C.P. No. 27
6517
A.R.C. Technical Report

MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL

CURRENT PAPERS

STABILITY TESTS ON A LARGE SCALE MODEL OF THE SHETLAND HULL BOTTOM

By

H. G White B.Sc
A. G Smith, B.Sc, D.I.C, A.R.C.S.

LONDON : HIS MAJESTY'S STATIONERY OFFICE

1950

Price 2s. 0d. net.

Report No. H/Res/159

16th January 1943

MARINE AIRCRAFT EXPERIMENTAL ESTABLISHMENT

Stability tests on a large scale model of the Shetland hull bottom

by

H. G. White, B.Sc.
A. G. Smith, B.Sc., D.I.C., A.R.C.S.

SUMMARY

Tests on the stability of a large scale model of the Shetland R 14/40 hull bottom were required to indicate the stability of the full scale flying boat and for comparison with the tank model results. These tests have been made at M.A.E.E. on a 1 : 2.75 scale model hull, but the superstructure and the wing tip floats used in the tests were not models of those of the Shetland, although the wings were closely to scale.

The results show that the Shetland has a reasonable stability range at 120,000 lb. which decreases with movement of the C.G., use of flaps, or with an increase in weight. The tank model stability range is wider below 85 knots but is in agreement near the take-off speed, if the less severe limits are chosen. The Shetland stability range appears to be less than the faired step Sunderland III. However, the pilots at M.A.E.E. are of the opinion that the Shetland is as good as the Sunderland III in normal handling.

The Shetland appears to be dirty at speeds below 55 knots and care will be needed to avoid damage to the propellers and tailplane. A bouncing porpoise is likely to occur in take-off if the Shetland is pulled off, or if a big water disturbance is hit, and also in landing if the touch down speed is too slow. Increase in weight accentuates dirtiness at low speeds and increases the possibility of the bouncing porpoise occurring.

Tests have also been made with the Shetland tail unit and wing tip floats5.

1. Introduction

Tests on the stability and water performance of a large scale model of the Shetland (R 14/40) hull bottom were required to determine the stability characteristics of the full scale flying boat and to check the R.A.E. tank results. Preliminary tests were made at the M.A.E.E. on a 1 : 2.75 scale model hull attached to a Saro 37 superstructure, and the results are given in this report. Further tests have been made with the Shetland tail unit and wing tip floats.

2. Range of investigation

Attitude, acceleration and stability characteristics were measured in steady runs and take-offs. The tests were made at a weight of 5,700 lb. and 6,250 lb. which correspond respectively to 120,000 lb. and 130,000 lb. full scale. Steady runs were done at 5,700 lb. with 0° flap and C.G. in normal, forward and aft positions, and then with 15° flap and C.G. normal; take-offs at this weight were done with C.G. normal with 0° flap and 20° flap. Steady runs and take-offs were done at 6,250 lb. with the C.G. normal and 0° flap.

The general outlines of the Saro 37 with the lines of the Shetland hull bottom are given in Fig. 1. The hull lines are similar in general layout to those of the faired step Sunderland (Mark III). The step fairing has a fairing ratio of 5: 1. The different C.G. positions relative to the step are given in Table 1 (A), which also gives general aircraft data. C.G. normal is at 30% M.A.C. and the forward and aft positions are at 25% and 35% M.A.C. respectively. Table 1 (B) gives a general comparison of the large model with the full scale Shetland also with the full scale Sunderland, and indicates that the model is very closely a scale model of the Shetland.

Attitude and acceleration were recorded by an R.A.E. two axis accelerometer and gyro pitch recorder. The elevator angle was indicated by a two way voltmeter on the pilot's instrument board[1]. Speed in take-off has been obtained by integrating the acceleration, making allowance for the initial speed. Speed in steady runs has been derived from the indicated air speed and measured wind speed. The position error which was applied in calculating the speed in steady runs has been obtained by taxying over a speed course.

3. Results and discussion

The results are discussed under (1) steady runs, (2) take-offs. Each figure is plotted with the full scale Shetland speed as base, and the attitudes shown are those relative to the Shetland hull datum. In the figures and text, reference is made to the full scale weight only. The test results are compared with the Shetland tank tests[2] and with the full scale faired step Sunderland III. An index to the figures is given before Fig. 1.

3.1 Steady runs

Steady runs were done at 120,000 lb. to find the nature of the stability and also the effect of C.G. travel and of flaps on stability. Tests were made at 130,000 lb. to investigate the stability at the higher overload. The points obtained in the steady run tests for each condition are shown in Figs. 2 to 6. Each figure shows the mean attitude curve for stick central and the interpolated stability limits. Stick central corresponds to the stick held fixed with the elevator angle zero, the flying boat being then free to trim in pitch. The porpoising points are plotted at the mean attitude of the porpoise and details of the porpoising results are given in Tables 2 to 6. Every definite oscillation in pitch recorded in the tests is shown in the tables whatever the amplitude, unless the oscillation damped out, but the interpolated stability limits are based on porpoising points of over 2° amplitude only.

Fig. 2 and Table 2 give the steady run results at 120,000 lb. for C.G. normal with 0o flap. Fig. 2 (A) gives the steady run points, and Fig. 2 (B) the mean curves of attitude for a range of stick positions. Three stability limits have been found, the normal conventional upper and lower limits which define the stability range, and a second upper limit which marks the incidence of a bouncing porpoise similar to that obtained on the faired step

Sunderland III[3]. The stability limits drawn in Fig. 2 suggest a reasonable stable region over the whole speed range if the small amplitude porpoising is neglected as of no importance. The narrowest stability range is $3\frac{1}{2}°$ at 68 knots, the range increasing both below and above this speed. At speeds above 75 knots with the stick hard back (i.e. at high attitude) the bouncing porpoise is experienced and is rather vicious. It is however unlikely that this would be encountered unless the boat is deliberately pulled off or hits a bad water disturbance.

The effect of moving the C.G. forward (Fig. 3, Table 3) is to raise the lower limit by $3\frac{1}{2}°$ at 50 knots although it is little changed above 70 knots and to raise the normal upper limit beyond the practical range of attitudes attainable. The mean attitude stick central is also higher at the hump because of the increase in porpoising; as the report on the Scion[4] shows, porpoising in the lower region of instability tends to raise the mean attitude. The bouncing porpoise is still found at high speeds and high attitudes but is less likely to occur than in the C.G. normal case, for the attitudes are higher. The general result is a wider stable range above 60 knots, but porpoising cannot be avoided over the hump speed range. The porpoising which occurs over the hump is not very important, unless damage to the tailplane or propellers is experienced, since it will be damped out quickly above 60 knots.

When the C.G. is moved aft from the normal position (Fig. 4, Table 4) the lower stability limit is raised about $1°$ at 50 knots but is little changed above 70 knots. The upper stability limit is slightly lower at 55 knots. but is otherwise very similar to the C.G. normal limit. The resultant stability band therefore becomes narrower than for C.G. normal below 70 knots, decreasing to $1\frac{1}{2}°$ at 60 knots. This narrow range is however very local in speed and any porpoising, although of fairly high amplitude, should be controlled quickly above 60 knots. The bouncing porpoise occurs at slightly lower attitudes at high speeds and is therefore more likely to occur than in the C.G. normal case.

The test results for 120,000 lb., C.G. normal, with $15°$ flap are given in Fig. 5 and Table 5.( )? As compared with the $0°$ flap case, the lower stability limit is unaltered at 50 knots although it is $2°$ lower at 70 knots. The upper limit is both lower over the whole speed range and extends down to 50 knots. The general effect is to lower the running attitudes by $1°$, to narrow the stability range by about $1°$ above 75 knots and reduce the stability range between 45 and 65 knots to $1\frac{1}{2}°$. Porpoising in this range is unlikely to be dangerous, but may cause damage to the tailplane and propellers. The upper stability limit comes so low at 85 knots, that take-offs in which the flap is lowered just before flying speed is reached, would be subject to porpoising before the machine was airborne and might possibly cause damage to the aircraft. The bouncing porpoise is unchanged.

The effect of changing the weight to 130,000 lb. ($0°$ flap, C.G. normal) is shown in Fig. 6. The lower stability limit is raised $1°$ at 50 knots although it is again little changed above 70 knots; the upper limit is generally lower by $2°$ at 80 knots and $1°$ at 70 knots; the bouncing porpoise limit is also lowered about $1\frac{1}{2}°$. The stability range is still quite fair at take-off speeds but is reduced to about $2°$ from 50 to 70 knots. The lowering of the bouncing porpoise region increases the liability to porpoise and may indicate a steady worsening of conditions as the weight increases. Porpoising at the lower speeds is again not dangerous, except that at the high weight there is more likelihood of damage to the tailplane and propellers.

3.2 Take-off results and comparison with steady runs

All recorded take-offs were made with the C.G. in the normal position. Each take-off figure contains the appropriate steady run results drawn to the same scale.

The take-offs made for a weight of 120,000 lb. and $0°$ flap (Fig. 7) cover the whole range of elevator position available, and are in very good agreement with the steady run results of Fig. 2. The low amplitude porpoising neglected by the steady run limits occurs in the take-offs but never exceeds 2°. The bounce porpoise is experienced, when the stick is held half to fully back, just before take-off (above 90 knots) but should not occur in a take-off with normal handling.

The take-offs with 20° flap (Fig. 8) do not cover the whole range of attitude available, but within the attitude range measured they agree very well with the steady run results. The running attitudes are lowered by about 1° and the stable range decreased below 65 knots, when compared with the 0° flap case. Considerable spray was thrown up into the propellers at the lower speeds during porpoising.

