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Water Stability Tests on Saro 37 Fitted With Shetland Hull Bottom Wing Tip Floats and Tail

By

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SUMMARY

Tests have been made on the Saro 37 with a Shetland hull bottom, wing-tip floats and tail, to find the water stability limits over a range of weights and C.G. positions. Free-to-trim attitude and elevator effectiveness were also measured. The Shetland stability limits should be satisfactory during take-offs and landings at all C.G. positions at 120,000 lb. all up weight. With elevator central, however, the trim will be rather low with C.G. normal or C.G. forward and porpoising will occur over the hump during take-offs. At 130,000 lb. all up weight the lower limit joins the upper limit at the hump for a 10 knots range in speed during take-off.

A comparison of the measurements on the Saro 37 fitted with Shetland tail, and with its original tail, shows no change in stability limits although the attitude over the hump was lower with the original tail at the same tail setting. The Shetland tail was more effective near take-off speeds although the original tail had an advantage over the hump.

1. Introduction.

Information was required on water stability and trim during take-offs and landings of the Saro 37 fitted with a 1/2.75 scale Shetland hull bottom and tail.

2. Range of investigation.

Tests were made at a weight of 5,700 lb. corresponding to the full scale Shetland at 120,000 lb. for a C.G. normal (30% M.A.C.), C.G. aft (35% M.A.C.), C.G. forward (25% M.A.C.). These were made with flap settings of 0°, 10°, 20°, and 30° during take-off and 40°, 30°, 20°, and 10° during landings.

Tests were also made at 6,250 lb. corresponding to the full scale Shetland at 130,000 lb. with the C.G. in the normal position (30% M.A.C.). In the latter case, 0°, 10° and 20° flap were used during take-off and 40°, 30° and 20° of flap during landings.

All tests were carried out in winds under 6 knots. The tail setting during the tests was 1.5° nose down relative to the setting proposed for the Shetland. Aircraft details are given in Table 1.

3. Method of Analysis.

Attitude, acceleration and elevator angle during take-offs and landings were plotted against water speed, and stability limits deduced by the method given in Ref. 1. The curve of attitude against elevator angle was used to obtain elevator effectiveness.

4. Results.

The stability limits, free-to-trim attitudes and elevator effectiveness for the different weights, C.G. positions and flap angle settings are shown in Fig. 1 to 34. Weights and speed are quoted as full scale Shetland values.

Fig. 35 and 36 give a comparison of the stability limits, free-to-trim attitudes and elevator effectiveness in take-off at C.G. normal and zero flap obtained with the original S.37 tail and the Shetland tail.

5. Discussion of results.

(1) Stability and trim at 120,000 lb. C.G. 30% M.A.C.

Fig. 1 shows a fair degree of stability during take-off with 0° flap except over the hump when the stable region is rather narrow and porpoising will occur with elevator central. With 10° and 20° of flap (Fig. 2 and 3), the stable region at the hump is widened although porpoising will still occur with elevator central. With 30° of flap (fig.4) porpoising cannot be avoided over the hump and only stick back take-offs can safely be made. Landings with 40° and 30° of flap (fig. 5 and 6) gave ample stable limits although some severe porpoising occurred at the higher attitudes; with 20° and 10° of flap (fig. 7 and 8) bounce porpoising was encountered at an attitude of 8 at speeds from 100 to 115 knots. This region could not be attained with 40° or 30° of flap.

The effect of flap on elevator effectiveness during take-off is shown in fig. 31. This shows that flap has little effect except at 85 knots where the decreased displacement on lowering flaps is shown by the increased effectiveness with large flap angles. This is more marked in landings (fig. 32) where the effectiveness at 85 knots is 0.50 with 40° of flap and 0.27 with 10°.

(2) Stability and trim at 120,000 lb. C.G. 25% M.A.C.

During take-offs with 0° flap (fig. 9) the free-to-trim attitude was lowered $1\frac{1}{2}^\circ$ at the hump and approximately $1\frac{3}{4}^\circ$ at 85 knots from the attitudes with C.G. normal. The lower limit is practically unchanged, being lowered, at the most, by $\frac{1}{4}^\circ$. The upper limit is lowered by approximately $\frac{1}{2}^\circ$ at take-off but not so much at the hump; the stable range is therefore less throughout the speed range and the aircraft tends to trim more into the lower instability region. With 10° and 20° of flap (fig. 10 and 11) the effect is the same but here stick central is unstable right up to take-off. With 30° of flap (fig. 12) no upper limit was found during take-off. No bounce porpoising was encountered during landings (fig. 13 and 16). The trim was lowered $1\frac{1}{2}^\circ$ at the hump and about 2° at touch-down. Landings elevator central therefore trimmed into the lower limit at the hump. The position of the lower limit was as in take-off practically unchanged by the forward movement of the C.G. except at the hump where it was slightly lowered. The upper limit was lowered between $\frac{1}{2}^\circ$ and 1°.

The elevator was less effective in this C.G. position than in C.G. normal both in take-off and landing. (fig. 33 and 34).

(3) Stability and trim at 120,000 lb. C.G. 35% M.A.C.

Movement of the C.G. aft from 30% to 35% M.A.C. had not as much effect on trim as the forward movement considered above. The trim during take-off was raised $\frac{1}{2}^\circ$ at the hump and about 1° near take-off. The lower limit was slightly lowered at the hump. During take-offs with zero flap (fig. 17) the stability was improved both by the lowering of the lower limit at the hump and the raising of the upper limit. Stick central take-offs did not now involve porpoising. With 10° and 20° of flap (fig. 18 and 19) (stick central) take-offs were also free of porpoising, and the upper limit was raised between $\frac{1}{2}^\circ$ and 1°. There was again very little change in the lower limit. With 30° of flap (fig. 20) porpoising was encountered at the hump during take-off and the free-to-trim attitude was little raised by the C.G. movement. During landings the free-to-trim attitude was raised 3° to 4° at touch-down and between 1° and $1\frac{1}{2}^\circ$ over the hump. There was little change in the position of the upper limit which was now only 1° from the free-to-trim attitude. With 40° of flap (fig. 21) the limits were narrow over the hump, being about 2° in width. With 30° of flap (fig. 22), no lower limit was found at the hump though some lower limit porpoising was encountered at higher speeds. With 20° of flap (fig. 23) slight lower limit porpoising was found at the hump but none at higher speeds. Bounce porpoising was first encountered with 10° flap (fig. 24) and as with C.G. normal at about 8 in attitude, between 100 and 115 knots in speed. There was little change in elevator effectiveness compared with C.G. normal case; the elevator is sligthly more effective in take-off (fig. 33) and slightly less in landing (fig. 34).

(4) Stability and trim at 130,000 lb. C.G. 30% M.A.C.

During take-offs at this weight a band of instability occurred at the hump extending for a range of 10 knots in speed (fig. 25 to 27). This may be serious as the acceleration will be low. Take-offs with 0° flap (fig.25) encountered porpoising at the hump, stick central; this disappeared at higher speeds. With 10° of flap (fig. 26) porpoising at the hump was more serious stick central but again damped out at take-off. With 20° of flap (fig. 27) porpoising was encountered at take-off as well as at the hump the free-to-trim attitude being stable only for a range of 15 knots. The stable range at take-off was about 5° in width for all flap angles. During landings there was a small stable region at the hump for all flap positions. With 40° and 30° flap (fig. 28 and 29) there was a 4° stable region at touch-down speeds and no bounce porpoising occurred. With 20° of flap bounce porpoising was encountered on one occasion but this was at a very high attitude (fig.30).

There was little change in trim with this increase in weight the free-to-trim attitude being slightly higher at the hump and lower at take-off. The elevator effectiveness was slightly lower in take-off (fig. 33). The difference was more marked on landing (fig. 34), the effectiveness being lowered from 0.50 to 0.32 at 85 knots.

(5) Comparison of Shetland and Saro tails.

The two stability diagrams in fig. 35 are practically identical but the attitude over the hump is less with the S.37 tail although at take-off they are the same. It must be noted here that the setting of the Shetland, tail fitted, was $1\frac{1}{2}^{\circ}$ nose down to the setting proposed on the Shetland. A change to the Shetland setting would have trimmed it further into the lower limit. Figure 36 shows that the Shetland type tail has a greater effectiveness at take-off although the S.37 twin tail is better over the hump.

Water handling.

Handling was satisfactory with this aircraft at 120,000 lb. (C.G. normal) although it was unsafe to hold the stick forward of central during take-offs or landings as this caused vicious porpoising and a pronounced tendency to swing to starboard. With C.G. forward it was more difficult to avoid lower limit porpoising and during the latter part of the take-off run the aircraft would be thrown out of the water by violent porpoising if the stick was held central up to take-off. A landing, stick central, however, was free of porpoising till the hump was reached. With C.G. aft there was a tendency to bounce porpoise and the aircraft tended to balloon on levelling out to land. At 130,000 lb., C.G. normal, running was very dirty up to the hump and solid water was thrown into the propellers; acceleration through this range of speeds was poor, a very pronounced tendency to swing to starboard was also noted and some take-offs had to be abandoned because of swinging. The limits of stick movement for a safe take-off were narrow; and bounce porpoising was experienced during stick back landings.

