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3rd Part of AAEE/852/1

MINISTRY OF SUPPLY

AEROPLANE AND ARMAMENT EXPERIMENTAL ESTABLISHMENT

BOSCOMBE DOWN

SEA BALLIOL T. MK.21 VR.599
(MERLIN 35)

LONGITUDINAL MANOEUVRABILITY AT LOW ALTITUDE

AAEE FORM 1.

10/51 (A1068) Wt.8856/1527. 32M. 2. 5/52. H. E. & S. Gp.848

3rd Part of Report No. AAEE/852/1

25.SEP.1953

AEROPLANE AND ARMAMENT EXPERIMENTAL ESTABLISHMENT
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Sea Balliol T. Mk.21 VR.599
(Merlin 35)

Longitudinal manoeuvrability at low altitude

A. & A.E.E. Ref: AAEE/5702,3/10/GK/W
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Period of test : February - March 1953

Progress of issue of Report

Report No.	Title
1st Part of AAEE/852/1	VR.596) VR.597) VR.598) A further deck landing assessment and Initial carrier trials.
2nd - do -	VR.599 General handling.

Summary

Measurements of stick force per 'g', stick force in turns and stick force and acceleration in out of trim dives have been made at low altitude on Sea Balliol T. Mk.21 VR.599.

The stick force per 'g' at low altitude was within the limits laid down by AP.970 at speeds up to 125 knots I.A.S. at the practical forward C.G. and 250 knots I.A.S. at the aft C.G., exceeding the upper limit at higher speeds. Pilots considered that although the results were in some cases above the limits, the elevator loads were not excessive in manoeuvres.

The out of trim dives up to the limiting speed were satisfactory in that they were within the AP. 970 limit, except above 310 kts. I.A.S., when the elevator force at the practical forward C.G. exceeded the limit and above 320 knots I.A.S. at the aft C.G. limit with external stores.

Application of the proposed new stick force/'g' requirements of AAEE/Res/270 would permit the aft C.G. limit to be extended, if necessary, to 36.0% S.M.C. undercarriage up, and such a C.G. would also be satisfactory from the point of view of out-of-trim dives.

This Report is issued with the authority of

Air Commodore
Commanding A. & A.E.E.

1. Introduction

Handling trials were required to be made on Sea Balliol T. Mk.21 VR.599 at this Establishment to obtain a C.S.(A) release for the aircraft. The tests consisted of check handling trials to be compared with the Balliol T Mk.2 which had already been proved and found to be acceptable.

Part of these tests consisted of measuring stick force per 'g', stick force in turns and stick force and acceleration on release of the stick from out of trim dives, at various loadings. The results of these tests form the subject of this part of the Report.

2. Condition of aircraft relevant to tests

2.1 General. The aircraft was as described in the 2nd part of this Report but for ease of reference certain details relevant to tests are repeated below.

2.2 Airframe limitations. The following limitations have been extracted from R.D.(A) Form 13 dated 18.12.52:-

Maximum permissible speed	350 knots I.A.S.
Maximum permissible accelerometer reading at a weight of 8950 lb.	5g *

2.3 Details of tailplane and elevator. The tailplane elevator and trimming tabs were metal covered and there was a small horn balance.

Gross area, tailplane and elevator	51.4 sq.ft.
Gross area of elevator	11.46 sq.ft. per side.
Area aft of hinge line	9.43 sq.ft. per side.
Area of horn forward of hinge	0.77 sq.ft. per side.
Area forward of hinge (excluding horn)	1.26 sq.ft. per side.
Area of tabs aft of hinge (tw)	1.46 sq.ft.
Elevator: stick gearing	0.235 rads/ft.
Elevator travel	24.7° up 12 .3° down
Elevator tab travel	6.9° up 3.9° down

2.4 Loadings. The tests were carried out at the following take-off loadings:-

Loading No.	Take-off weight lb.	C.G. position in inches aft of datum and %SMC				Remarks
		Undercarriage down		Undercarriage up		
		Inches	%S.M.C.	Inches	%S.M.C.	
1	8,970	31.2	29.8	31.4	30.1	Practical fwd. limit.
2	8,895	34.4	34.0	34.6	34.3	Aft limit.
3	9,120	34.4	34.0	34.6	34.3	Aft limit with external stores

The design C.G. range was from 27.5 ins. to 34.4 ins. aft of datum (i.e. 25.0% to 34.0% S.M.C.) undercarriage down.