Take-offs with 0° flap at the overload weight of 130,000 lb. are shown in Fig. 9. The stick positions indicated in the figure only apply above 40 knots since the stick had to be held fully back at lower speeds to avoid excessive damage to the propellers by spray. The results are again in very good agreement with the steady run results, with respect to the porpoising of both above and below 2° amplitude. The reduction of the stable range at 130,000 lb. is confirmed. The porpoising experienced between 45 and 65 knots caused damage to the propellers and tailplane by water. With the stick half back a vicious bouncing porpoise took place at 85 knots when the boat was disturbed by a swell.

No landings were recorded but it was noticed that a bouncing porpoise occured at 120,000 lb. although it could be avoided without much difficulty. At the overload weight there was a greater tendency to bounce porpoise. Further tests will be made to confirm these results.

3.3 Comparison with pilots' opinions

The general opinion of the pilots at M.A.E.E. on the model over the tested range of conditions was that it was quite satisfactory in take off under all conditions provided that the pilot did nothing abnormal. They were satisfied with the stability range which did not seem unduly narrow to them even at the overload weight or with flaps down, because they felt that they had a sufficient margin of control and that the stability was very good inside that range. The porpoising at speeds of 45 to 65 knots, mostly of less than 2° amplitude, was generally ignored; in the worst cases the stick was usually held well back to avoid damage to the propellers. It was reported that the bouncing porpoise, experienced at high speeds, was unpleasant and would occur if the stick was held well back, but this was considered to be bad handling in take-off from the pilots' viewpoint. They also thought that some trouble might occur in wrongly made landings but this was avoidable. They considered that the model compared favourably with the faired step Sunderland III.

3.4 Comparison with the tank model result

The tank model take off at 120,000 lb. with 0° flap is shown in Fig. 10. Since the tank model C.G. is slightly aft of C.G. normal on the large model, the result is compared with the C.G. normal steady runs and take-offs in Figs. 2 and 7 and the steady runs with C.G. aft in Fig. 4, all of which were done at 120,000 lb. with 0° flap.

The tank model stick central, free to trim, attitude is 1° higher at 50 knots and 80 knots but is 1° lower at 90 knots in comparison with the steady runs in Fig. 2 (C.G. normal). The take-offs in Fig. 7 agree with this comparison below 80 knots; at 80 knots there is agreement with the tank model, and above 80 knots the take-off attitudes are between the steady run results and those for the tank model. The lower limit below 60 knots lies between those for C.G. normal and C.G. aft, being nearer the latter. Above 80 knots it is about 1° higher. The upper limit, however, is of quite different form although the mean values are of the same order. It is concave downwards instead of upwards and is 2° high from 60 to 85 knots, and then joins up with the lower limit at 90 knots giving no stable range above this speed. The alternative limit given agrees fairly well with the bouncing porpoise limits between 90 and 100 knots. No mention of a bounce porpoise is made in the tank report.

Generally the lower limit is in fair agreement, the upper limit is 2° high except above 90 knots in the take-off region. The more severe limits have not been found full scale so far, but may be bound up with the occurrence of bouncing porpoise.

3.5 Comparison of the results with the full scale faired step "Sunderland" take-offs

Take-offs for the full scale Sunderland with 1 in 6 step fairing are shown in Fig. 11 for a weight of 49,000 lb. and 0° flap. This weight corresponds to 101,600 lb. on the Shetland for the same beam loading (W/b^3). These take-offs have been used in the comparison since there are no stability records for a higher weight on the Sunderland.

The Shetland large scale model take-offs (Fig. 7) and the full scale Sunderland take-offs (Fig. 11) show that the Shetland is generally more unstable than the faired step Sunderland. The lower stability limit is generally 1° lower but the form is very similar. The more violent porpoising shown for the Sunderland take-off with stick fully forward developed because the stick remained forward until a much higher speed was reached than in the corresponding Shetland take-off. The upper limit for normal or bouncing porpoise is outside the practical range of attitudes during Sunderland take-offs. The bouncing porpoise experienced in the Shetland take-off has only been observed in Sunderland steady runs. The bouncing porpoise is also only found in the Sunderland landings at the stalling speed, and then only occasionally.

Table 1 (B) indicates that the Sunderland at 56,000 lb. (the highest weight at which the performance of the Sunderland is well known) has lighter wing and beam loadings than the Shetland at 130,000 lb. The Sunderland weight which corresponds to the same beam loading condition as 130,000 lb. on the Shetland is 63,800 lb., and at this weight it is thought that the Sunderland might be more difficult to handle and it would be very dirty at low speeds. The stability range of the Shetland decreases with increase of weight and hence the Sunderland at 63,800 lb. might behave similarly to the Shetland.

4. Conclusions.

The Shetland at 120,000 lb., C.G. normal, 0° flap, has a reasonable range of stability over the whole of the take-off speed range, if porpoising of less than 2° amplitude is neglected. The range generally increases from $3\frac{1}{2}^{\circ}$ both above and below 68 knots, but at high attitudes and high speeds a bouncing porpoise may be encountered if the boat is pulled off strongly, or hits a water disturbance which leads to a high attitude.

Increase of weight to 130,000 lb., and change of C.G. forward both raise the lower stability limit considerably from 40 to 75 knots, but otherwise leave it little affected. Change of C.G. aft raises the lower stability limit slightly. The lower limit is not greatly affected by use of flaps. Porpoising between 40 to 75 knots is not always avoidable but is not dangerous and can soon be damped out, although damage might result to the propellers and tailplane. It is advisable to hold the stick well back over the region of the hump speed.

The upper limit consists of two parts corresponding to normal and bouncing porpoising. The attitude of the latter is lowered with increase in weight and it may therefore become more troublesome if the weight is increased further. The normal upper limit disappears from the practicable range of attitude for C.G. forward, is unchanged for C.G. aft, but is lower and extends to lower speeds with 15° flap and at 130,000 lb. With the C.G. aft at 120,000 lb., and C.G. normal at 130,000 lb., the stability range from 45 to 65 knots is only $1\frac{1}{2}^{\circ}$ but again the porpoising is not dangerous, except for possible damage to the propellers and tailplane, and can easily be controlled at higher speeds.

No landings have been measured but it seems that the bouncing porpoise may be encountered at low landing speeds, the frequency of occurrence increasing with increase in weight. Further tests will be made when the aircraft is again available.

In the opinion of the pilots who have flown the aircraft at M.A.E.E. the Shetland is as good as the Sunderland III under conditions of normal handling.

The stability range from tank results for C.G. normal, 0^{o} flap and 120,000 lb. is wider below 85 knots (due to the upper limit being 2^{o} higher), but is about the same at higher speeds if the less severe limits are chosen. The severe limits, which show no stability above 85 knots, are not found full scale; they may be bound up with the occurrence of the bouncing porpoise with large disturbances although no bouncing porpoise was mentioned in the tank results.

The Shetland at 120,000 lb. is less stable than the faired step Sunderland at 49,000 lb. This difference is specially marked in the bouncing porpoise and normal upper stability limits, both of which do not appear in Sunderland take-offs and have only been observed in steady runs. The Shetland has a narrower stability range at the hump for the overload weight and this is likely to lead to more damage to the propellers and tailplane. Below the hump speed the Shetland at 130,000 lb. is very dirty and liable to suffer damage to the propellers. In the practical take-off conditions for the two aircraft the Shetland is not as good as the Sunderland III particularly at low speeds, at the hump speed and near the take-off speed.

5. Further developments

Further tests[5] have been made on the Saro 37 with the Shetland tail unit and wing tip floats to confirm the stability results. It is suggested that further tests be made in the tank with an increase in beam of 6" full scale, which would give the Shetland at 130,000 lb. a beam loading equal to that of the Sunderland III at 56,000 lb. Model tests of the effect of 12" and 18" (full scale) increase in beam are also recommended.

List of References

Ref. No.	Author	Title etc.
1	R. A. Shaw	A new form of control position indicator. F/Res/132. A.R.C.4248
2	-	Tank tests on the Short Saro R.14/40 flying boat. Aero 1745. Restricted.
3	G. J. Evans A. G. Smith R. A. Shaw W. Morris	Water performance of Sunderland K.4774 with step fairing. H/Res/140. A.R.C.4948 (to be published).
4	H. G. White A. G. Smith	Attitude and stability measurements on a half scale Sunderland hull fitted to the Scion seaplane. H/Res/158. A.R.C.6481.
5	I. W. McCaig	Water stability tests on Saro 37 fitted with Shetland hull bottom, wing tip floats and tail. H/Res/180. Current Paper No.3.