(6) Conclusions.

The Shetland should be satisfactory at 120,000 lb. at the tail setting of $-5^{\circ}\ 41'$ to the wing no lift line as tested on the Saro 37. Any further nose down moment will tend to trim it into the lower limit. Bounce porpoising may occur during slow landings with C.G. in the aft or normal positions but will probably not be serious. The effect of moving the C.G. forward is to lower the trim and the upper limit, the lower limit and bounce porpoising limit remain practically unchanged. Movement of the C.G. aft raises both the upper limit and trim but here the trim comes closer to the bounce porpoising limit; as before, the lower limit is almost unchanged. At 130,000 lb. a band of instability will be encountered at the hump extending over 10 knots. Very dirty running is encountered up to the hump.

The change from the S.37 to Shetland type tail has little or no effect on the stability limits but the Shetland tail gives a higher attitude over the hump and is more effective at take-off.

REFERENCES

Ref. No.	Author	Title	Report No.
1.	H. G. White A. G. Smith	A method for determining the water stability of a seaplane in take-off and landing.	H/Res/163.

TABLE 1

Particulars of Saro 37 with Shetland bottom and tail

Hull

Beam	4 ft. 6.25 in.
Scale	1/2.75
Angle of keel to hull datum	$= 1^\circ\ 32'$
Angle of keel to hull datum on Shetland	$= 2^\circ\ 38'$

Distance of C.G. forward of step	C.G. normal	1 ft. 8.11 in.
	C.G. forward	2 ft. 0.55 in.
	C.G. aft	1 ft. 3.67 in.

Wings

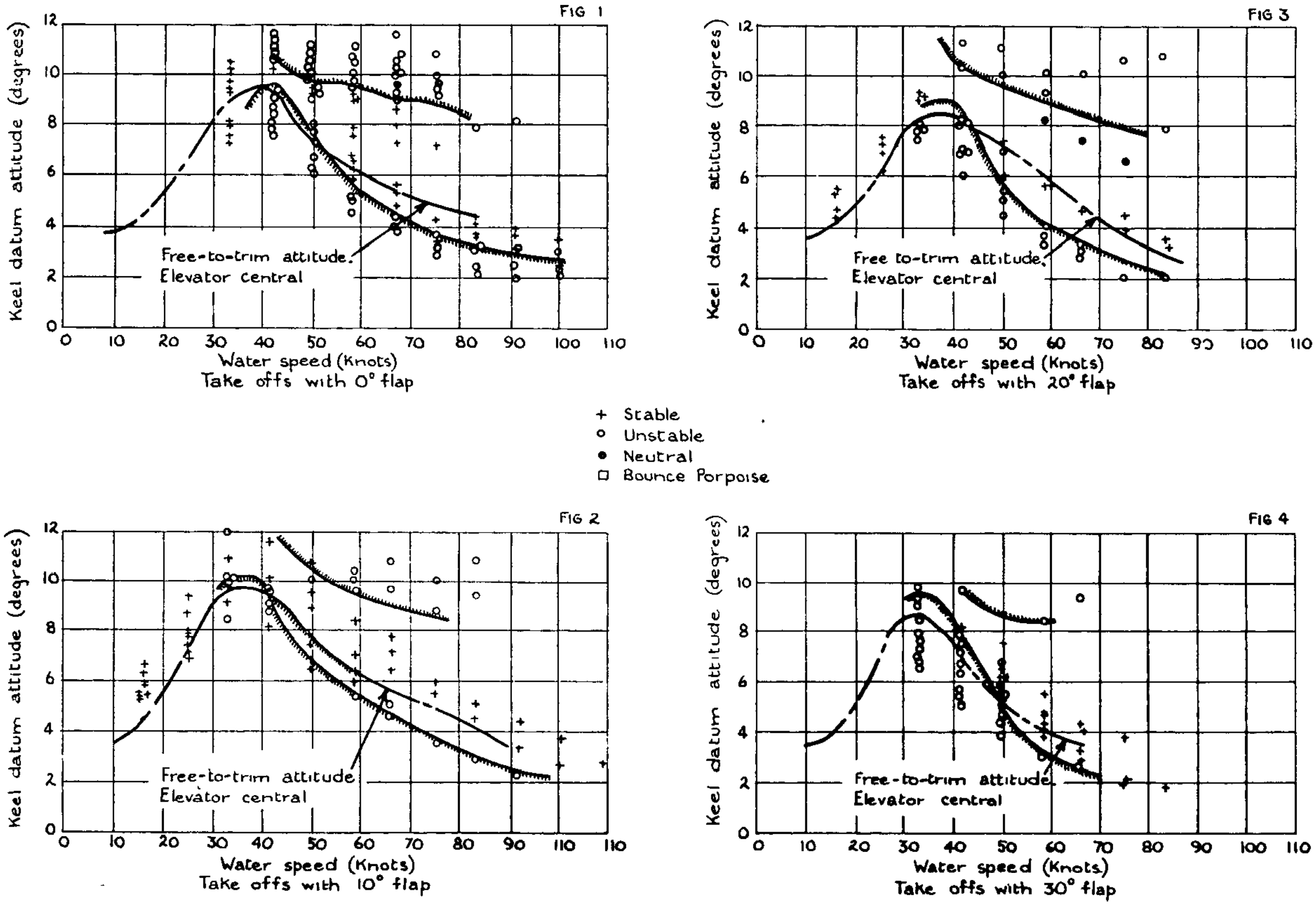
Gross area	340 sq. ft.
Span	50 ft.
Mean Chord	6.8 ft.
Aspect Ratio	7.35
Aerodynamic chord to Shetland hull datum	$6^\circ\ 11'$

Tailplane

	Shetland Type	S.37 Type
Total area	53.85 sq. ft.	64.60 sq. ft.
Span	16.54 ft.	15 ft.
Elevator Area	18.25 sq. ft.	21.4 sq. ft.
Elevator Movement	24° up 23° down	27° up 20° down
Setting of tail, Angle to keel	$0^\circ\ 28'$	$0^\circ\ 28'$
Shetland	$2^\circ\ 0'$	

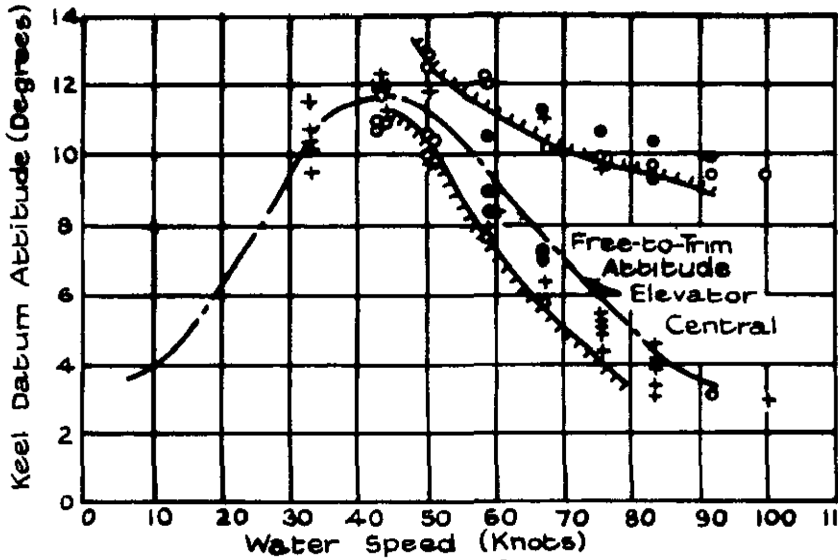
TABLE 2

Fig. No.	Weight lb.	C.G.	Condition	Flap Angle	Subject
1	120,000	30% M.A.C.	Take-off	0°	Stability and trim
2	"	"	"	10°	"
3	"	"	"	20°	"
4	"	"	"	30°	"
5	"	"	Landing	40°	"
6	"	"	"	30°	"
7	"	"	"	20°	"
8	"	"	"	10°	"
9	"	25% M.A.C.	Take-off	0°	"
10	"	"	"	10°	"
11	"	"	"	20°	"
12	"	"	"	30°	"
13	"	"	Landing	40°	"
14	"	"	"	30°	"
15	"	"	"	20°	"
16	"	"	"	10°	"
17	"	35% M.A.C.	Take-off	0°	"
18	"	"	"	10°	"
19	"	"	"	20°	"
20	"	"	"	30°	"
21	"	"	Landing	40°	"
22	"	"	"	30°	"
23	"	"	"	20°	"
24	"	"	"	10°	"
25	130,000	30% M.A.C.	Take-off	0°	"
26	"	"	"	10°	"
27	"	"	"	20°	"
28	"	"	Landing	40°	"
29	"	"	"	30°	"
30	"	"	"	20°	"
31	120,000	"	Take-off	0°,10°,20°,30°	Elevator Effectiveness
32	"	"	Landing	40°,30°,20°,10°	"
33	120,000 - 130,000	Range	Take-off	0°	"
34	"	"	Landing	40°	"
35	120,000	30% M.A.C.	Take-off	0°	Comparison of stabilit and trim
36	"	"	"	0°	Comparison of elevator effectiveness



