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EDITOR'S NOTE (1952)

The first full-scale tests made to investigate the use of main step fairings on flying boats were completed at the Marine Aircraft Experimental Establishment in 1940 and 1941, and results given in the two following reports,

No.	*Author*	*Title*
1	G. J. Evans, A. G. Smith, R. A. Shaw and W Morris	Water performance of *Sunderland* K.4774 with step fairing. M.A.E.E. Report No. H/Res/140. A.R.C. 4948. December, 1940.
2	G. J. Evans and R. A. Shaw ..	Water performance of *Sunderland* K.4774 with a 1 in 6 step fairing. M.A.E.E. Report No. H/Res/142. April, 1941.

These two reports have been combined together in this paper. They are thought to be of particular interest in that the results first demonstrated the importance of the possible interference between the water wake from the forebody and the afterbody bottom on porpoising instability. The avoidance of such interference was to become a major problem in the search for more efficient hydrodynamic hull forms. The reports also give an outline of the mechanism of the water flow over the forebody and clearance from the afterbody in the course of take-offs and landings, both with and without the various forms of porpoising instability. The knowledge so gained showed in what directions the later research had to be directed for successful development of efficient step fairings.

Summary.—Tests were made to investigate the hydrodynamic qualities of the *Sunderland* flying boat, when fitted with step fairings of mean gradient 1 : 3, 1 : 6 and 1 : 9.

Attitude and acceleration measurements were made during take-offs, landings and constant-speed taxying runs. Water pressure measurements were made at various stations over the forebody and afterbody hull bottoms with and without the step fairings of 1 : 6 and 1 : 9 ratio.

The fairings have no perceptible effect on water moments and water drag of the flying boat in steady conditions, although there appears to be a small reduction of the hump speed of 3 to 5 knots with the 6 and 9 : 1 step fairings. The 6 and 9 : 1 step fairings, however, introduce a bouncing type of porpoise in taxying runs at high speeds and high attitudes, although there is no evidence of the normal single- and two-step stability limits being affected. This bounce porpoise was not encountered during any take-off or landing with the 6 : 1 fairing, but was severe in landings with the 9 : 1 fairing whenever the datum attitude on touch-down was greater than 3 deg.

The bounce porpoise is associated with a fluctuating water flow over the forebody and over the afterbody behind the fairing, and pressure and suctions of the order of 5 lb/sq in. and — 2 lb/sq in. respectively were recorded on the afterbody. On the forebody, all pressures were positive.

This bounce porpoising takes the form of violent pitching, combined with violent heaving in which the flying boat apparently bounces off the water once per complete cycle at less than stalling speed. Ordinary single- and two-step porpoising is accompanied by fluctuating water pressures on the forebody only. Zero pressures were recorded on the afterbody stations of the hull, with and without the fairings, for all stable hydroplaning conditions during take-off, landing and steady runs. The aft step was just immersed in some very high-attitude runs at high speed, but no recorders were located at the actual step.

This bounce form of instability is undoubtedly due to afterbody interference with the wake from the forebody. The water flow from the forebody re-attaches itself periodically to the afterbody because of the presence of the step fairing. This probably occurs on the step fairings, but measurements were not obtained in these tests. The greater the fairing, the greater the re-attachment seems to be and, therefore, the more severe and the more frequent the attendant instability.

A further programme of tests will be made to investigate the water flow conditions with the various fairings and means of making these efficient hydrodynamically.

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1. *Introduction.*—Wind-tunnel tests[1] have shown that a reduction of the total air-drag of the *Sunderland* flying boat of the order of ten per cent may be obtained by fairing the main step. This result is confirmed by high Reynolds number tests made in the Compressed Air Tunnel at the National Physical Laboratory. Tests made full-scale on the prototype *Sunderland* K.4774 with a fairing gave a five per cent decrease in drag. This fairing was retractable and was used in flight only, and it was not so clean aerodynamically as a fixed step fairing.