Table 1 (A)

General particulars of Saro 37 with Shetland bottom

1. **Wings**		2. **Tailplane**	
Area/gross	340 sq.ft.	Total area	43.2 sq.ft.
Span	50 ft.	Span	15.5 ft.
Mean Chord	6.8 ft.	Elevator area (including tabs)	10.7 sq.ft.
Aspect ratio	7.35	Elevator movement	27° up 20° down
Aerodynamic Chord to R.14/40 hull datum	6° 11'		
Flaps H.P. slotted 20% wing chord			
Flap semi span	11 ft.		
Flap angle - fully out	48°		
3. **Propellers** Fixed pitch, two blade wooden propellers.		4. **Engine** 4 Pobjoy Niagara III	
Diameter	6.5 ft.	88 B.H.P. at 3300 r.p.m.	
Blade chord at 0.7 radius	5.98 ins.	85 B.H.P. at 3135 r.p.m. (for take-off)	
Blade angle at 0.7 radius	28.1°	Gear ratio	0.468

	Large Model	Full Scale
5. **Hull**		
Overall length	41 ft. 6.75 ins.	110 ft.
Beam	4 ft. 6.28 ins.	12 ft. 6 ins.
Angle of forebody to hull datum (R.14/40)	2° 38'	2° 38'
Scale	1/2.75	1
6. **Loads at which tests were performed**	5,700 lb. 6,250 lb.	120,000 lb. 130,000 lb.
C.G. normal distant forward of step along hull datum	1 ft. 8.11 ins.	4 ft. 7.3 ins.
C.G forward	2 ft. 0.55 ins.	5 ft. 7.5 ins.
C.G. aft	1 ft. 3.67 ins.	3 ft. 7.1 ins.
Tank model C.G.		4 ft. 1.8 ins.
Sunderland C.G. on Shetland scale		3 ft. 9.9 ins.
Corresponding speeds based on Froude's Law	V knots	$\sqrt{2.75}$ V knots

Table 1 (B)

Comparison of Large Model and Full Scale Shetland and Full Scale Sunderland III

	Unit	Large model Shetland	Full scale Shetland	Full scale Sunderland III
Beam (b)	ft.	4.54	12.5	9.8
Wing Area S	sq.ft.	340	2618	1690
Span	ft.	50	150.4	112.7
Scale (based on beam)		1/2.75	1	1/1.275
Overload weight (W)	lb.	6,250	130,000	56,000
Wing loading (W/S)	lb./sq.ft.	18.4	49.7	33.1
Wing loading sealed up to full scale Shetland		50.6	49.7	42.3
Beam loading W/b^3	lb./c.ft.	66.6	66.6	59.5
Corresponding weight to give Shetland W/b^3		6,250	130,000	63,800
Corresponding wing loading for Shetland W/b^3		50.6	49.7	48.2
Height of C.G. above step (perp. hull datum)	ft.	5.8	16.0	11.8
- ditto - Scaled up to Shetland	ft.	15.95	16.0	15.1
Water clearance of propellers at rest (approx.)	ft.	2.35	6.4	4.8
- ditto - Scaled up to Shetland	ft.	6.46	6.4	6.1

Table 2

Details of porpoising points

Steady runs: C.G. Normal   Weight 120,000 lb. Flap 0°

Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees	Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees
64.2	1/3rd forward	3.9	4.1	43.2	Fully forward	4.9	4.0
66.3	"	2.5	3.3	47.5	"	5.4	7.4
66.7	"	3.3	3.9	57.0	"	4.6	6.6
78.7	"	2.5	2.0	68.2	"	5.3	2.3
80.8	"	1.4	2.2	71.2	"	3.0	7.0
84.5	"	1.5	2.5	75.5	"	2.2	0.7
40.5	½ forward	5.2	1.5	75.5	"	2.0	4.7
43.3	"	4.9	6.5	42.0	½ back	8.2	1.3
46.3	"	4.6	4.6	44.8	"	8.1	1.5
47.9	"	4.2	3.7	69.0	"	7.2	2.6
56.3	"	3.5	4.3	78.7	"	6.6	3.1
61.3	"	2.9	3.4	48.8	2/3rds back	8.9	1.2
61.7	"	2.7	2.3	65.0	"	8.1	1.3
63.3	"	2.2	1.2	51.7	Fully back	7.5	3.4
66.0	"	4.1	4.5	69.7	"	9.0	4.6
69.3	"	2.7	2.5	72.5	"	9.0	4.7
69.3	"	2.4	3.0	78.2	"	8.7	5.9 bounce
69.3	"	2.6	3.4	79.0	½ back	8.5	4.1 bounce
87.7	"	2.2	1.4	86.3	"	8.5	6.7 bounce
				85.3	Fully back	7.3	4.2 bounce

Table 3

Details of porpoising points

Steady runs: C.G. Forward. Weight 120,000 lb. Flap 0°

Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees	Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees
39.3	Central	8.1	1.2	72.3	1/3rd forward	3.2	3.1
46.8	"	8.7	2.6	72.3	"	2.6	1.5
47.2	"	7.0	5.4	84.8	"	2.5	2.5
48.3	"	10.1	4.9	83.7	½ forward	1.7	3.4
55.3	"	7.0	5.6	61.7	Fully forward	3.4	7.0
57.2	"	9.2	2.4	87.0	Fully back	9.8	8.0 bounce
58.3	"	7.1	1.2	85.0	"	8.5	4.0 bounce
59.3	"	5.8	1.6	93.7	"	7.2	9.0 bounce

Table 4

Details of porpoising points

Steady Runs: C.G. aft. Weight 120,000 lb. Flap 0°

Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees	Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees
43.4	Central	7.7	2.3	47.8	½ back	9.5	0.8
47.0	"	7.3	1.9	58.7	"	8.8	2.3
53.3	"	6.8	1.9	62.0	"	8.2	2.0
54.2	"	7.3	2.6	62.3	"	8.4	2.2
55.7	"	7.3	1.9	66.7	"	7.2	1.6
71.8	"	2.7	1.1	58.8	Fully back	8.0	5.0
86.8	"	4.0	2.1	60.7	"	9.5	1.9

Table 4 (continued)

Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees	Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees
55.8	½ Forward	6.4	1.8	62.5	Fully Back	9.2	1.8
60.3	"	5.4	1.0	70.5	"	8.5	1.5
68.7	"	3.9	1.6	73.3	"	8.6	5.2
79.8	"	2.4	1.7	67.8	"	9.6	5.2 bounce
55.6	Fully Forward	4.1	5.3	76.7	"	10.2	3.0 bounce
60.3	"	5.6	6.5	82.3	"	8.2	2.5 bounce
68.3	"	3.2	3.1	85.3	"	7.4	4.2 bounce
69.3	"	2.6	3.0	88.0	"	6.2	5.1 bounce
74.2	"	2.1	4.4				

Table 5

Details of porpoising points

Steady runs: C.G. Normal Weight: 120,000 lb. Flap 15°

Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees	Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees
47.0	Central	6.4	4.4	58.8	1/3rd forward	4.0	4.6
48.0	"	5.8	5.6	65.3	"	1.9	2.6
48.3	"	6.4	2.9	68.8	"	1.4	3.3
50.0	"	4.7	7.9	74.0	"	1.5	3.3
55.3	"	5.9	2.6	43.0	½ Back	6.7	3.6
57.8	"	3.4	2.0	85.0	"	5.4	1.0
59.2	"	3.6	1.2	89.7	"	4.5	2.2
60.5	"	4.7	4.6	51.0	Fully Forward	7.7	5.1
63.0	"	4.9	4.5	62.0	"	6.8	2.1
49.8	1/3rd forward	5.3	7.9	77.2	"	7.1	7.0 bounce

Table 6

Details of porpoising points

Steady runs: C.G. Normal Weight 130,000 lb. Flap 0°

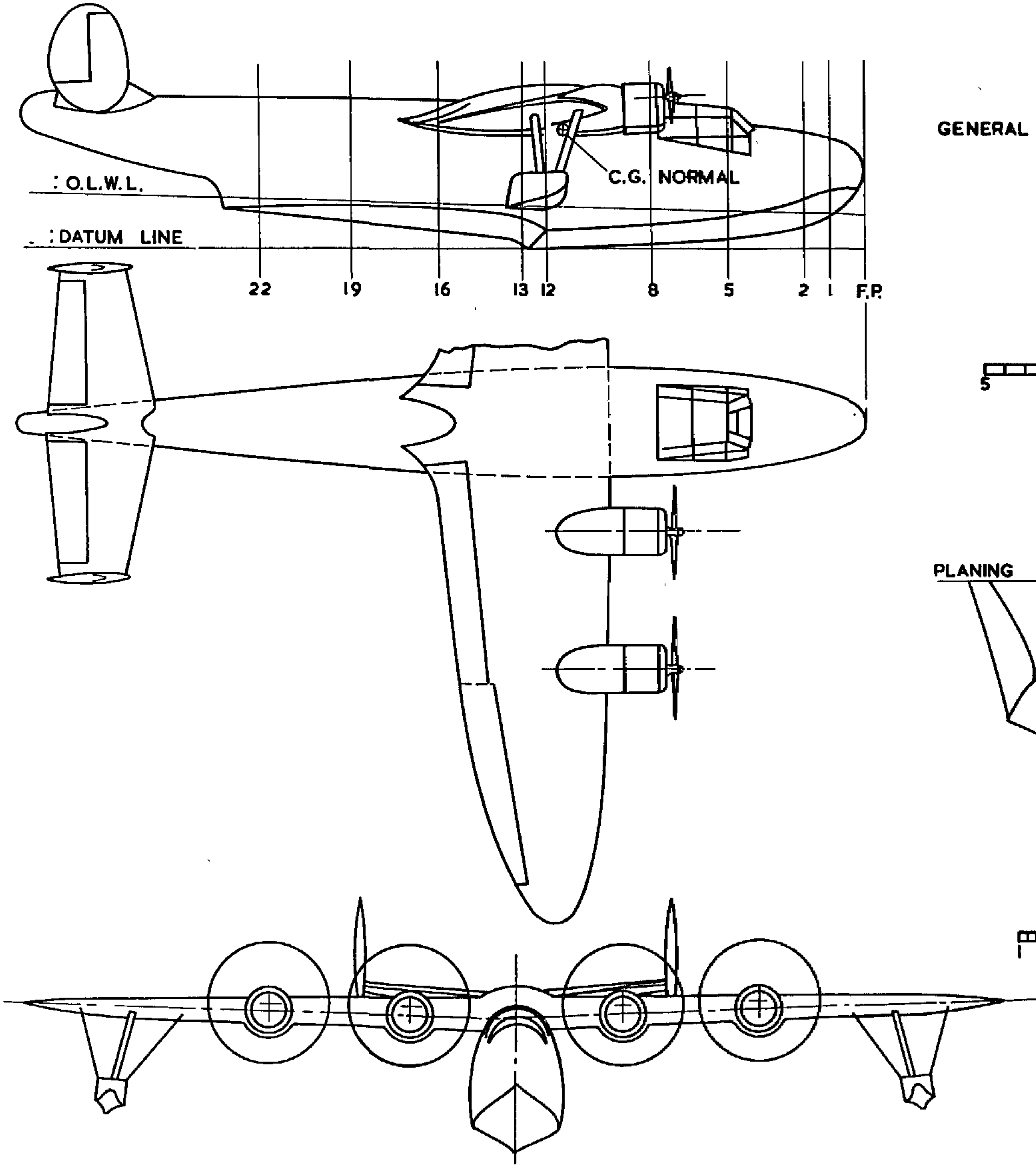
Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees	Water speed knots full scale	Stick position	Mean attitude degrees	Amplitude degrees
43.7	Central	6.1	4.3	75.8	½ Forward	1.3	1.1
50.7	"	6.1	2.2	81.7	"	0.4	2.7
50.7	"	6.1	2.2	65.7	Fully forward	3.6	8.0
50.7	"	5.6	2.2	65.7	"	2.8	3.6
52.0	"	5.4	4.3	95.8	"	1.4	2.0
52.8	"	5.2	4.4	46.7	1/8th back	7.5	2.3
54.8	"	5.6	3.7	37.3	1/4th back	7.8	3.9
55.0	"	6.3	3.3	85.7	½ Back	7.2	4.0 bounce
58.2	"	3.9	2.8	45.7	Fully back	8.6	1.5
67.0	"	4.3	1.8	55.0	"	7.7	1.5
77.2	"	3.4	1.0	67.3	"	6.4	3.4
82.2	"	0 9	1.9	72.0	"	6.5	1.0
52.8	¼ Forward	4.8	5.1	77.0	"	5.9	0.7
82.0	"	0.8	2.1	85.9	"	4.3	2.7
96.0	"	1.0	0.7	74.2	"	8.0	4.7 bounce
60.0	½ Forward	4.0	5.4	82.3	"	7.3	5.0 bounce
65.0	"	4.0	3.6	86.8	"	5.8	3.0 bounce
61.8	"	2.2	4.1	85.3	"	5.7	5.0 bounce