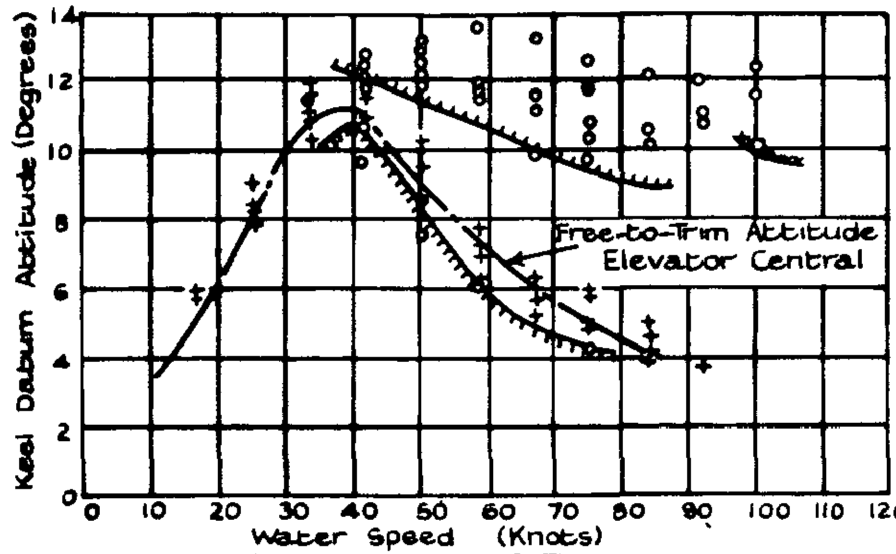
Shetland Weight 120,000 lb. C.G 30% M.A.C.
Stability and Free-To-Trim Attitude During Take-Offs

FIG. 5.



Landings 40° Flap

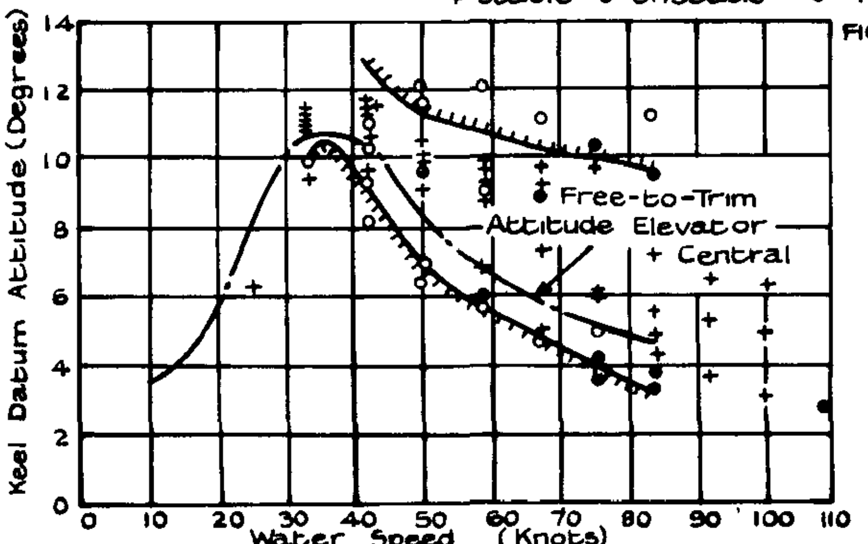
FIG 7.



Landings 20° Flap

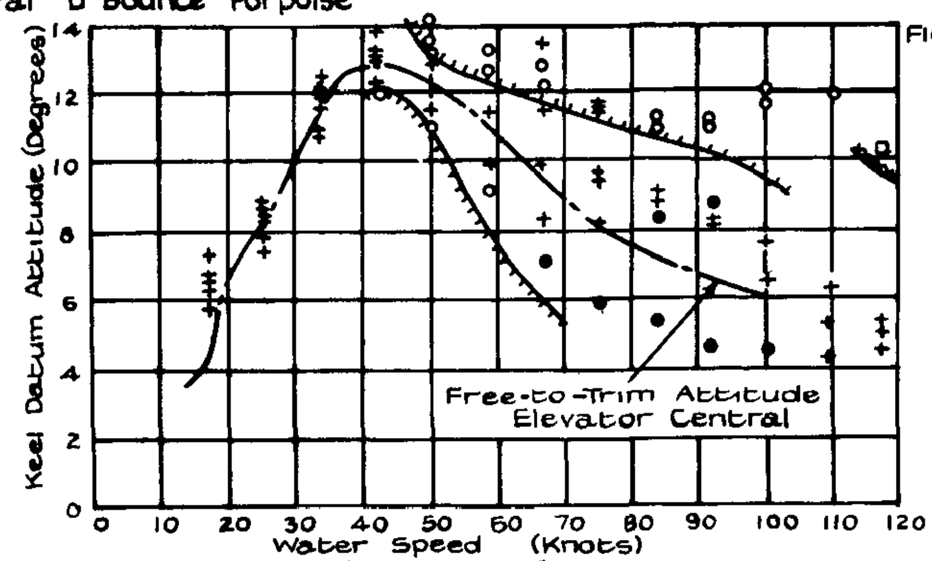
+ Stable o Unstable ● Neutral □ Bounce Porpoise

FIG. 6



Landings 30° Flap

FIG 8



Landings 10° Flap

Shetland Weight 120,000 lb C G 30% M.A.C.

Stability and Free to - Trim Attitude During Landings

DS 34603

FIG. 9

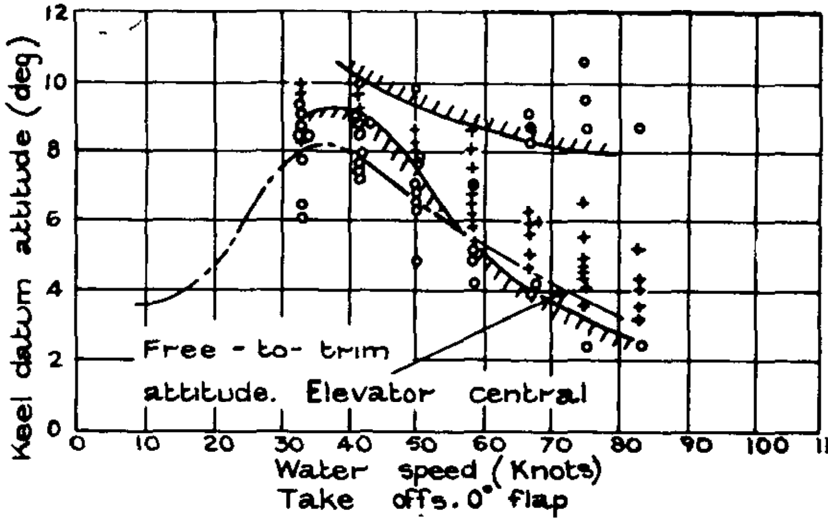
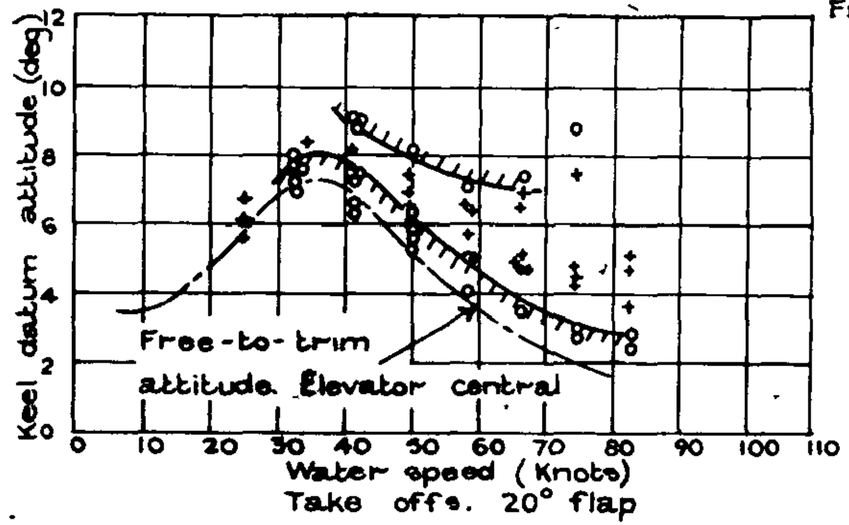