Preliminary towing-tank tests on a dynamic model[2] appeared to show that a 1 : 9 fairing had a negligible effect on the attitude, water moments and water drag, and the upper attitude stability limit was lowered only 1 deg. In later tank tests, however, using a severer stability test technique more representative of full-scale conditions, the stable range was eliminated above 65 knots.

Full-scale experiments were therefore made to determine the extent to which a fixed fairing could be fitted to the step without impairing the hydrodynamic qualities of the hull, and also to examine any instability which might be found.

2. *Range of Investigation.*—Fig. 1 shows a general arrangement drawing of the *Sunderland*, and Table 1 gives general data. The fairings fitted were of nominal 1 : 3, 1 : 6 and 1 : 9 gradient* and sketches of these with dimensions are given in Figs. 2 and 3. Photographs of the 1 : 6 and 1 : 9 fairings are shown in Fig. 4. For constructional reasons, it was convenient to finish the fairings on a transverse section and the fore-and-aft angle of the fairings is therefore greater at the keel than at the chine. For convenience, these fairings are respectively called fairings 1, 2 and 3 on the figures and henceforward.

Measurements were made of the hull attitudes, elevator angles and accelerations during take-offs, landings, loop† and steady runs, for the three fairings. Tests with fairing 1 were of a cursory nature only, being sufficient to show that there was no perceptible effect upon the water handling and stability. More complete tests were made with fairing 2, and fairly detailed investigations were made of the porpoising instability found at high water speeds and high attitudes. Tests with fairing 3 were concentrated largely on stability measurements.

The associated effect of the fairings on the water flow over the hull bottom was also investigated. The positions and dimensions of the recorders are shown in Figs. 5, 6 and 7. Static and dynamic pressure measurements were first made at a number of stations on the fore and after bodies with no fairings and then on the afterbody only with fairings 2 and 3. In the last case, one forebody station was recorded to correlate forebody and afterbody flows. It was thought possible that the water flow might be adhering to the afterbody even when no static pressures were recorded, and so in later tests some of the diaphragm instruments were adapted to measure pitot pressure.

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* Fairing ratio is defined by length of afterbody keel intercepted by fairing/height of step at keel.

† In loop runs, the aircraft is accelerated to near take-off speed and then decelerated to rest.

2.1. *Methods of Measurements.*—The methods used for measuring attitude, horizontal and vertical acceleration, and elevator angle have been fully described in Ref. 3. Measurements of the local static pressures on the hull bottom were made with small flush-type diaphragms operating D.V.L. scratch recorders. These pressure recording units have been fully described in Ref. 4. Pressure measurements with no fairings were made with 0·31-mm thick diaphragms. These diaphragms proved to be sufficiently sensitive only for the higher pressures found forward of the step (greater than 1 lb/sq in.), so that more sensitive diaphragms of thickness 0·22 mm were fitted to measure afterbody pressures, when the step was fitted with fairing 2. These more sensitive diaphragms were fitted also to the afterbody of a standard *Sunderland* (L.2158) to amplify the results obtained with 0·31-mm diaphragms. These were, however, still insufficiently sensitive to satisfactorily measure afterbody pressures, and diaphragms 0·10-mm thick were therefore fitted for the step fairing 3 tests.

For steady runs, the flying boat was first headed into wind with engines throttled back and the D.V.L. recorders were run to give a datum. The throttles were opened until the flying boat attained the required speed and the recorders were then run for approximately 20 sec. During take-offs and landings, the procedure was identical with that adopted for obtaining attitude and acceleration records[3]. All records were correlated on a common time scale, time being controlled from a master clock.

3. *Results of Acceleration, Attitude and Stability Measurements.*—Results for fairing 1 are given in Figs. 8 to 11. These were all made at a weight of 43,000 lb. The take-offs were made with and without $\frac{1}{3}$ flap and landings with zero flap. Steady runs were made, with zero flap and stick fully back, at water speeds ranging from 20 to 50 knots. The only porpoising obtained in these runs was of 2 deg amplitude and the normal smooth type and occurred at 52 knots.