Index to Figures

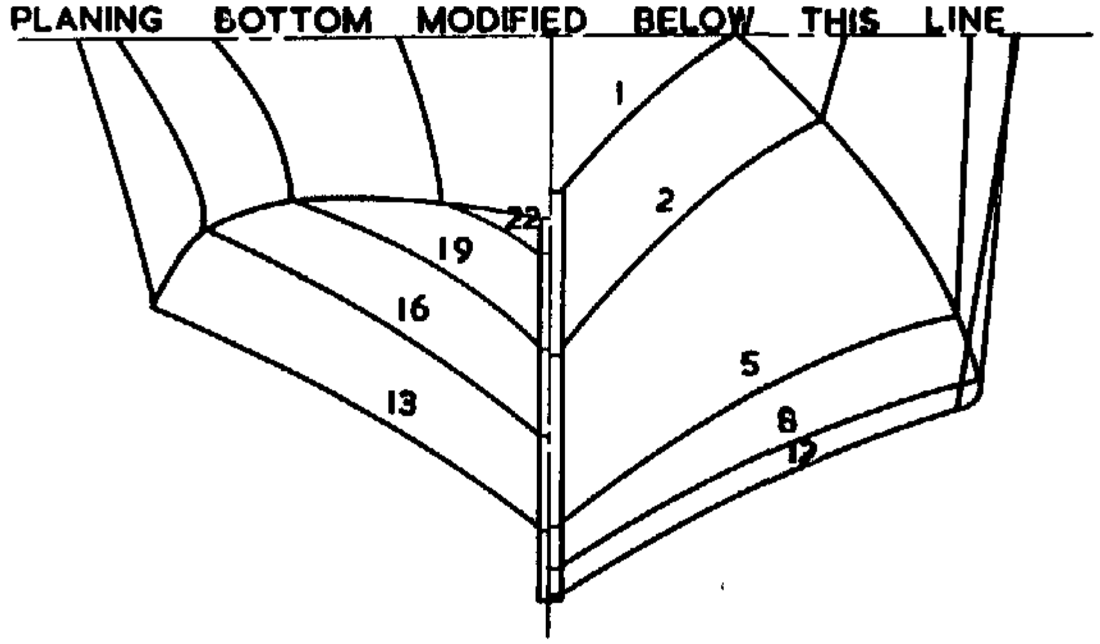
Full scale weight lb.	Saro weight lb.	Test	Flap	C.G.	Figures
12,000	5,700	S.R.	0°	Normal	2
		"	0°	Forward	3
		"	0°	Aft	4
		"	15°	Normal	5
		T.O.	0°	Normal	7
		"	20°	Normal	8
130,000	6,250	S.R.	0°	Normal	6
		T.O.	0°	Normal	9
120,000		T.O.	0°	Normal	10 Tank Model
49,000		T.O.	0°	Normal	11 Full Scale Sunderland III

FIG. 1.

GENERAL ARRANGEMENT OF SHETLAND HULL BOTTOM ON SARO 37.