FIG 11



+ Stable
• Neutral
∘ Unstable
□ Bounce porpoising

FIG 10

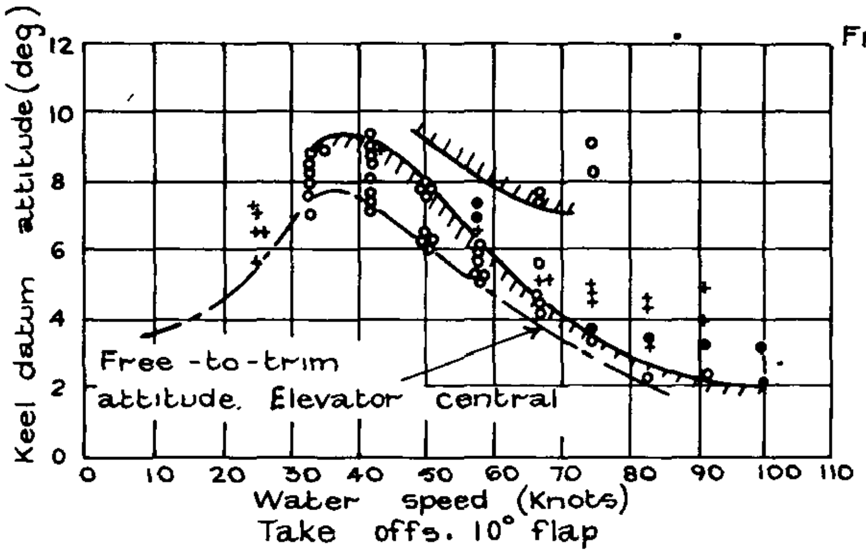
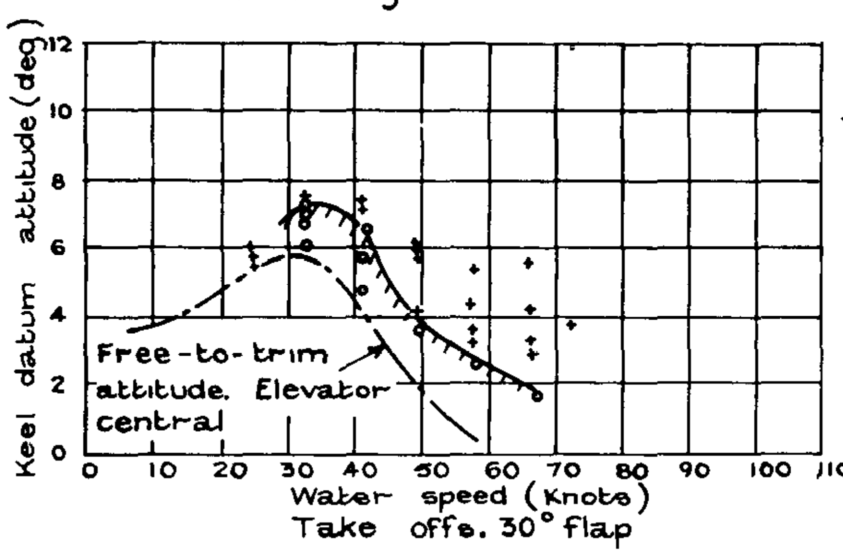
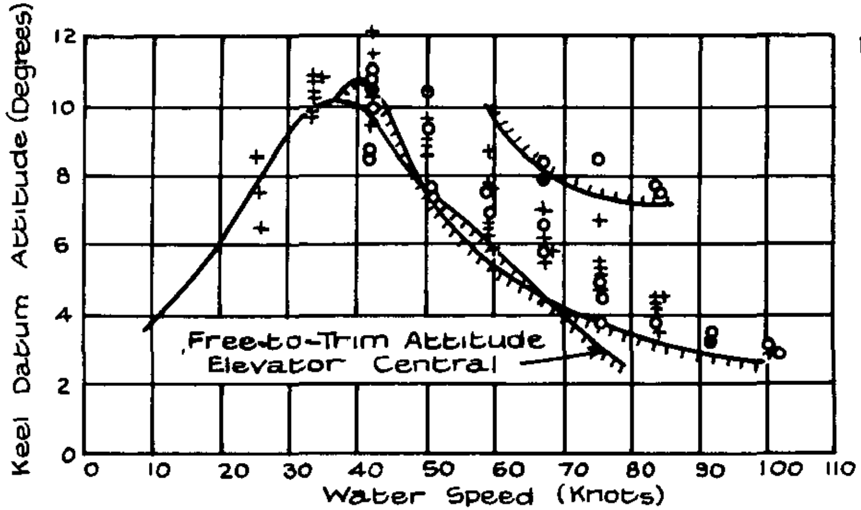


FIG 12

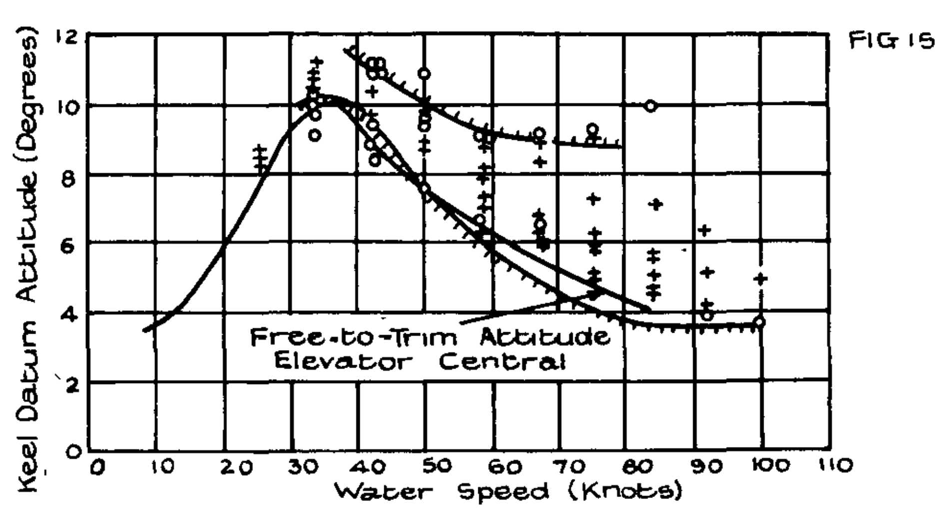


Shetland weight 120,000 lb CG 25% MAC.
Stability and free-to-trim attitude during take-offs