Results for fairing 2, of loop runs and take-offs at 43,000 lb, are given in Figs. 12 to 14, and of take-offs with $\frac{1}{3}$ flap and landings with full flap at 50,000 lb in Figs. 15 and 16.

The mean steady-run attitude and porpoising points for fairing 2, over the full range of elevator angle and water speed, are given in Fig. 17.

Results for fairing 3 are given in Figs. 18 to 20 for take-offs and landings at weights of 38,000 to 43,000 lb. The take-offs were made with $\frac{1}{3}$ flap and the landings with full flap. The steady-run results at 43,000 lb are shown in Fig. 21.

In Fig. 22, all the porpoising points measured in steady run and landing conditions, for no fairing and fairings 1, 2 and 3, are plotted around the mean-attitude curves found for fairing 2.

3.1. *Effect of Fairing on Attitude.*—Mean curves of attitude against water speed and zero elevator angle during take-off with no flap, and with $\frac{1}{3}$ flap for no fairing and fairings 1, 2 and 3, are shown in Fig. 23.

The effect of the fairings on the attitude is negligible, the differences being within the experimental error. Fairings 2 and 3 appear to reduce the hump speed by 3 to 5 knots.

3.2. *Effect of Fairing on Hull Pitching Moments.*—Elevator effectiveness curves for take-off are given in Fig. 24. These are identical, within experimental error, for no fairing and fairings 1 and 2.

3.3. *Effect of Fairing on Acceleration.*—Accelerations obtained in take-offs with no flap and $\frac{1}{3}$ flap for no fairing[3] and fairings 1, 2 and 3 have been re-plotted as available against attitude, for a range of water speeds, in Fig. 25. The results show that there is a possible small reduction of drag at speeds below 15 knots when the fairings are fitted, but negligible change at higher speeds.

3.4. *Effect of Fairing on Stability.*—Fairing 1 has no perceptible effect on the stability range.

Fairing 2, however, produced a bouncing porpoise at high attitudes and at high speeds during steady-speed taxying runs, but as may be seen from Figs. 14 to 17, this instability was outside the attitude range of normal take-off and landing runs. This was confirmed by a large number of take-offs and landings made but not recorded.

In the bouncing porpoise, the amplitude of oscillation was of the order of 4 deg and period 2 to 3 sec., and occurred at water speeds of from 55 to 70 knots. In low-attitude runs, the behaviour of the flying-boat was unchanged, normal porpoising occurring at water speeds over 45 knots. There is no perceptible changes in the stability range.

Fairing 3 also produced a bounce porpoise at high speeds and attitudes during steady-speed taxying runs, but this also occurred in both take-off and landing runs. The steady-run results are little different from the 1 : 6 fairing results (Fig. 22), but did not cover the speed/attitude range at which take-off and landing bounce-porpoising was found.

During all take-offs except one, which was not recorded, the stick position was left to the pilot's discretion, and no porpoising occurred. During this exceptional take-off, the stick was held in the $\frac{1}{3}$ back position throughout the run, and a vicious porpoise occurred at the point of take-off.

Typical landings are shown in two groups in Fig. 19. The first group gives landings at fine angles and the second at coarse angles. It will be seen that no porpoising occurs if the landings are made at a fine attitude. This is illustrated in Fig. 20 where attitudes at touch-down on all recorded landings have been plotted against true air speed. It will be seen that a bouncing type of porpoising occurs if the attitude at touch-down is greater than 3 deg, but that the run is steady if the attitude is less than 2 deg.