The external stores carried for loading 3 were 8 x 25 lb. flash bombs under the wings.

2.5 Instrumentation. All readings quoted in this Report were obtained visually by pilots from calibrated instruments. These were:-

A.S.I.
Altimeter
Kollsman accelerometer
Stick force dosynn.

/3.....

* This is the maximum normal acceleration attained during Contractors tests at a weight of 8,600 lb. It should be noted that the design maximum normal acceleration for this aircraft (n_1) is 6.7g.

3. Scope of tests

3.1 Elevator stick force and normal accelerations were measured in accordance with the technique of R.A.E. Report Aero 2223 in pull outs from straight trimmed flight at heights between 3,000 and 5,000 ft.

The tests were carried out over the speed range 85-335 knots I.A.S. and the pull-outs made at accelerometer readings varying from 1.6g at low speeds to 3.5g at high speeds. Tests were made at loadings 1 and 2.

3.2 Elevator stick force and accelerometer reading were measured in steady turns at constant speed from trimmed level flight at 5,000 ft. at speeds between 90 and 200 knots I.A.S. Tests were made at loading 1 and 2.

3.3 Elevator stick force in out of trim dives and accelerometer readings on release of the stick were measured up to a speed approaching the limiting speed. The tests were made with the aircraft trimmed for level flight at 175 knots I.A.S. (i.e. half limiting diving speed).

These tests were made at both loadings 1, 2 and 3.

4. Results of tests

4.1 Stick force per 'g'. The aircraft was trimmed at various speeds over the speed range covered, using maximum continuous cruising power i.e. 2100 r.p.m. + 4 lb/sq.in. boost. Undercarriage and flaps were up, airbrakes in and the radiator flap set at "auto". Values of stick force per 'g' obtained from these pull outs are shown in Fig. 1 plotted against indicated airspeed in knots.

The stick force/'g' for this aircraft varied linearly at both C.G.'s at which tests were made, with indicated airspeed. At the practical forward C.G. the stick force/'g' varied linearly from 11 lb/'g' at 100 knots I.A.S. to 22 lb/'g' at 335 knots I.A.S. and at the aft limit varied linearly from 6 lb/'g' at 120 knots I.A.S. (the lowest speed tested at this loading) to 15 lb/'g' at 320 knots I.A.S. (the highest speed tested). By reference to Fig. 1 it can be seen that at the aft C.G. the stick force/'g' was of the order of 6 lb/'g' less than at the practical forward C.G. Rough checks of the stick force/'g' were made with flaps and undercarriage down, airbrakes out, power off, at both C.G.'s. These results have not been plotted in Fig.1 but the few points obtained indicated that these results also increased linearly for both C.G.'s but are some 1-2 lb/'g' higher over the speed range 125 - 250 knots I.A.S.

4.2 Stick forces in turns. The aircraft was trimmed in level flight at various speeds and aircraft configurations as detailed in the table given below. A steady turn was then made and the steady airspeed, accelerometer reading and stick force to maintain conditions recorded. There was little difference in the stick force required for similar turns in either direction.

Trimmed flight conditions	Accelero-meter reading 'g'	Elevator stick force lb. pull.	Direction of turn.	Remarks
120 knots I.A.S. Power 2650 rpm + 7 lb/sq.in. boost Flaps and undercarriage up.	1.8 1.8	7 7	Turn port Turn stbd.	
150 knots I.A.S. Power 2000 rpm + 2 lb/sq.in. boost. Flaps and undercarriage up.	2.4 2.4	10 12½	Turn port Turn stbd.	
200 knots I.A.S. Power 3000 rpm + 9 lb/sq.in.boost i.e. operational necessity power. Flaps and undercarriage up.	2.8 2.8	18 19½	Turn port Turn stbd.	
120 knots I.A.S. Power off. Flaps and undercarriage up.	2.0 2.0	7 10½	Turn port Turn stbd.	Full port rudder trim required +10 lb. foot force
90 knots I.A.S. Power 2650 rpm. 0 boost Flaps and undercarriage down	1.0 1.0	Very slight pull force (approx. 2-3lb)	Turn port Turn stbd.	Shuddering occurred.