DS 34603

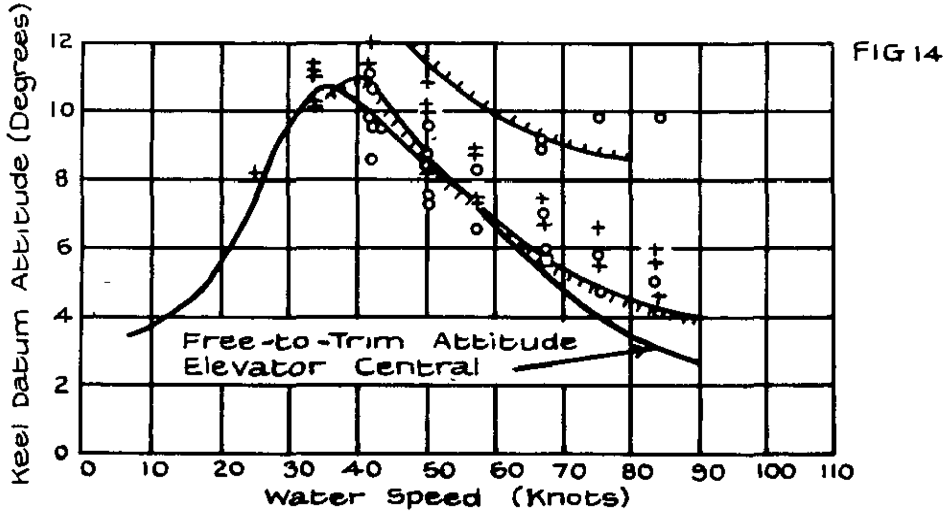


Landings - 40° Flap

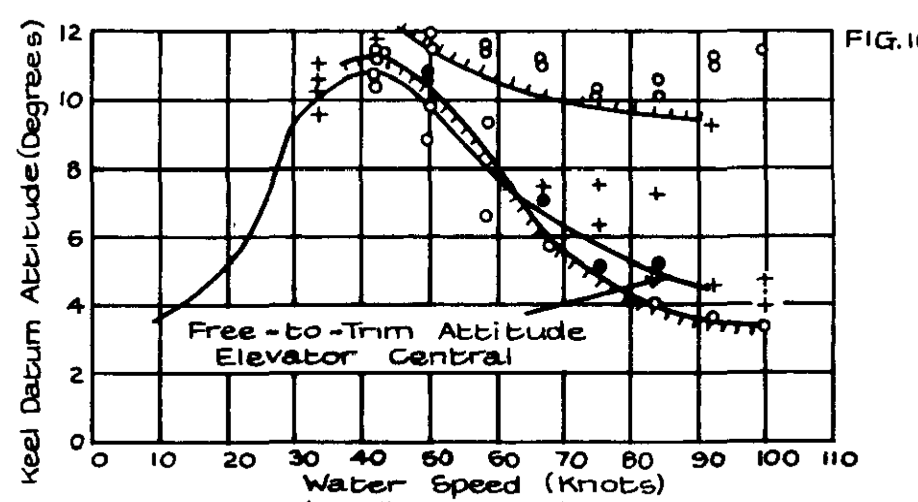


Landings 20° Flap

+ Stable
o Unstable
● Neutral
□ Bounce Porpoise



Landings 30° Flap

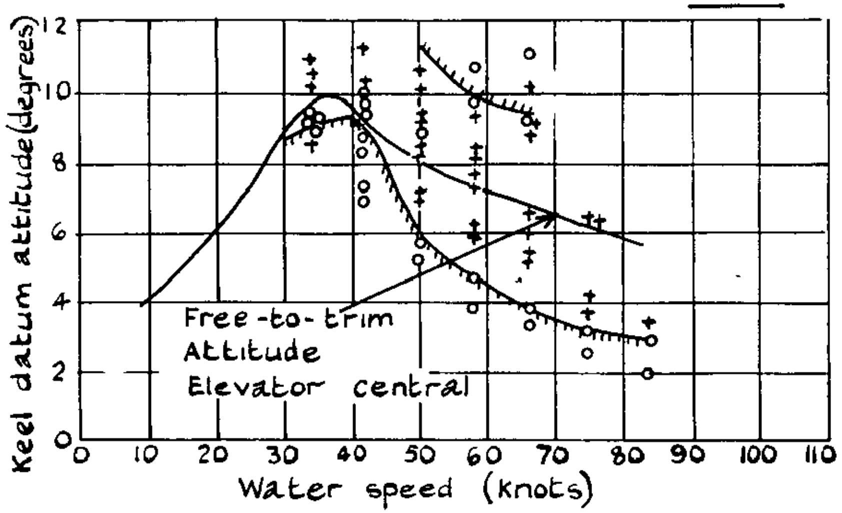


Landings 10° Flap

Shetland Weight 120,000 lb C.G 25% M.A.C.
Stability and Free to Trim Attitude during Landings.

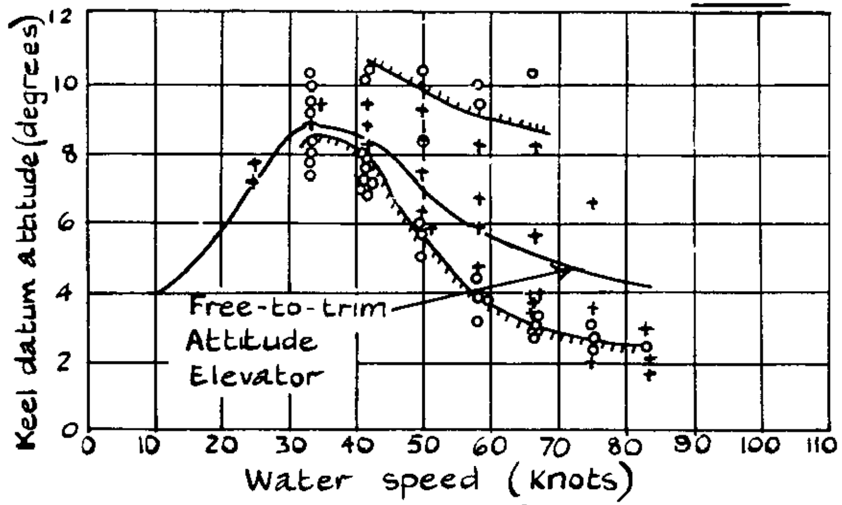
DS 34603

Fig 17



Take-off with 0° flap

Fig 19.

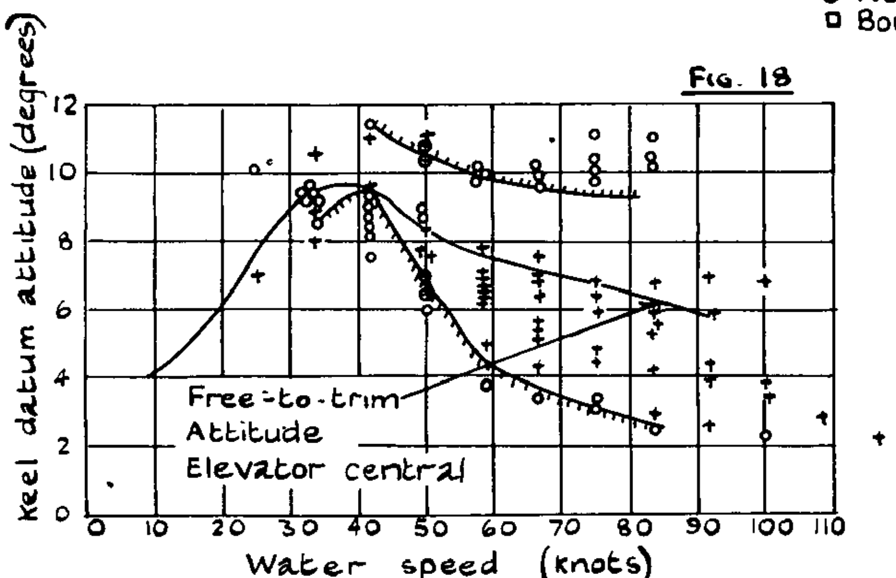


Take-off with 20° flap

+ Stable
o Unstable
⊕ Neutral
□ Bounce porpoise

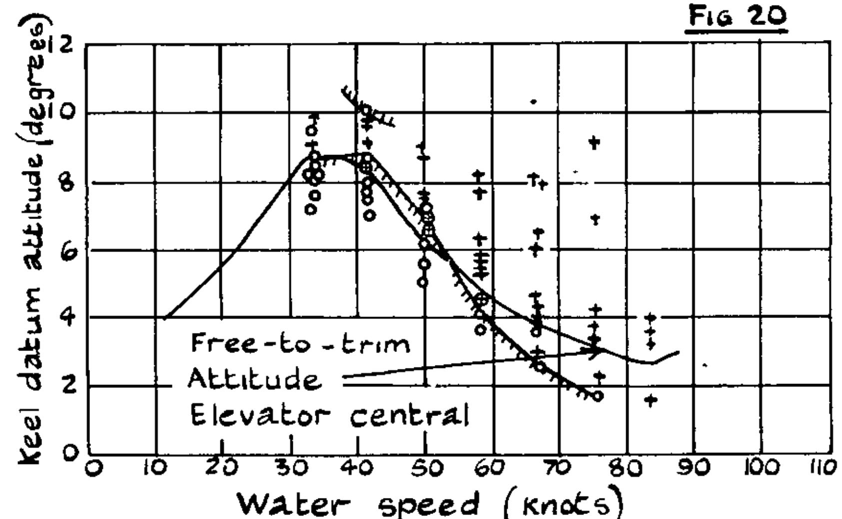
11

Fig. 18



Take-off with 10° flap

Fig 20



Take-off with 30° flap

Shetland weight 120,000 lb CG 35% MAC

Stability and free-to-trim attitude during take-off

DS 34603

FIG.21

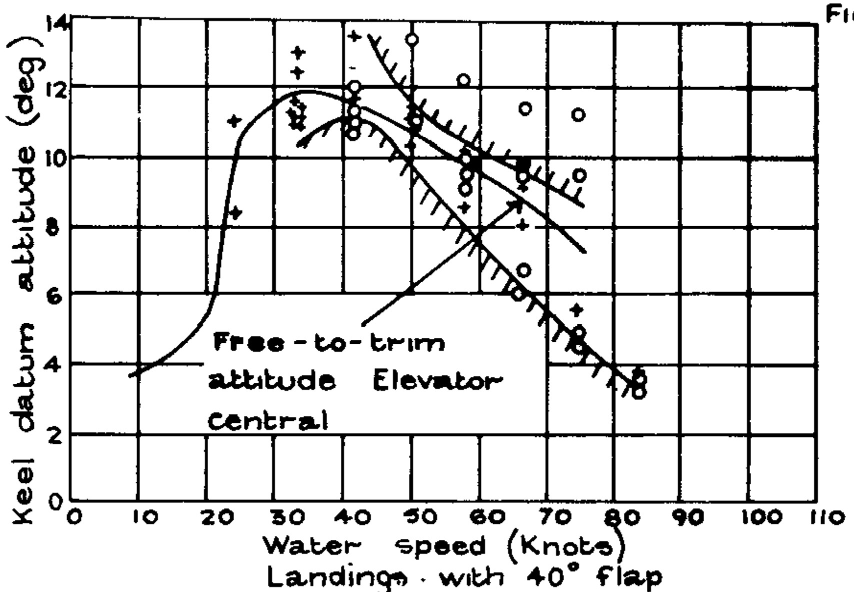
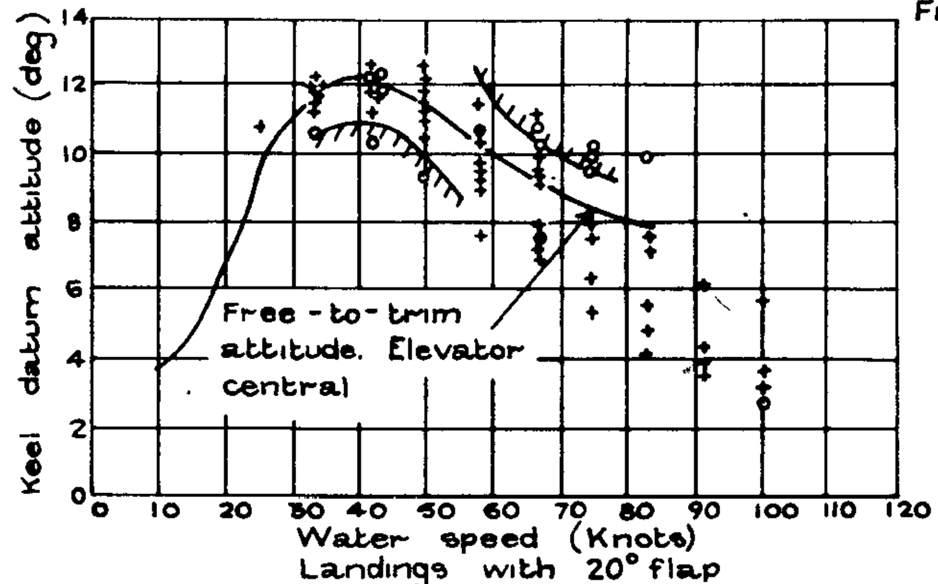