Attitude and acceleration records taken from the gyro accelerometer are shown in Fig. 26 to give a comparison of an ordinary forebody porpoising run at low attitude and a bouncing porpoising run at high attitude. In Fig. 27, attitude and vertical acceleration, velocity and displacement curves are given for a complete forebody (ordinary) porpoise and an afterbody (bouncing) porpoise. Photographs of a bouncing porpoise taken from a cine-film are shown in Fig. 34. The bounce porpoise is similar for fairings 2 and 3.

In order to find out whether the bouncing type of porpoise was present on the standard *Sunderland*, further tests were made on *Sunderland* L.2158 with no fairing. The elevator control was insufficient to raise the attitude beyond that reached in the tests with a faired step. In this region, the standard *Sunderland* hull is usually stable. One unstable run was, however, experienced at high attitude which indicates that the stable points are close to the boundary of the stability zone.

4. *Results of Pressure Measurements*.—4.1. *Pressure Measurements without Fairing*.—4.1.1. *Steady runs*.—The pressures observed during steady runs are given in Table 2.

The pressure records observed forward of the step during porpoising were of a complex oscillatory character and in some cases consisted of intermittent peak ranges. A typical mean-pressure curve and a typical detailed range are shown in Fig. 28, drawn on a time basis. The highest pressures were found in the vicinity of the step, in stick-back runs, when only a small area of the hull was immersed. In low-attitude runs, pressures are smaller but were spread over a larger area. During porpoising, the flow surges backward and forward as the attitude increases and decreases. Fig. 28 illustrates this at Position 4, which is nearly on the step. Atmospheric pressure was recorded on all diaphragms stationed behind the step, and at Station 10 which was a pitot instrument. These results indicate that in this smooth type of porpoising, with the stick fully forward, the afterbody is clear of the water and, with the stick fully back, clear as far back as Station 10.

4.1.2. *Take-offs and landings*.—In take-offs and landings, positive pressure was only recorded on the afterbody at low speeds. Occasionally, when landing at high attitude, a slight suction occurred just aft of the step, as shown in Fig. 30. The distribution of flow behind the step is shown in Figs. 29 and 30 for take-off and landing at maximum attitudes, when pressures are most likely to occur. It will be seen that the action of getting on to the step in take-off, and coming off the step in landing, is clearly shown by the pressures. In take-off, the flow breaks away from the afterbody first of all just behind the step near the chine (at 12 knots for Position 1), and then progressively further aft as the speed increases, Position 5 becoming clear of water at 20 knots. In the landing run, the process is reversed.

The evidence that the afterbody is clear at the moment of take-off and normal landings and the occasional presence of suctions at high attitude during some landings, are in agreement with some results found with a *Southampton*[4].

4.2. *Pressure Measurements over Afterbody with Fairing* 2.—4.2.1. *Steady runs.*—Zero pressure, *i.e.*, atmospheric, was recorded on the afterbody on all runs other than those of the bouncing porpoise type.

The attitude, vertical acceleration and pressures for one of these runs are shown in Fig. 31. The analysis for one typical bounce is shown in Fig. 32. The pitot pressures have been converted into approximate speeds of water flow. The motion during a typical bouncing porpoise is shown by stills taken from a cine-film record in Fig. 34. It may be seen that at the static stations, pressures are built up as the flying boat reaches its minimum attitude on the water (A), and are immediately followed by suctions as the attitude begins to increase. The water pitot records show that the pressure increases as the water flow attaches itself to the afterbody, and the suctions occur as the flow detaches itself.

These suctions appear to aggravate the increase in attitude which is taking place and ultimately the flying boat lifts clear of the water (B and C).

Pressures occur at all stations as the maximum attitude is reached, which is just before the flying boat becomes airborne. The flying boat is in the airborne state for a comparatively short time ($\frac{1}{2}$ to 1 sec) (D). It then touches the water again (E), the attitude decreases to a minimum (G) and the whole process is repeated. The period for a complete porpoise of this type varies between 2 and 3 sec.