5 0 5 10 15 20
SCALE OF FEET



1 0 1 2 5
SCALE OF FEET

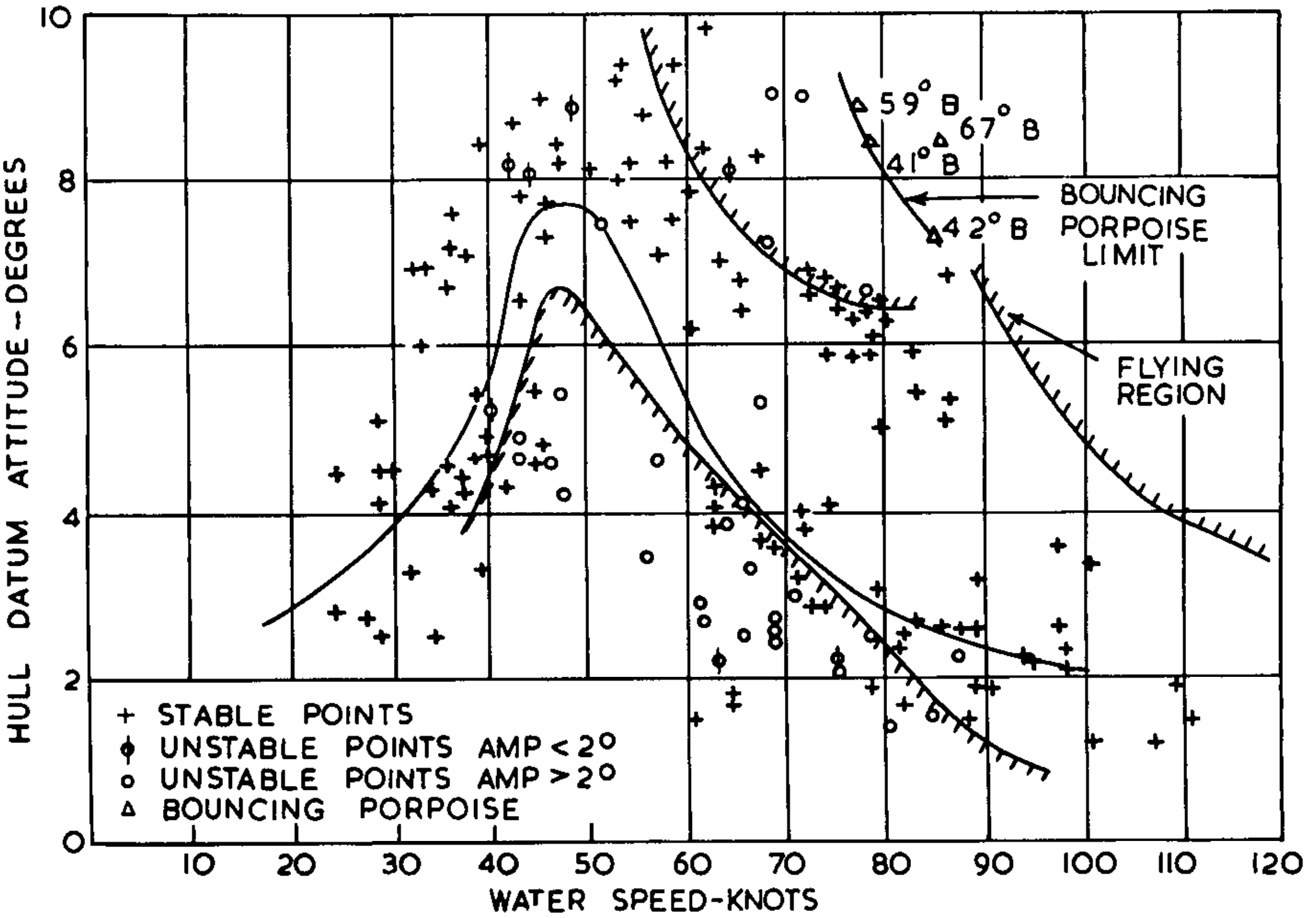


FIG 2a STEADY RUNS

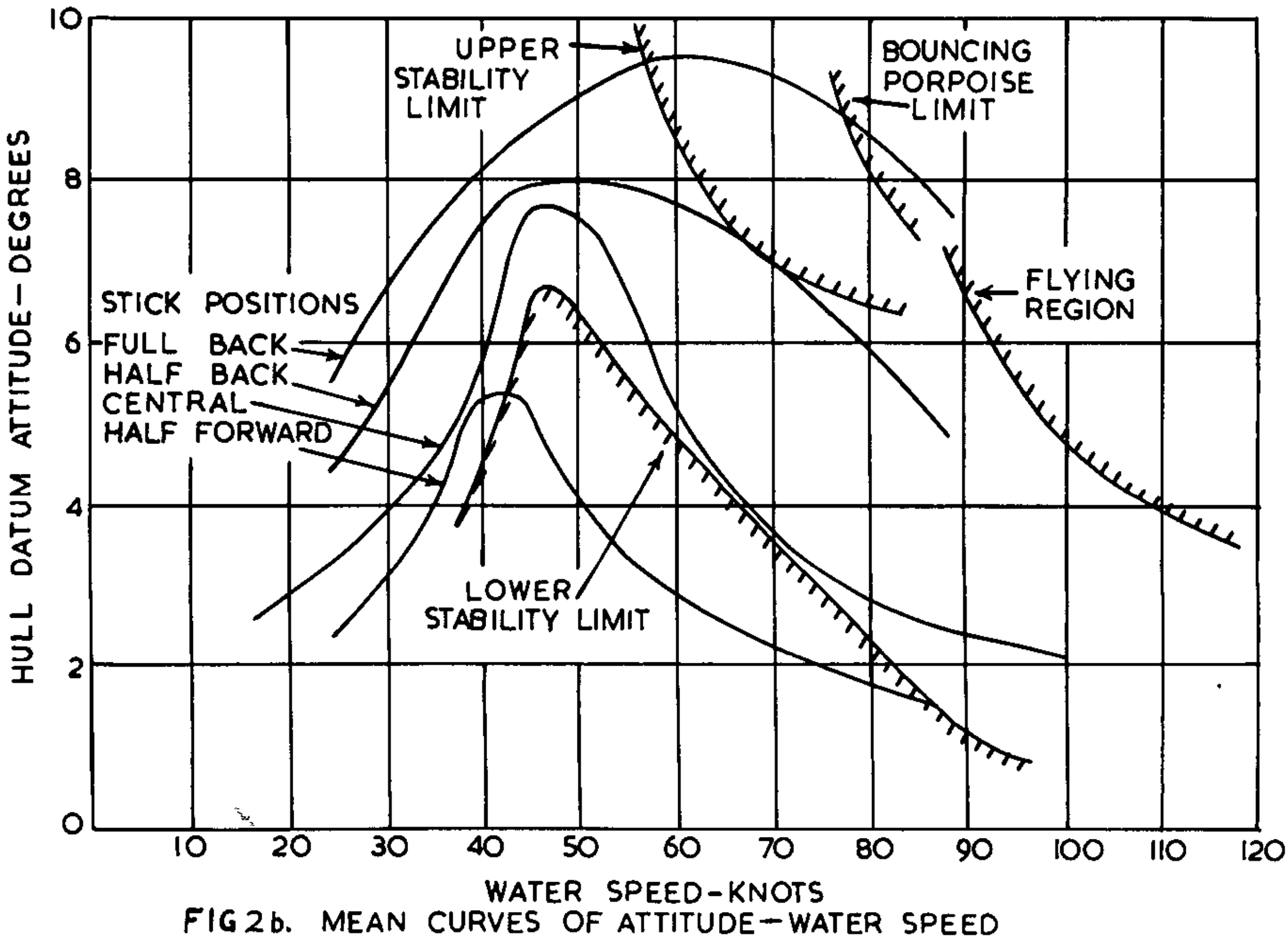


FIG 2b. MEAN CURVES OF ATTITUDE—WATER SPEED

SHETLAND STEADY RUNS-C G NORMAL- 120,000 lb 0° FLAPS

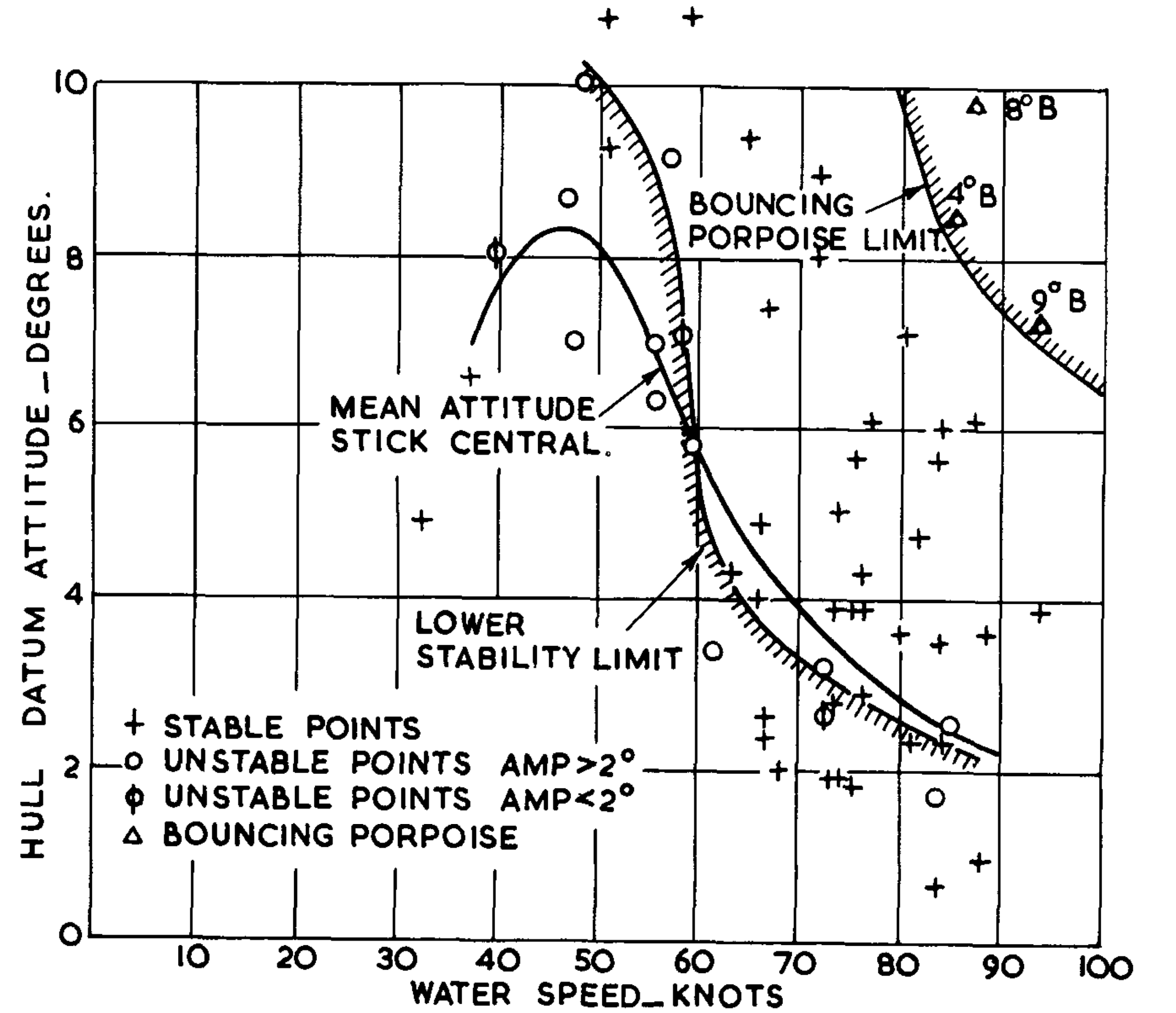


FIG. 3. SHETLAND STEADY RUNS_C.G. FORWARD_120,000LB. 0° FLAPS.

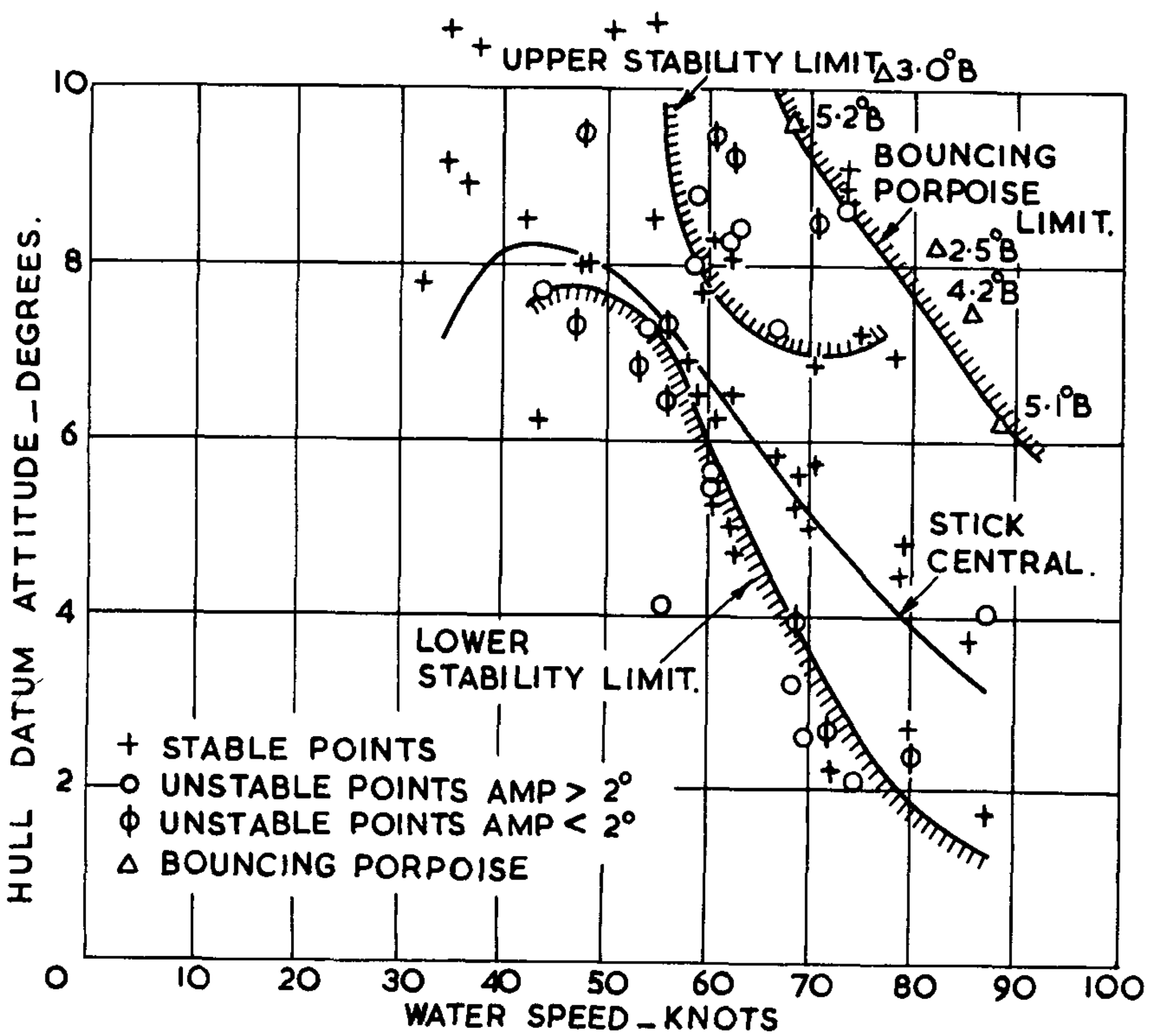


FIG. 4. SHETLAND STEADY RUNS_C.G. AFT _ 120,000 LB. 0° FLAPS.