FIG. 23



+ Stable ● Neutral
o Unstable □ Bounce porpoise

FIG 22

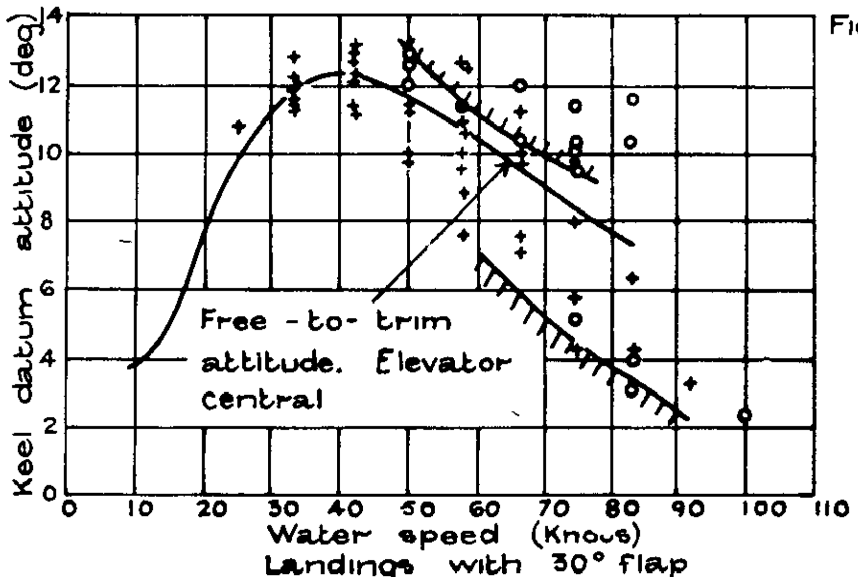
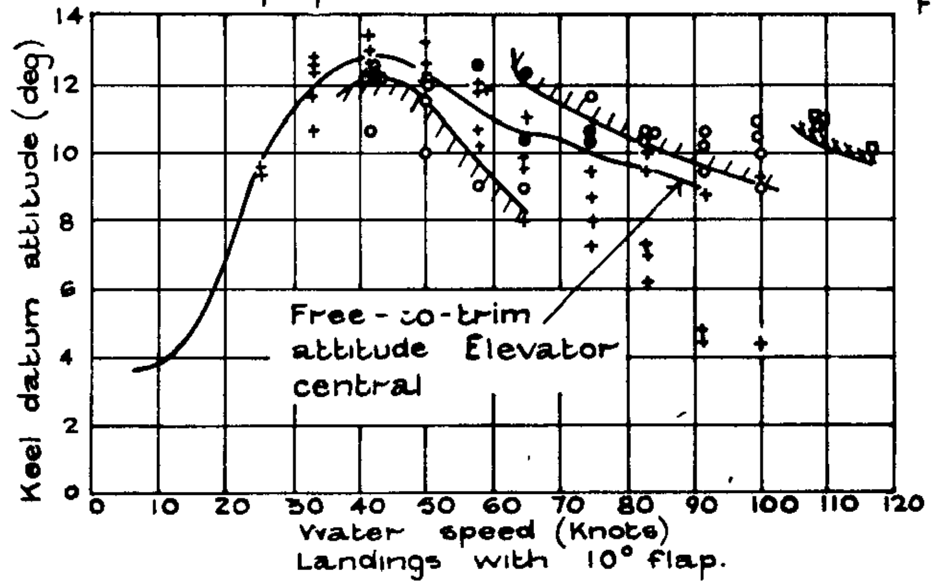
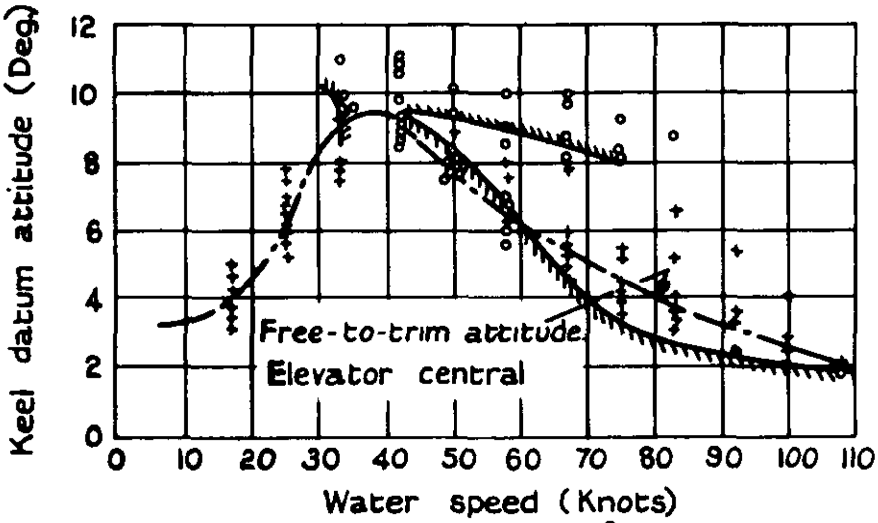


FIG. 24



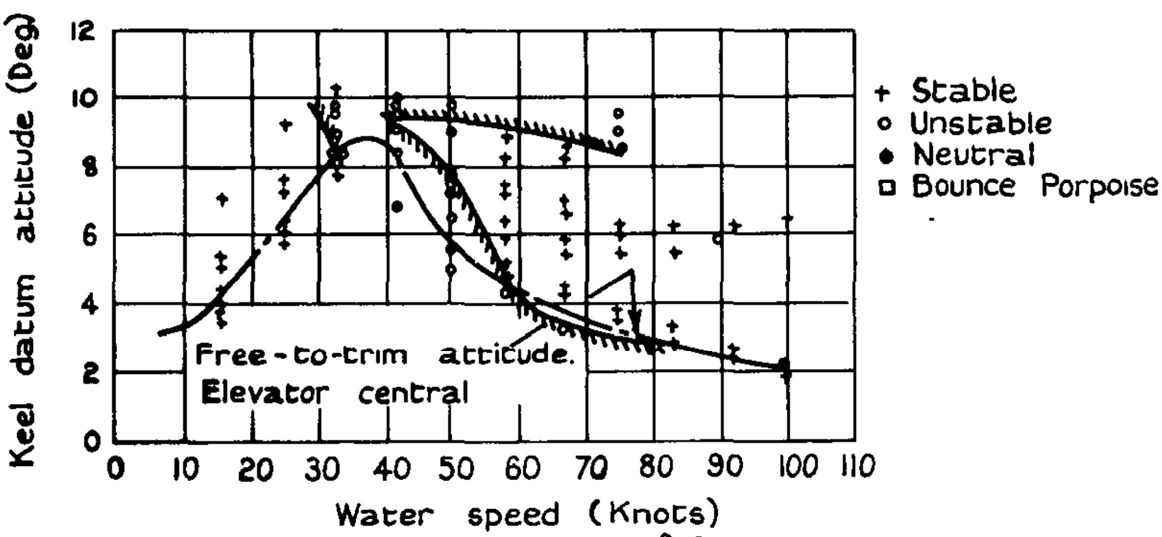
Shetland weight 120,000 lb CG 35% MAC
Stability and free-to-trim attitude during landings

Fig 25



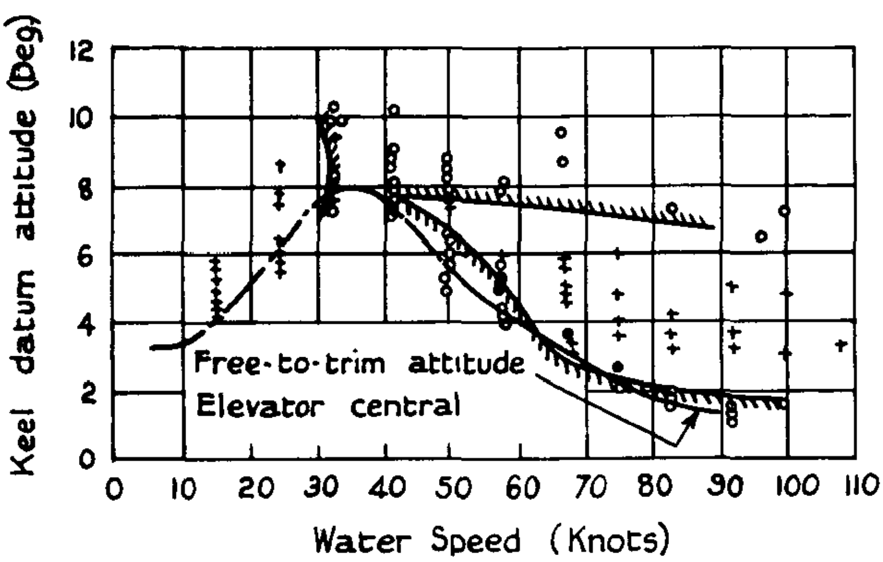
Take offs with 0° flap

Fig 26



Take offs with 10° flap

Fig 27



Take offs with 20° flap

Shetland weight 130,000 lb C G 30 % M.A.C stability and free-to-trim attitude during take-off.