The most interesting phenomenon in the porpoising is the development of suctions on the afterbody. When the flying boat hits the water after a bounce, the records show that pressures are developed on the afterbody. At this stage the attitude is a minimum, *i.e.*, there is no angular velocity. In these tests, no pressure recorder was fitted on the forebody, but tests with fairing 3 (section 4.3) show that the forebody is also in the water after a bounce, and is experiencing pressures. About a quarter of a second later and without any appreciable change in attitude, the pressures on the afterbody have given place to suctions.

4.2.2. *Results of take-off and landing measurements.*—Flow conditions in take-offs and landings made over the normal range of elevator angles showed no change from the results obtained with no step fairing. A take-off with stick back and a landing with stick back after touchdown are shown respectively in Figs. 29 and 30, together with results for no fairing. It appears that the presence of the fairing does not affect planing at normal attitudes in take-offs and landings.

4.3. *Pressure Measurements over Forebody and Afterbodies with Fairing* 3.—In the planing period during take-offs and during stable landings, zero pressure was recorded at all the afterbody stations, showing that the afterbody was still running clear of the water. A steady pressure of about 4 lb/sq in. was recorded at the single forebody station. Small steady positive pressures were recorded on the afterbody at speeds below 20 knots, *i.e.*, in take-offs before planing had begun and in landings after planing had finished.

When a bouncing porpoise occurred in landing, pressures and suctions were recorded on the afterbody stations. Fluctuating positive pressures were recorded on the forebody station. Fig. 33 shows an analysis of one of these landings. The pressure and suction records behind the step, shown here, are very similar to those found during a bouncing porpoise in a steady-speed run at high attitude both with the 1 : 9 and 1 : 6 fairings.

Zero pressures were recorded on the afterbody in all steady runs in which normal smooth (*i.e.*, non-bouncing) porpoising occurred, whether at high or low attitudes. For example, no pressures were recorded in a run at 55 knots with stick fully back when the mean attitude was 6·6 deg and the amplitude 2 deg, and none in a run at 39 knots with stick fully forward when the mean attitude was 5 deg and the amplitude 5 deg.

5. *Conclusions.*—The 1 : 3 and 1 : 6 step fairings have no appreciable adverse effect on the hydrodynamic qualities of the flying boat during take-off and landing, up to the maximum weight tested of 50,000 lb but, when taxying at high speeds and high attitudes, a bouncing type of porpoise is introduced between the two steps, combined with big changes in draft in which the flying boat leaves the water below stalling speed.

The 1 : 9 fairing, in steady runs at a weight of 43,000 lb, has the same effect on stability as the 1 : 6 fairing, but also produce a severe bouncing porpoise in landings at a weight of 43,000 lb. Tests at weights above this were not made.

The instability in landing occurs when the attitude at touch-down is greater than 3 deg. When the attitude is less than 2 deg, but greater than the normal lower stability limit, the hull is stable. The normal range of stable landing attitudes with no fairing is from 0 deg to 7 deg.

No bouncing porpoising is likely to occur in the take-off when the handling is normal, and this superiority in behaviour during take-off, as compared with that during landings, is probably caused by the stabilising effect of the slipstream, *i.e.*, greatly reduced load on water and better aerodynamic control.

The records of pressure on the hull bottom show that the bouncing type of porpoise is associated with fluctuating pressures and suctions on the afterbody, which were not recorded during steady planing conditions or even during normal (non-bouncing) propoising. Under these conditions the afterbody is completely clear of water for all except high attitudes, when the aft step is just immersed. It appears, therefore, that a step fairing will not interfere with the water qualities of a hull until it begins to oppose the normal action of the main step and allows the water flow to re-attach itself to the afterbody. The 1 : 9 fairing tends to do this at high speeds and high attitudes under steady-run or take-off conditions, and at high speeds and moderate attitudes under landing conditions.

The instability in landing is a very undesirable feature and it is considered that the 1 : 9 step fairing in its present form is quite unsafe for operational use.