4.3 Out of trim dives. The aircraft was trimmed in level flight at 5,000 ft. at half the limiting diving speed (i.e. 175 knots I.A.S.) with flaps and undercarriage up, airbrakes in and radiator flap set at "auto". The aircraft was climbed to a sufficient height above the test height and then put into a dive until the required speed was reached at about the test height; the stick force to hold this steady speed being recorded. The stick was released at the test height and the accelerometer reading noted. As in previous tests on Balliol aircraft difficulty was experienced in achieving the higher speeds even in prolonged steep dives and in fact the design speed of 350 knots I.A.S. was not reached.

The following table gives the results of the tests and plots of stick force V I.A.S. knots and accelerometer reading V I.A.S. knots are shown in Fig. 3.

Loading	I.A.S. Knots.	Trim settings	Stick force lb. push	Accelerometer reading 'g'
No. 1 Practical Forward Limit.	175	Elev. neutral	0	1.0
	218		10	1.5
	250		16	1.6
	280	Aileron: neutral	24	2.3
	295		33	2.6
	316	Rudder: 1.6 div. stbd.	39	3.0
	325		41	3.1
No. 2 Aft Limit	175		0	1.0
	200		4½	1.15
	220	Elev: 0.5 div. N.D.	7	1.25
	240		14	1.6
	260	Aileron: 1.4 div. stbd	16	2.0
	280		20	2.4
	300	Rudder: 1.4 divs. stbd.	30	2.9
	320		30	3.1
	340		30	3.1
No. 3 Aft limit with external stores.	200		4½	1.4
	218	Elev: 0.5 div. N.D.	5	1.6
	235		13	1.9
	255	Aileron: ½ div. port	14	2.3
	275		24	2.8
	295	Rudder: 2 divs. stbd.	26½	3.4
	315		33	3.9
	335		37	4.0

Recovery was quite straight forward at 5,000 ft.

5. Discussion

5.1 Stick force per 'g'

5.1.1 General. It is emphasized that in the stick force/'g' tests recorded in this Report, "time-histories" of the pullouts were not obtained as is the normal practice of this Establishment, the results being based on pilots readings of a stick force dynamometer and a Kollsman accelerometer. However a fairly large number of points were obtained at each C.G.

The C.G. range for the Sea Balliol is more aft than the range that was covered by this Establishment in measurements of stick force/'g' on a Balliol Mk.2 (ref. 18th part of Report No. AAEE/852). However the practical forward C.G. used for the trials on the Sea Balliol (i.e. 30.1% S.M.C. u/c up) was approximately comparable with the aft C.G. (i.e. 30.4% S.M.C. u/c up) used during the tests on a Balliol Mk.2. It can be seen that from these results the stick force/'g' is appreciably higher on the Sea Balliol.

No reason for such a difference is known since no changes, aerodynamically, have been made to the Sea Balliol Mk.21 compared with the Balliol Mk.2 which would be expected to effect the stick force/'g' (It will be appreciated that the spring inserted in the Sea Balliol Mk.21's elevator circuit should have no effect on a constant speed manoeuvre such as a stick force/'g' test other than

/any.....

any small change in hinge moments from the new tab angle.) More detailed tests using a continuous recording were not considered justified since pilots did not consider the elevator stick loads to be excessive in manoeuvres.

The results obtained on the Sea Balliol Mk.21 are discussed below in relation to AP. 970 requirements and the proposed new requirements of Report No. AAEE/Res/270 bearing in mind the above discussion.

5.1.2 Compliance with requirements. The AP.970 requirements for stick forces states that the force to obtain the design value of n_1 g shall be between 3.5 (14 - n_1) and 9.5 (14 - n_1). The value of n_1 for the Sea Balliol was 6.7 g giving stick forces of 25½ and 69½ lb. or, in terms of stick force/'g', 4.5 and 12.2 lb/'g'.

As will be seen by reference to Fig. 2 the results at the practical forward C.G. were within these AP. 970 limits up to about 125 knots I.A.S. but exceeded the upper limit above this speed, and at the aft C.G. limit the results met these limits up to a speed of 250 knots I.A.S. but above this speed also exceeded the upper limit.