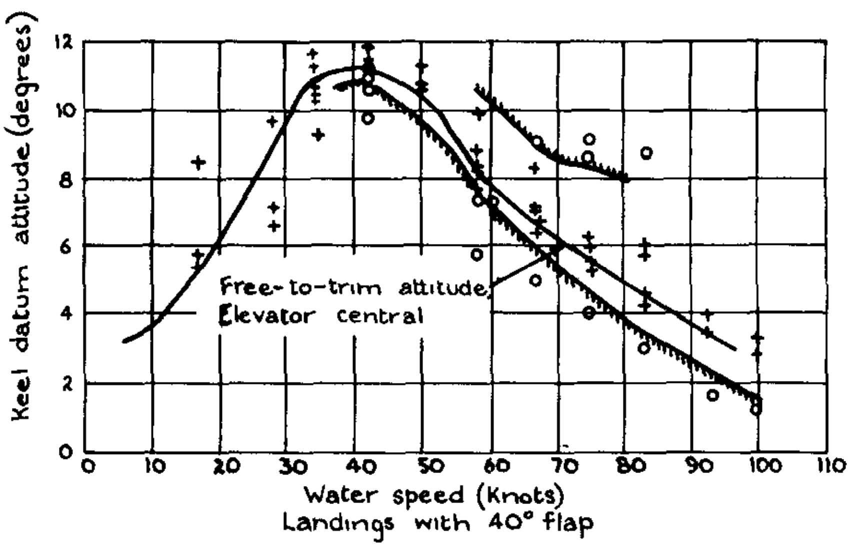


FIG 28

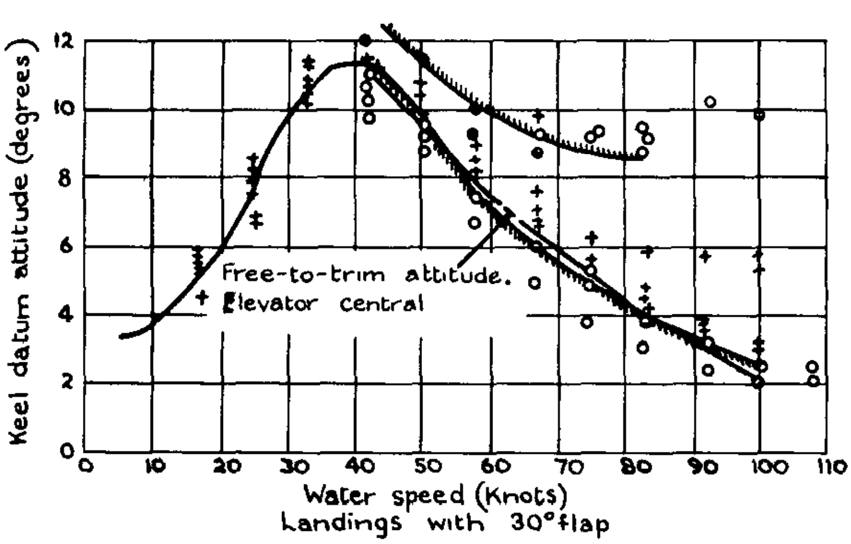


FIG 29

+ Stable
o Unstable
● Neutral
□ Bounce porpoise

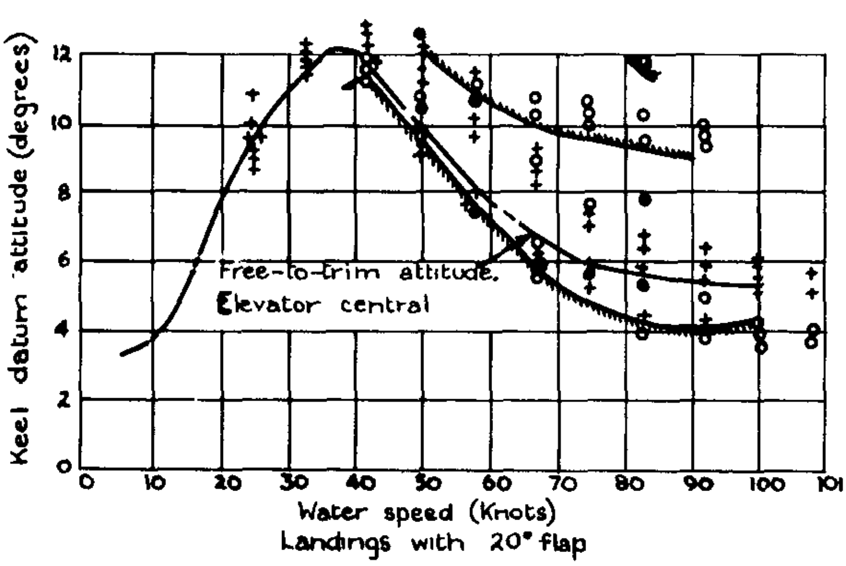
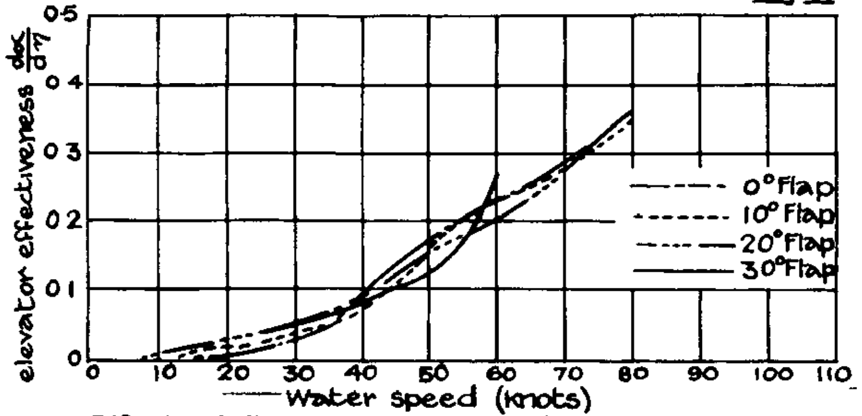


FIG 30

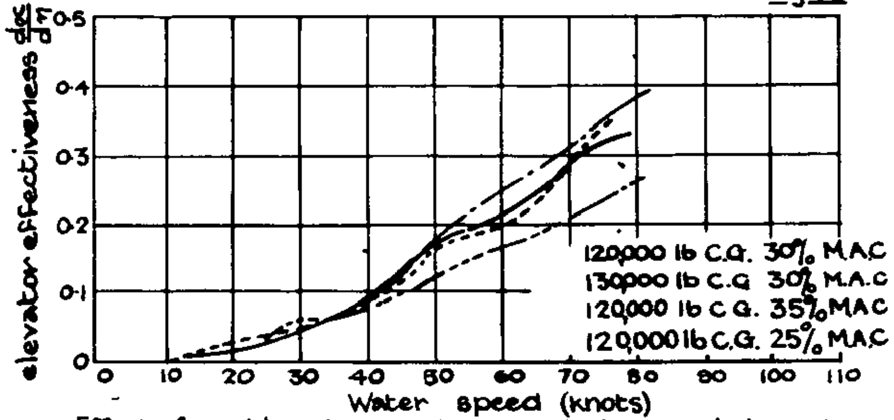
Shetland - Weight 13,000 lb CG 30% MAC
Stability and Free-to-Trim Attitude During Landings