The nature of the water flow over the step fairing itself will be investigated on a *Sunderland* 3 with a 1 : 6 fairing, with a view to improving fairing design.

REFERENCES

No.	*Author*	*Title, etc.*
1	K. W. Clark and D. Cameron ..	Wind-tunnel and tank tests on the drag of seaplane hulls. A.R.C. 3143. May, 1937.
2	—	Tank tests on a faired main step for the Short R.2/33 (*Sunderland*) flying boat. A.R.C. 3622.
3	R. A. Shaw, A. G. Smith, W. Morris and G. J. Evans.	An investigation of the water performance of the *Sunderland* flying boat. A.R.C. 4391.
4	E. T. Jones and W. H. Davies	Measurement of water pressure on the hull of a boat seaplane. R. & M. 1638. March, 1934.

TABLE 1

General Particulars of Sunderland

1. *Wings*
   - Area .. .. 1,504 sq ft
   - Span .. .. 112·7 ft
   - Mean chord .. .. 15·7 ft
   - Aspect ratio .. .. 7·2
   - Aerodynamic chord to datum .. .. +6·15 deg

   Flaps (Gouge type)
   - Increase in wing area .. .. 34·6 sq ft (flaps ⅓ out)
     50·2 sq ft (flaps fully out)
   - Flap semi-span .. .. 29·7 ft
   - Flap angle (fully out) .. .. 26 deg

2. *Tailplane*
   - Total area .. .. 205 sq ft
   - Span .. .. 35·75 ft
   - Elevator area (including tabs) .. .. 84·5 sq ft
   - Elevator movement .. .. 18 deg up and down
   - Angle of tailplane to datum .. .. .. +4 deg

3. *Loads at which tests were performed*—38,000 and 43,000 lb
   - C.G. position .. .. 1·5 ft aft of datum point measured parallel to datum line and 4·6 ft below datum point
   - Datum point .. .. 16·4 ft above and 4·5 ft forward of step, on line of symmetry of aircraft, full datum horizontal

4. *Airscrews*—Two-pitch, 3-blade, De Havilland type
   - Diameter .. .. 12·75 ft
   - Blade chord at 0·7 radius .. .. .. 0·69 ft
   - Blade angle at 0·7 radius .. .. .. fine pitch 23·5 deg
     coarse pitch 30·0 deg
   - Angle of thrust lines to aerodynamic chord .. —3 deg
   - Mean height of thrust line above c.g. .. .. 2·1 ft

5. *Engines*
   - K.4774 .. .. 4 Pegasus XXX radial air-cooled engines. Take-off power 950 b.h.p., 4½ lb/sq in. boost, 2,475 r.p.m.
   - L.2158 .. .. 4 Pegasus XXII radial air-cooled engines. Take-off power 980 b.h.p., 6 lb/sq in. boost, 2,600 r.p.m.

TABLE 2

Sunderland K.4774. No fairing. 43,000 lb.
Steady runs. 0 deg flaps. Wind 10 knots.
Mean pressure in lb/sq in.

Water speed knots	Stick position	Mean attitude	Stations on forebody				Stations on afterbody 5 6 7 8 9 10
			1	2	3	4	
55	Fully forward	0·7° (4°P)	2·5	1·5	—	0	
30	,, ,, ...	4·3° (4°P)	3·0	2·0	3·4	—	
66	,, ,, ...	0° (2°P)	1·0	0	1·0	0	
50	Fully back	7·0° (1·5°P)	—	—	—	6·0	Zero
50	,, ,, ...	7·4°	—	—	—	5·0	
30	,, ,, ...	7·1°	0	0	4·6	0	
34	,, ,, ...	8·2°	0	0	0	3·5	
30	,, ,, ...	8·0°	0	—	0	2·0	