Also included in Fig.2 are curves giving the lower and upper limits of stick force/'g' derived from the suggested new requirements of AAEE/Res/270. i.e.

(a) in the region where available lift is insufficient to permit $n_1 g$ to be reached (i.e. at low speeds) a lower limit of stick force corresponding to 3 lb/'g'.

(b) at higher speeds than in (a) a lower limit of stick force as already in AP. 970 i.e. 3.5 (14 - n_1) and an upper limit of 6.5 (14 - n_1) i.e. for the Sea Balliol 47½ lb. (3.3 lb/'g').

In producing these curves knowledge of the stalling speed in equivalent airspeed is strictly necessary since $V_s\sqrt{n_1}$ is the speed at which condition (a) above is replaced by condition (b). This information is not available for the Sea Balliol since pressure error tests have not been made to the stall. A stalling speed of 65 knots, flaps and undercarriage up, has therefore been assumed (bearing in mind the higher power settings which need to be considered in connection with stick force/'g' tests). It will be appreciated that the actual value of stalling speed assumed is not critical in the present connection since variation of this will merely shift to a rather higher or lower speed the changeover point from condition (a) to (b).

It will be noted that on the assumption made, and also assuming that stick force/'g' continues to vary linearly with speed at lower speeds than those tested, the stick force/'g' at the aft C.G. (34.3% S.M.C.) would be 3 lb/'g' at about the stalling speed assumed, thus meeting precisely the proposed new lower limit for the region where wing lift is inadequate to produce n_1 g. Clearly however it was not intended that this new low limit should apply right down to the flaps and undercarriage up stall, but only in regions of speed where the aircraft will need to be manoeuvred. It is considered that the spirit of the new proposal would be met by working to it at the lowest speed at which the aircraft would be expected to be manoeuvred frequently i.e. the climbing speed. This is 120 knots I.A.S. up to 8,000 ft. reducing by 2 knots per 1000 ft. thereafter. Assuming therefore a mean climbing speed of 110 knots I.A.S. a stick force/'g' of 3 lb/'g' would be adequate at this speed. In fact the figure at this speed at the aft C.G. tested is 5 lb/'g', and thus stick force /'g' characteristics would be satisfactory at rather more aft C.G.'s than 34.3% S.M.C. If the variation of stick force/'g' with C.G. position is linear, the aftmost acceptable C.G. position from this point of view would be 36.0% S.M.C., thus giving scope for aftward C.G. movement with further development of the type providing of course that other aspects of handling remain satisfactory. This is in fact the case - see the 2nd part of this Report.

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A further possibility is that by exploiting these further aft C.G.'s by fitting rear ballast the general level of stick force/'g' could be lowered immediately to some extent (giving at the practical forward C.G. of 30.1% S.M.C. a reduction from 21 lb/'g' to 19 lb/'g' at the Service limiting speed of 320 knots I.A.S.); however since pilots did not consider that the loads on the elevator were excessive in manoeuvres, this may not be worthwhile.

It may be noted that even with the aft shift of C.G. discussed in the last paragraph the stick force/'g' at the practical forward C.G. is further outside the proposed new requirements than it was at the present practical forward C.G. in relation to the AP. 970 requirements. It may be noted also that even at aft C.G.'s the range of speed at which the stick force/'g' values are within requirements is considerably reduced by application of the new proposals.

5.2 Stick forces in turns. The stick forces in turns increased progressively with acceleration, and there was no tendency to tighten up to the normal accelerations used in these trials. In fact the tests showed similar characteristics as found on previous Balliol aircraft. As stated in para. 5.1.2 pilots did not find the forces too heavy.

5.3 Out-of-trim dives. The AP. 970 requirements for out of trim dives for the Sea Balliol are that "the elevator control force should increase with speed and at the design speed (i.e. 350 knots I.A.S.) should be a push force of less than 35 lb.". From the results obtained it appears that these requirements should be met for the aft C.G. without external stores, but at both the practical forward C.G. and the aft C.G. with external stores the requirement is exceeded above 310 knots I.A.S. and 320 knots I.A.S. respectively. It should be noticed however that at the limiting speed for Service use of 320 knots I.A.S. the maximum force involved even at the practical forward C.G. is not greatly in excess of 35 lb. (i.e. 40 lb.). Also required by AP. 970 is "that on release of the control column the normal acceleration shall not exceed the design normal acceleration". This requirement was met at all three loadings up to the maximum speed tested.