Fig. 31



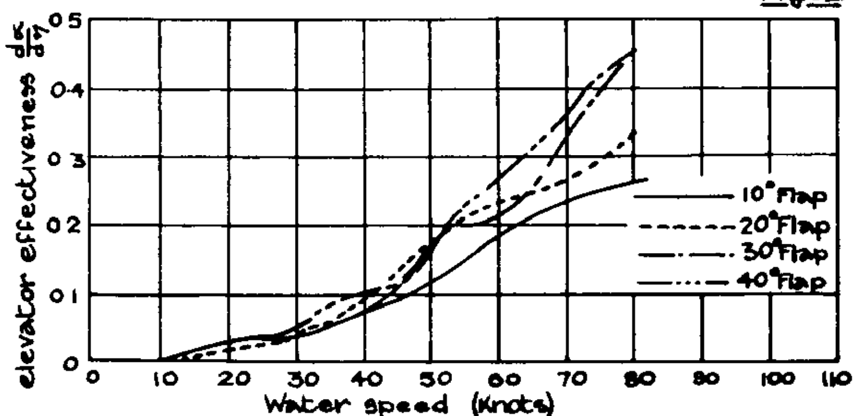
Effect of flap on elevator effectiveness during take-off
weight 120000 lb C.G. 30% M.A.C

Fig. 33



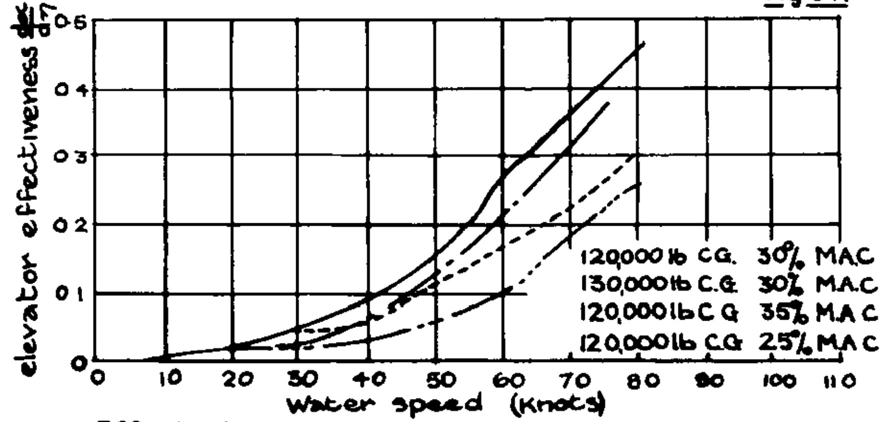
Effect of weight and C.G on elevator effectiveness during take-off
with zero flap

Fig. 32



Effect of flap on elevator effectiveness during landing
weight 120,000 lb C.G 30% M.A.C.

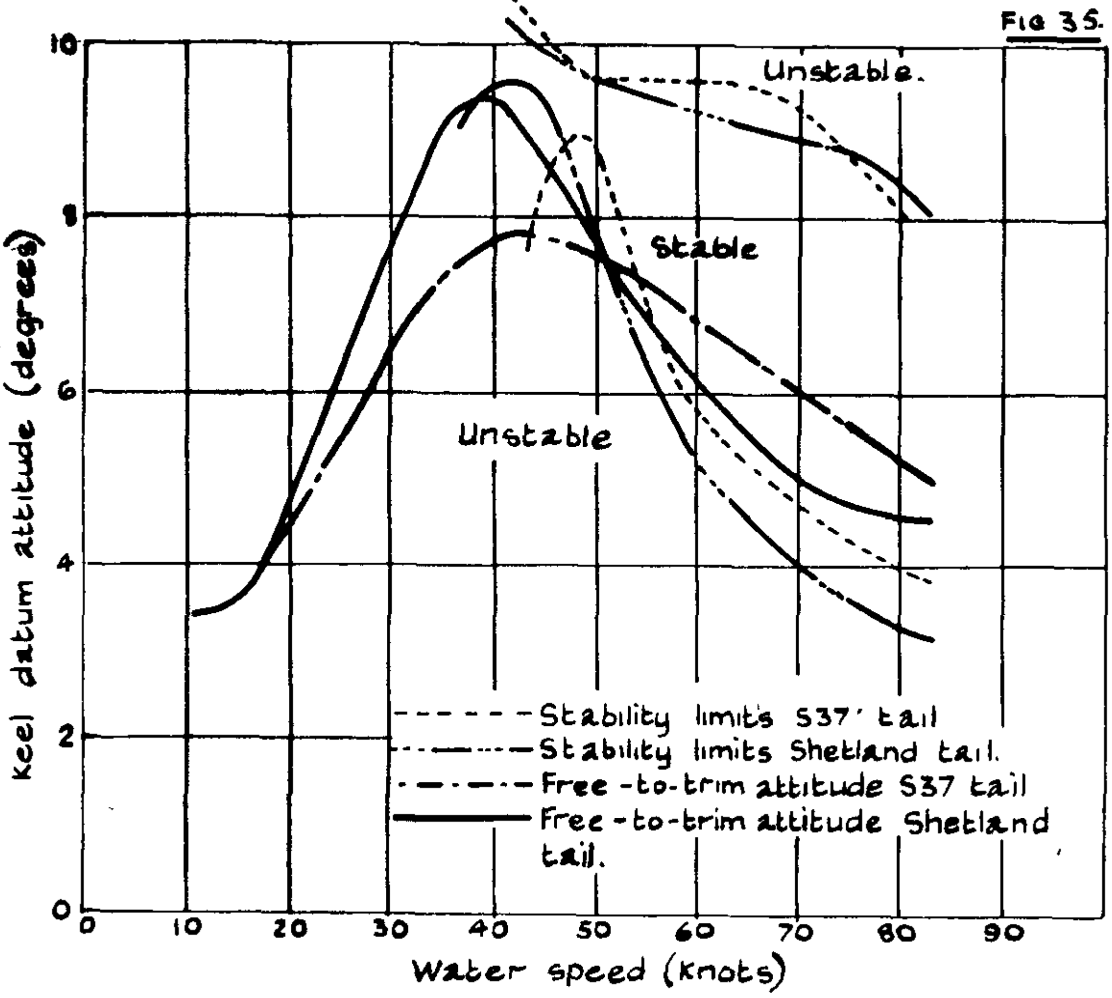
Fig 34.



Effect of weight and C.G on elevator effectiveness during
landing with 40° flap.

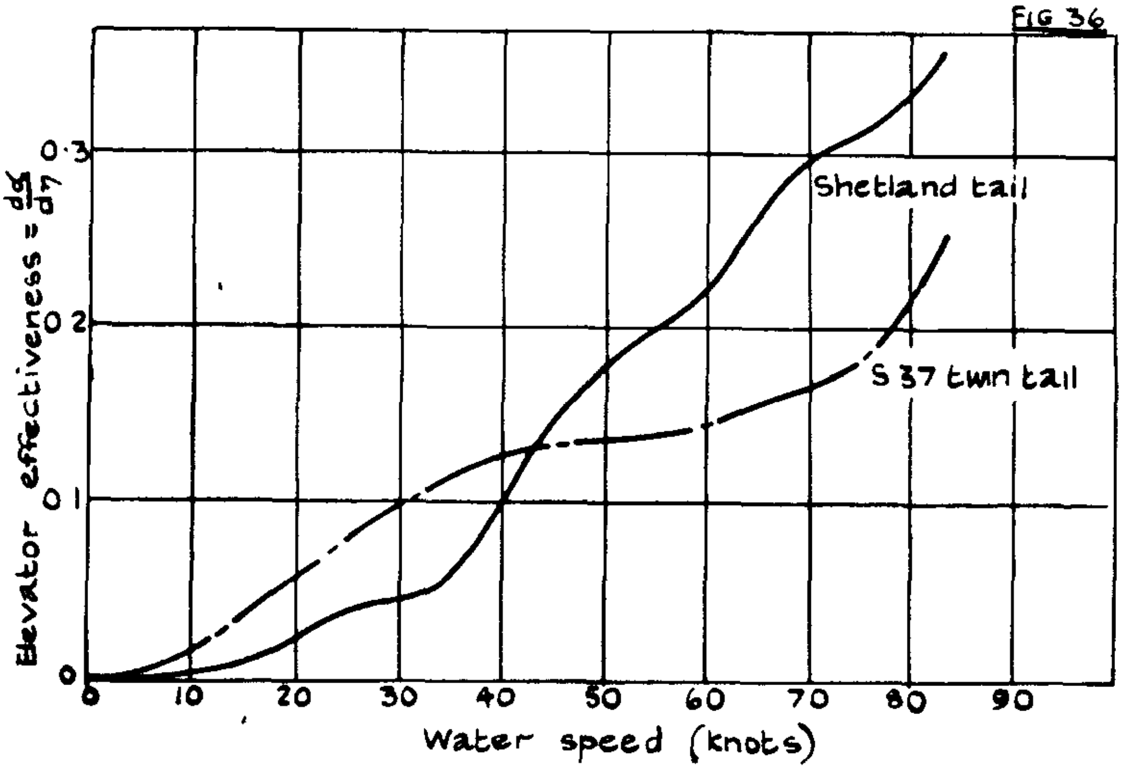
Shetland elevator effectiveness during take-off and landing

Fig 35.



Shetland 120,000 lb C.G 30% M.A.C comparison of stability and trim during take-off with 0° flap for S37 tail and Shetland tail.

Fig 36



Shetland 120,000 lb. C.G 30% M.A.C comparison for S37 tail and Shetland tail of elevator effectiveness in take-off with zero flap.

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