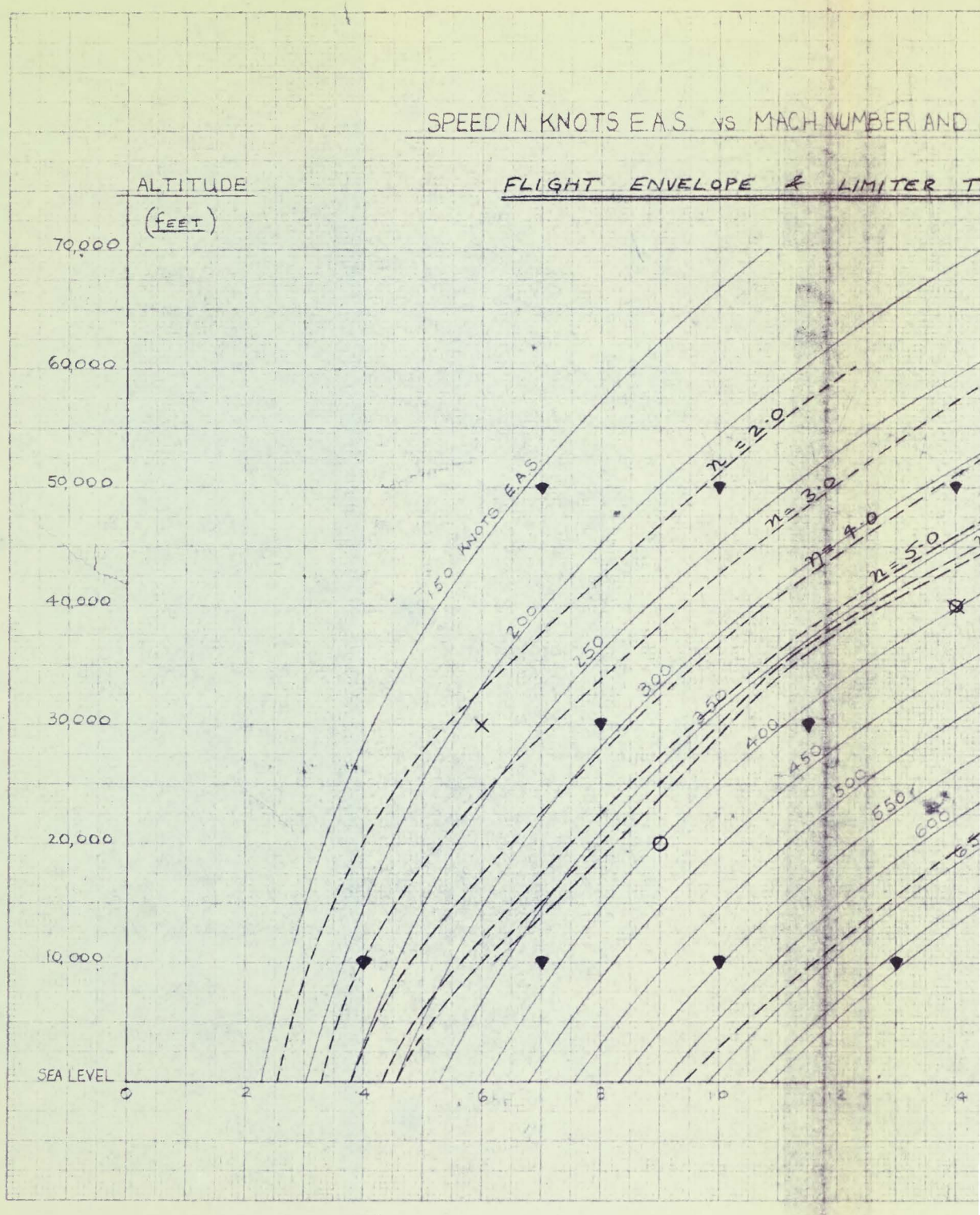
LIMITATIONS BASED ON W = 60,000 LB.

▼ TEST POINTS. ITEMS 4-1 4-2 OF SECTION 3.

O TEST POINTS ITEMS 4-3 & 4-4-1 OF SECTION 3.

X TEST POINTS ITEM 4-4-2 SECTION 3

FIG. 5.