It may be noted that all these tests were made with the radiator flap in "auto"; it is known however that operation of this flap has little effect on longitudinal characteristics.

With reference to the discussion in para. 5.1.2 above on stick force/'g' and the possibility of using C.G. positions beyond the present aft limit it may be noted that brief out-of-trim dive tests were reported in the 31st Part of AAEE/852 on a Balliol Mk.2 with a spring in the elevator circuit, and otherwise in similar configuration to the Sea Balliol, and showed that this characteristic was satisfactory at least as far aft as 37.3% S.M.C. undercarriage up.

6. Conclusions

The stick force per 'g' at low altitude was within the limits laid down by AP. 970 at speeds up to 125 knots I.A.S. at the practical forward c.g. (30.1% S.M.C.) and 250 knots I.A.S. at the present aft C.G. (34.3% S.M.C.) exceeding the upper limit at higher speeds.

Pilots considered that although the results were in some cases above the limits the elevator loads were not too excessive in manoeuvres.

The out of trim dives up to the limiting speed were satisfactory in that they were within the AP. 970 limit, except above 310 knots I.A.S. when the elevator force at the practical forward C.G. exceeded the limit, and above 320 knots I.A.S. at the aft c.g. limit with external stores.

Application of the proposed new stick force/'g' requirements of AAEE/Res/270 would permit the aft C.G. limit to be extended, if necessary, to 36.0% S.M.C. undercarriage up, and such a C.G. would also be satisfactory from the point of view of out-of-trim dives.

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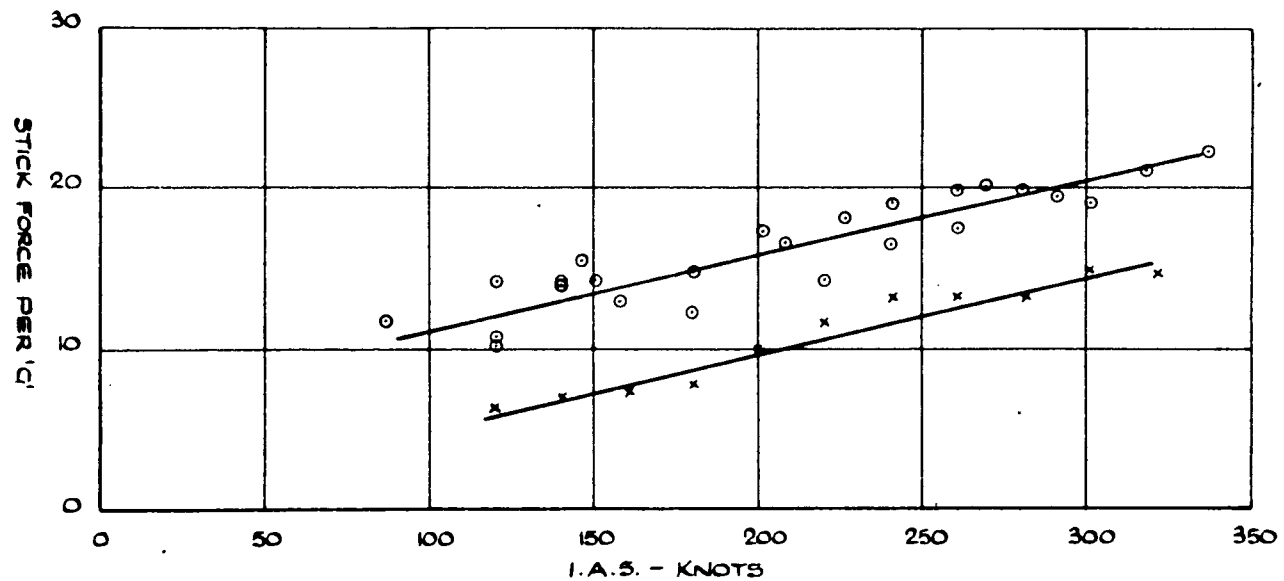
FLAPS AND UNDERCARRIAGE UP, AIRBRAKES IN, RADIATOR FLAP 'AUTO'

MAX. CONTINUOUS CRUISING POWER (i.e. 2100 R.P.M. +4 LB/IN² BOOST)

HEIGHT .3000 - 5000 FEET.