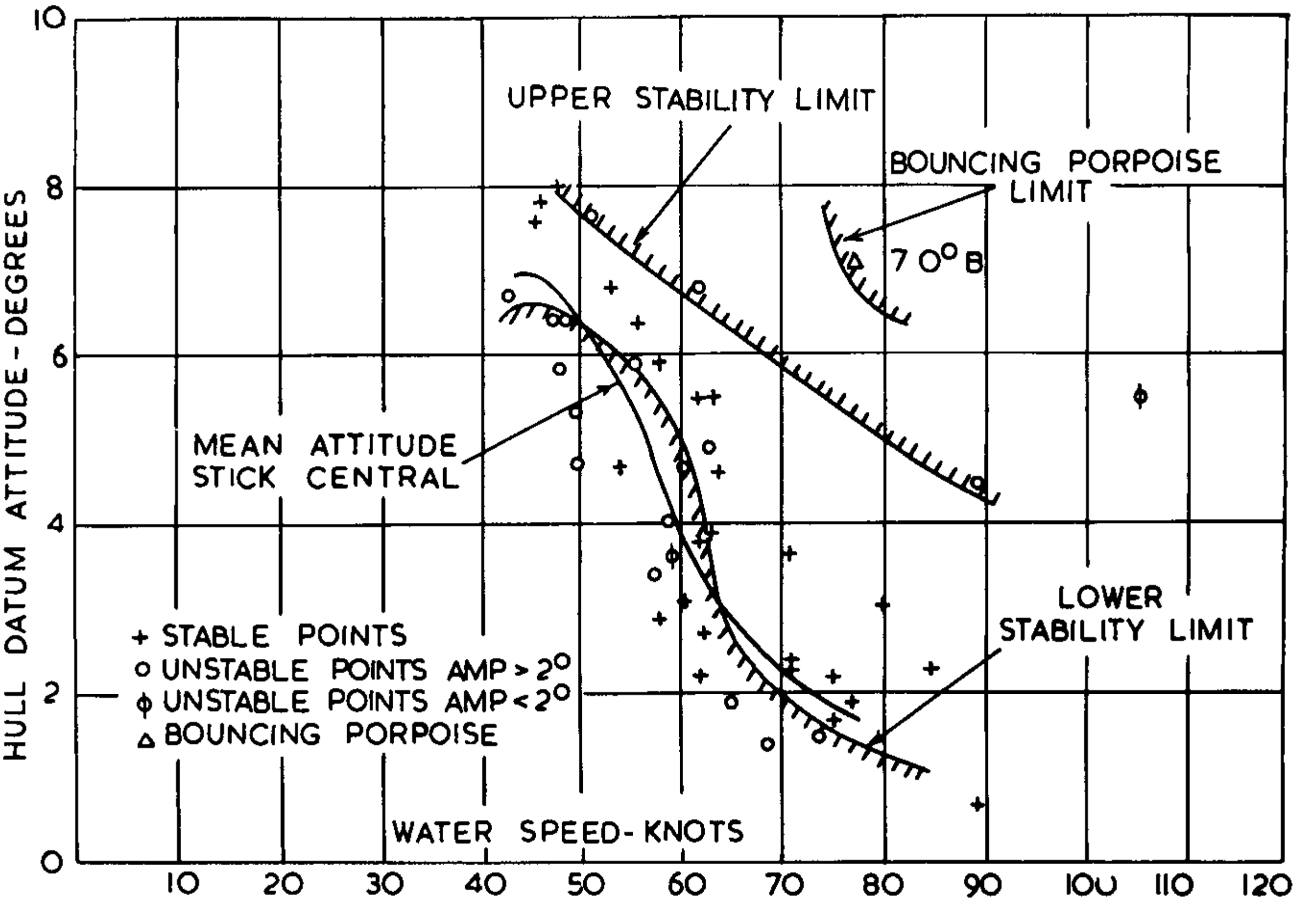


FIG 5 SHETLAND STEADY RUNS - C G NORMAL - 120,000 lb. 15° FLAPS.

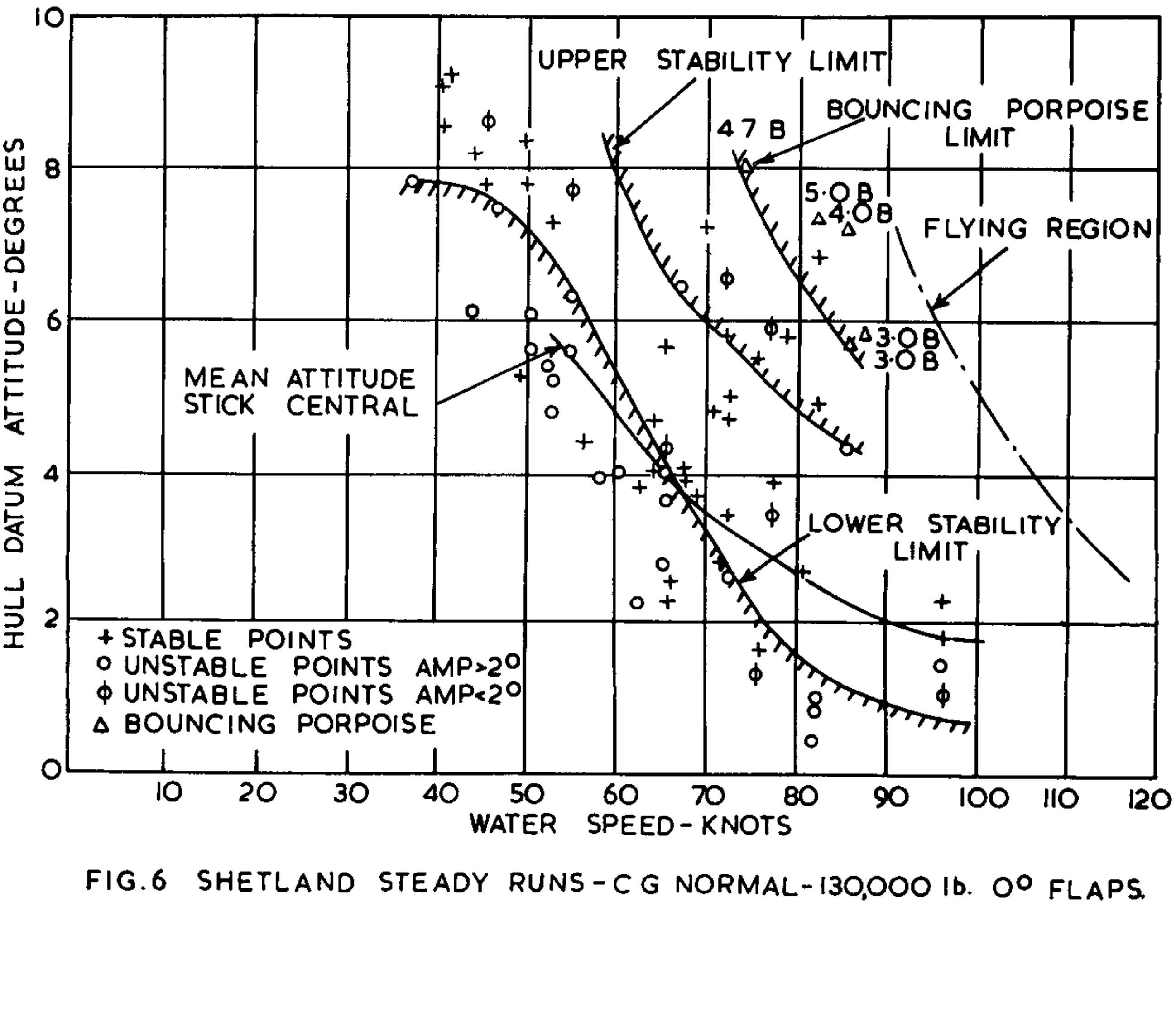


FIG.6 SHETLAND STEADY RUNS - C G NORMAL - 130,000 lb. 0° FLAPS.