SPEED IN KNOTS E.A.S. vs MACH NUMBER AND
FLIGHT ENVELOPE & LIMITER T
ALTITUDE
(FEET)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
SEA LEVEL
150 KNOTS E.A.S.
200
250
300
350
400
450
500
550
600
n = 2.0
n = 3.0
n = 4.0
n = 5.0
0
2
4
6
8
10
12
4

ARROW 1.

60% LIMITING SIDESLIP

(BASED ON 60% MAX. PERMISS. SIDESLIP OBTAINED FROM MAX. FIN LOAD WITH MAX. ADVERSE RUDDER, WHERE THIS IS LESS THAN 6° SIDESLIP. REFERENCE P/CONTROL/197).

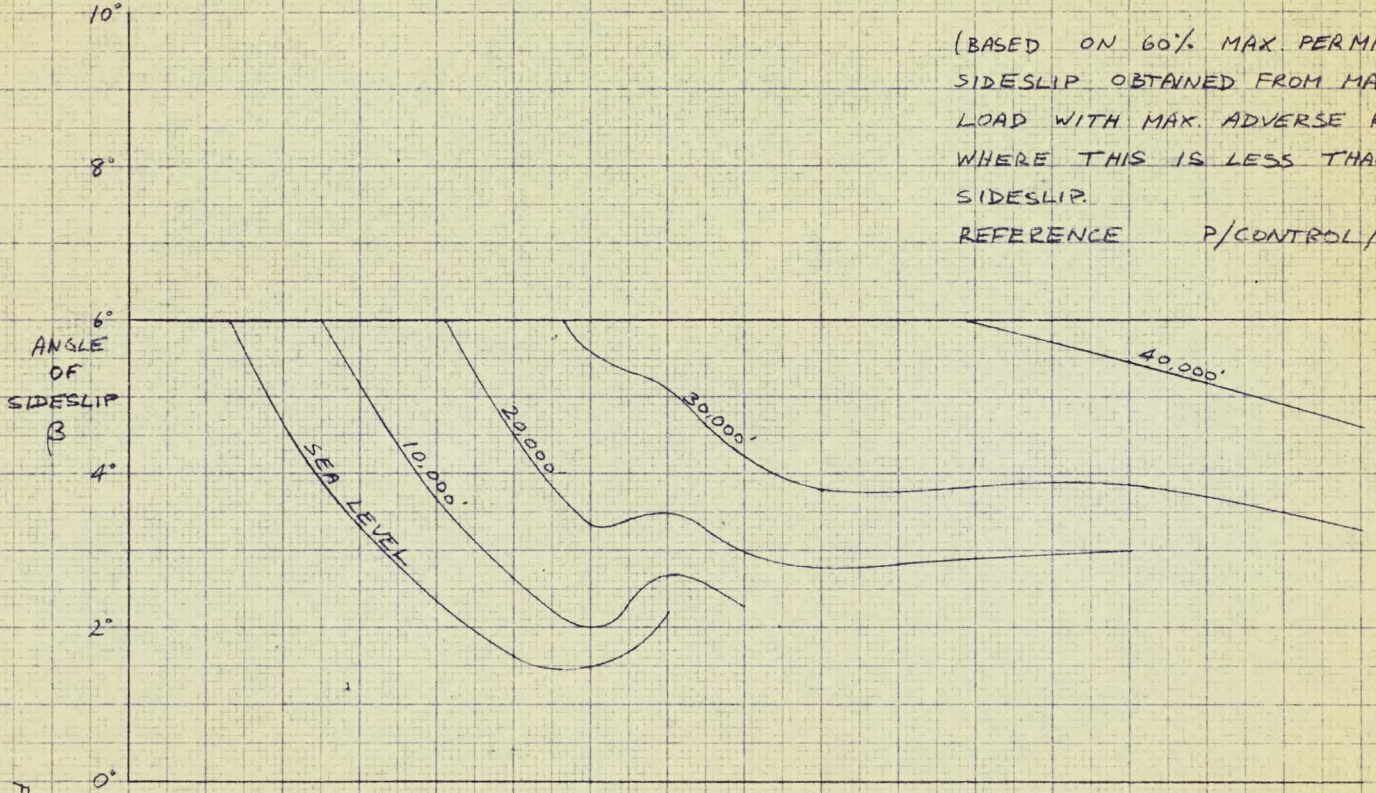


FIG. 8.