⊙ PRACTICAL FORWARD C.G. (30·1% S.M.C.)

× AFT C.G. LIMIT (34·3% S.M.C.)



STICK FORCE PER 'g'

FIG.1.

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LIMITS OF STICK FORCE/'g'

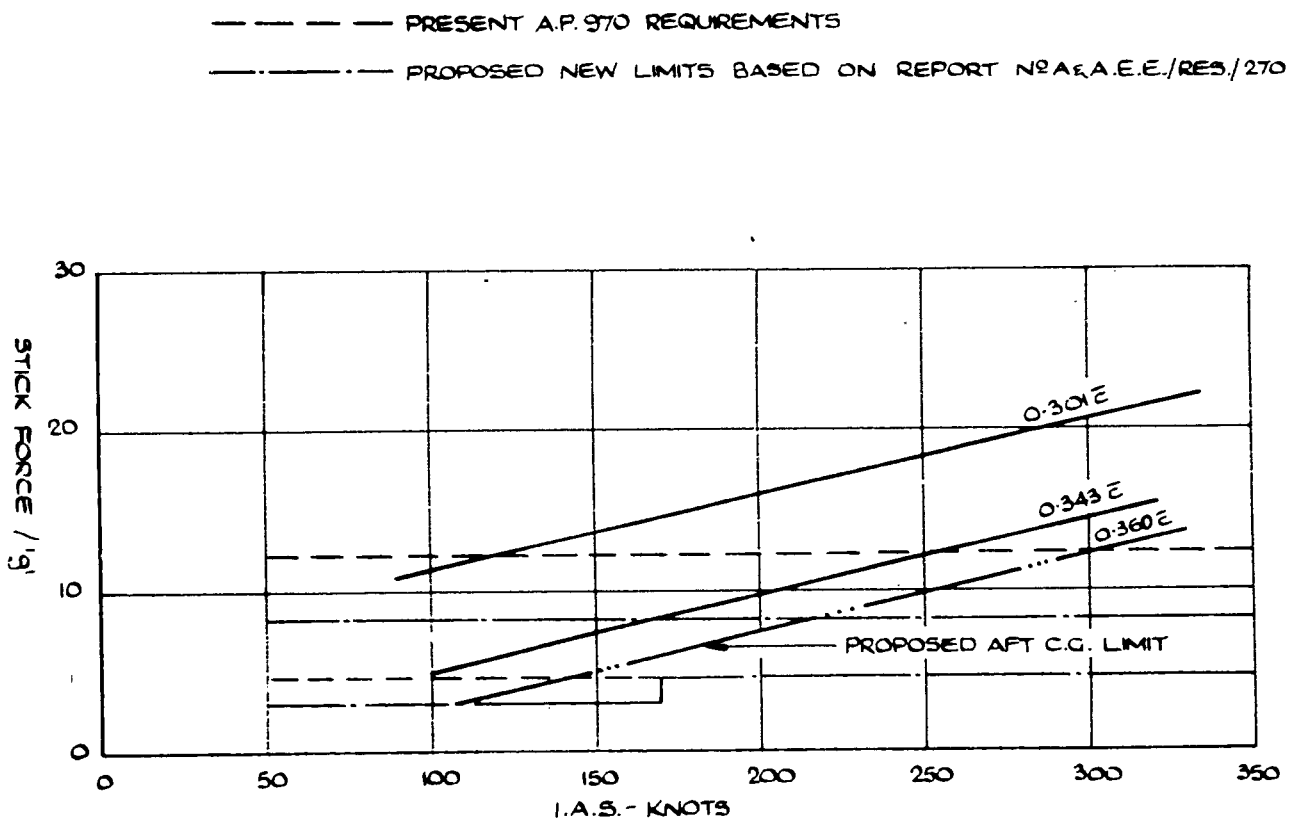


FIG.2.