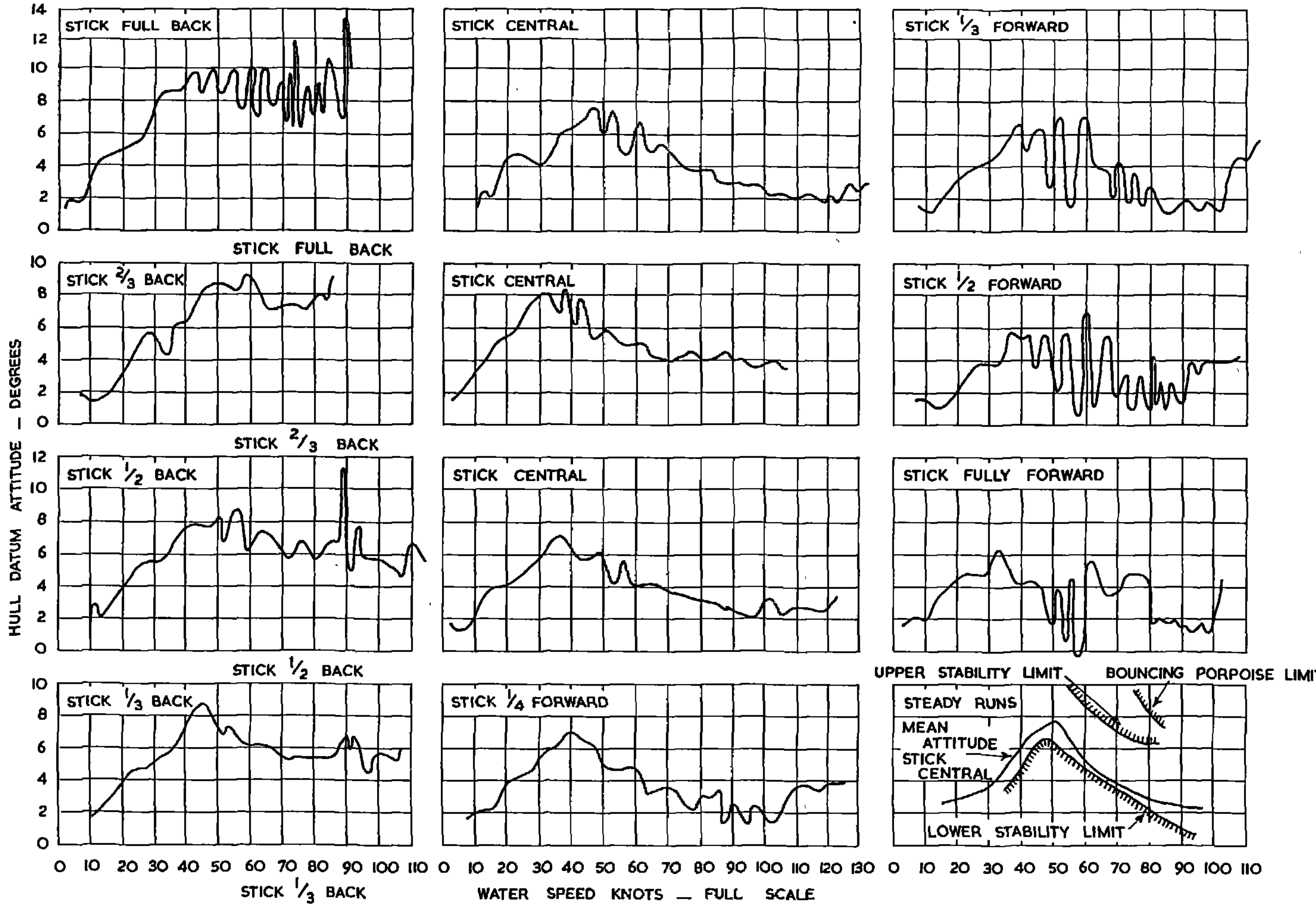


FIG.7. SHETLAND TAKE OFFS – C.G. NORMAL – 120,000 LB. – 0° FLAPS.

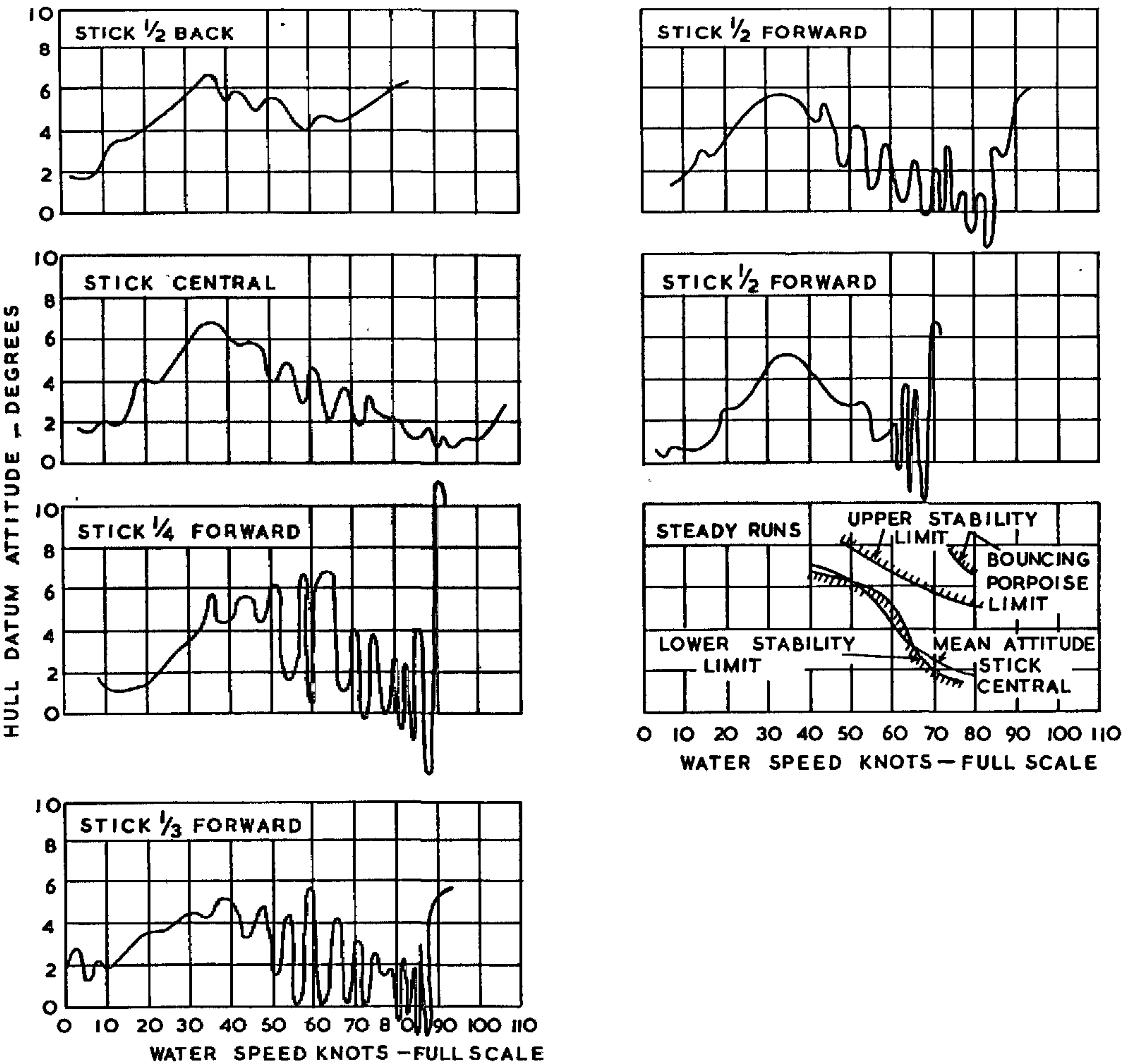


FIG. 8. SHETLAND TAKE OFFS – C.G. NORMAL – 120,000 LB – 20° FLAPS.