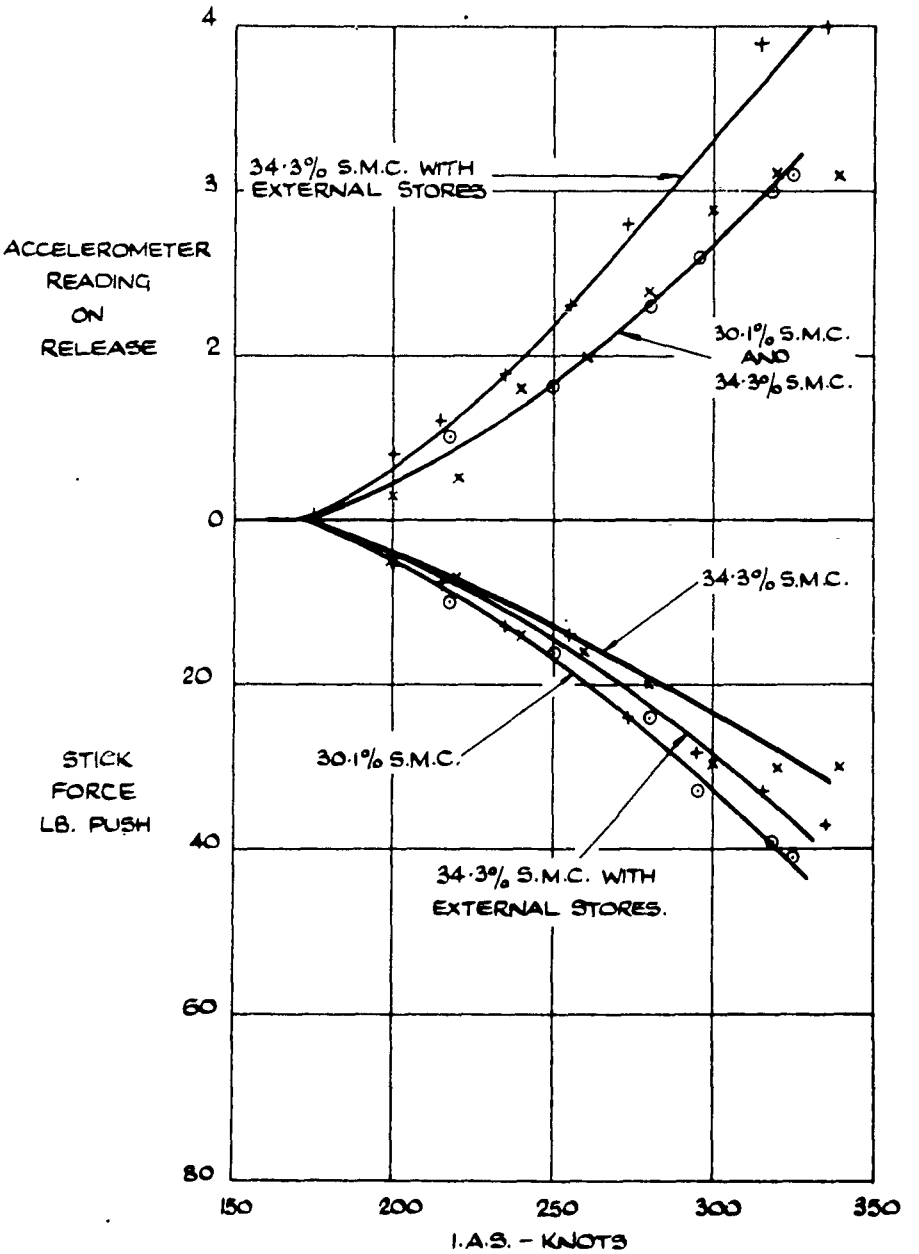
FIG.3.

FLAPS AND UNDERCARRIAGE UP. AIRBRAKES IN.

RADIATOR FLAP AT 'AUTO'

HEIGHT 5000FT.

⊙ PRACTICAL FWD. C.G. (30·1% S.M.C.)
× AFT LIMIT (34·3% S.M.C.)
+ AFT LIMIT WITH EXTERNAL STORES (34·3% S.M.C.)



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