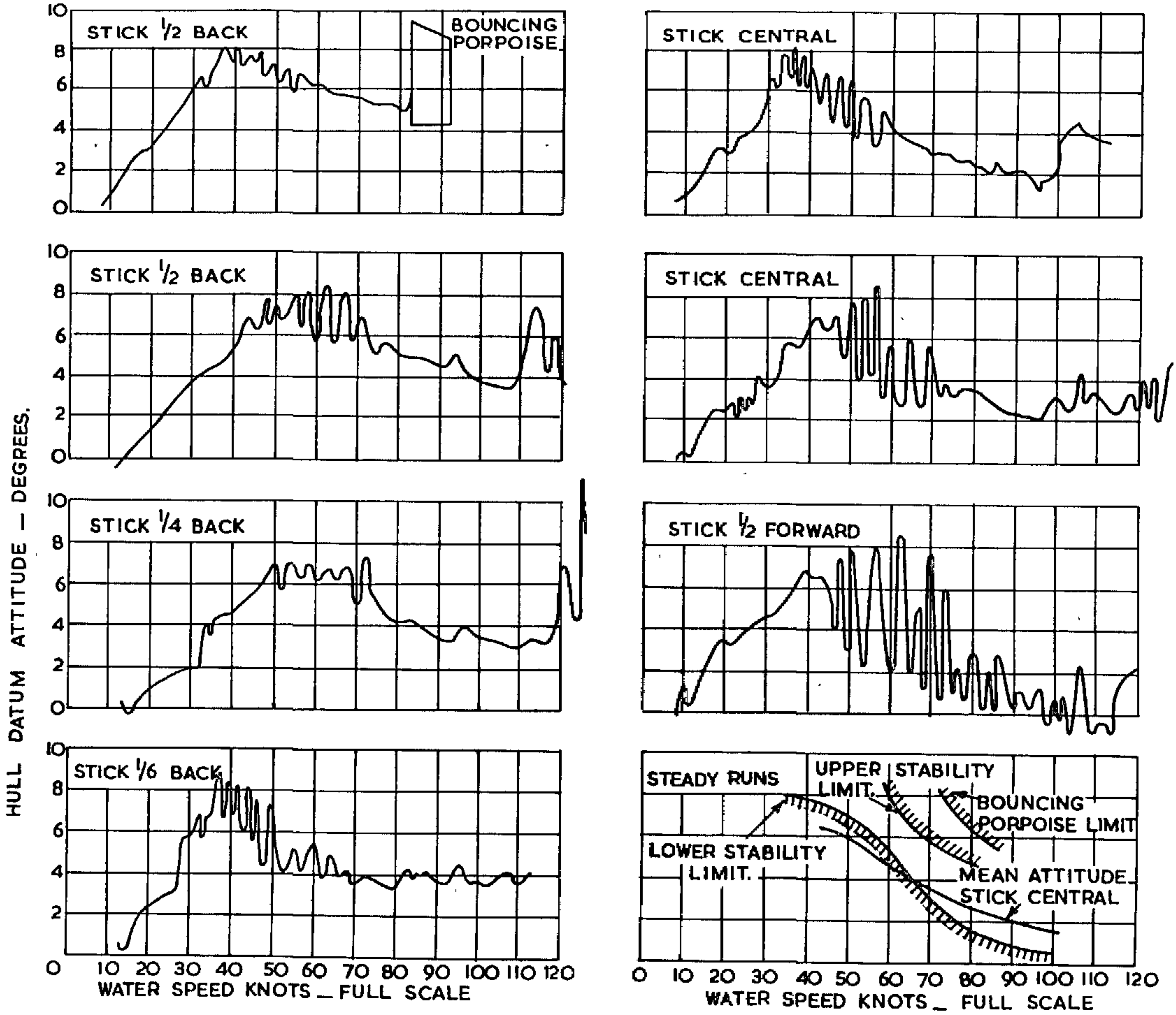


FIG. 9. SHETLAND TAKE OFFS — C.G. NORMAL — 130,000 LB. — 0° FLAPS.

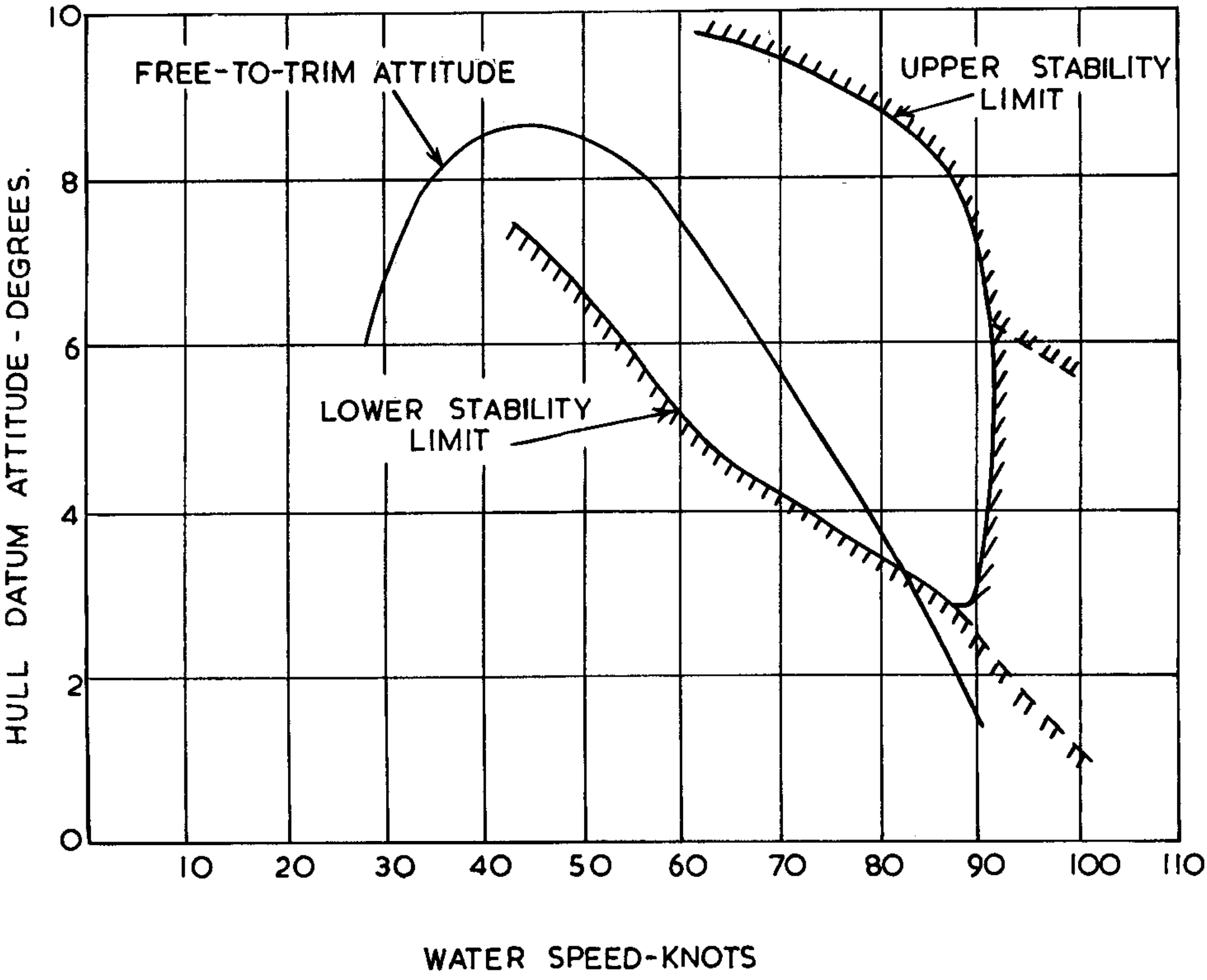


FIG 10

SHETLAND TANK MODEL TAKE-OFFS—C G. NORMAL.120,000 lb.-
0° FLAPS

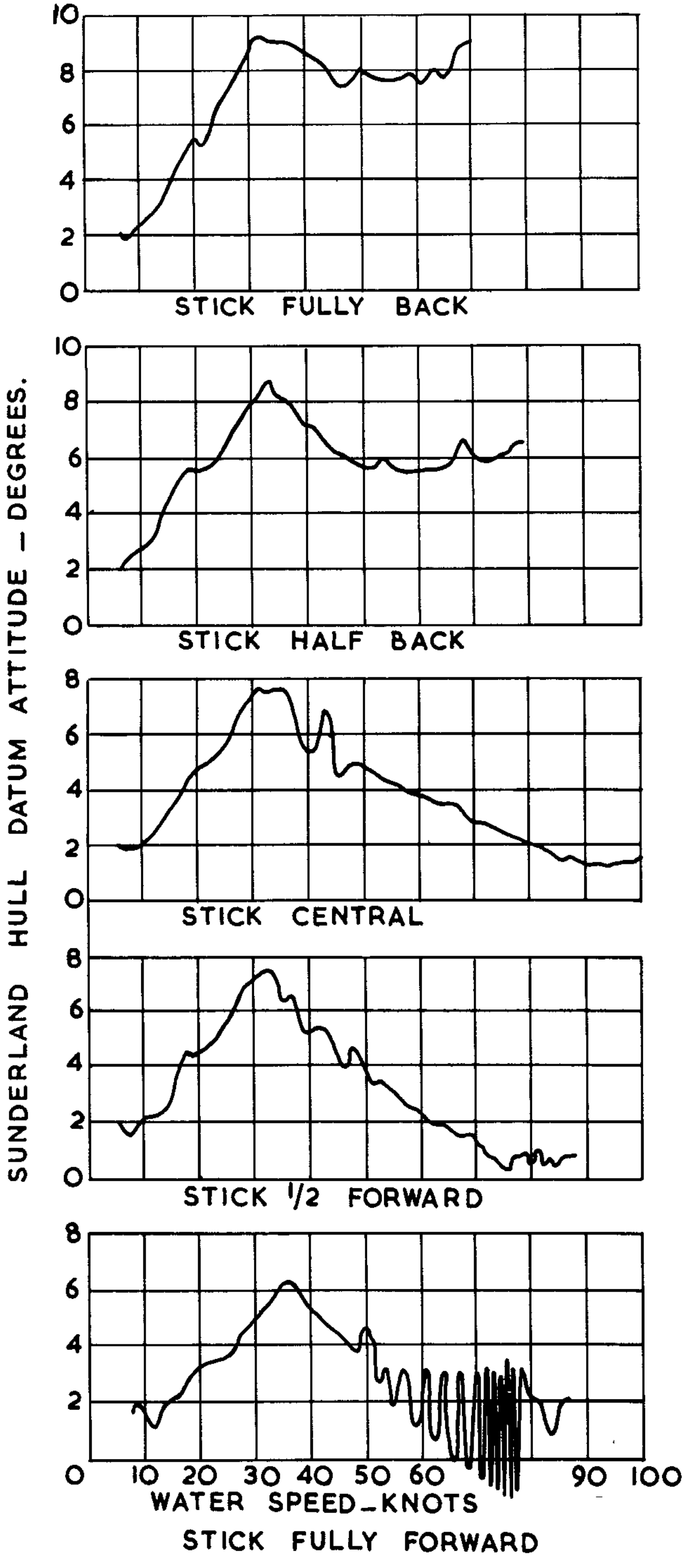


FIG.11. SUNDERLAND FAIRED STEP TAKE-OFFS AT 49,000 LB. C.G. NORMAL — O FLAPS.

3199

C.P. No. 27
6517
A.R.C. Technical Report

PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased from
York House, Kingsway, LONDON, W C 2   429 Oxford Street, LONDON, W.1
P O Box 569, LONDON, S E 1
13a Castle Street, EDINBURGH, 2   1 St Andrew's Crescent, CARDIFF
39 King Street, MANCHESTER, 2   Tower Lane, BRISTOL, 1
2 Edmund Street, BIRMINGHAM, 3   80 Chichester Street, BELFAST
or from any Bookseller
1950
Price 2s od net
PRINTED IN GREAT BRITAIN

DS 52172/K3/   S.O. Code No. 23-9006-27