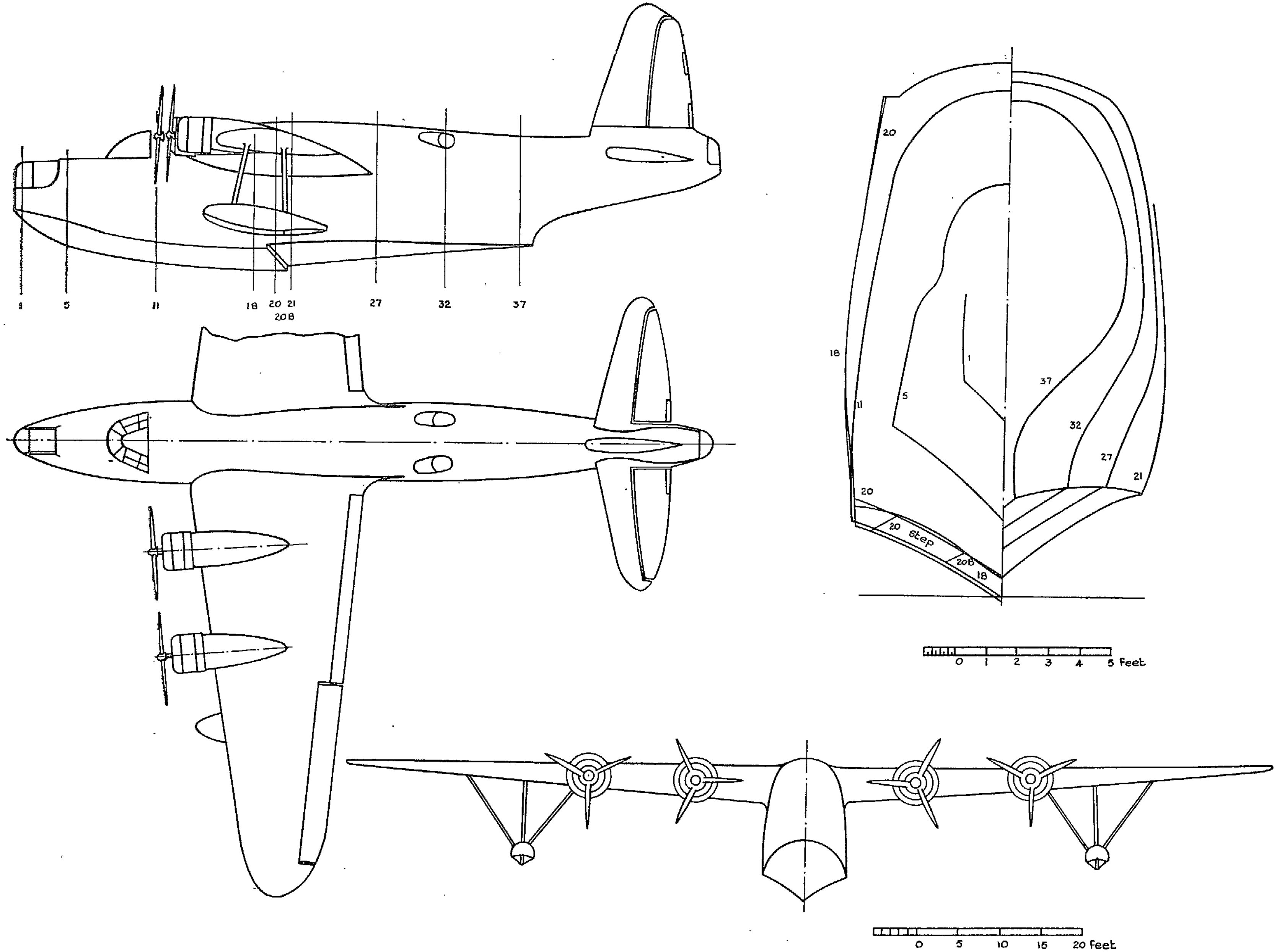


FIG. 1. Sunderland.

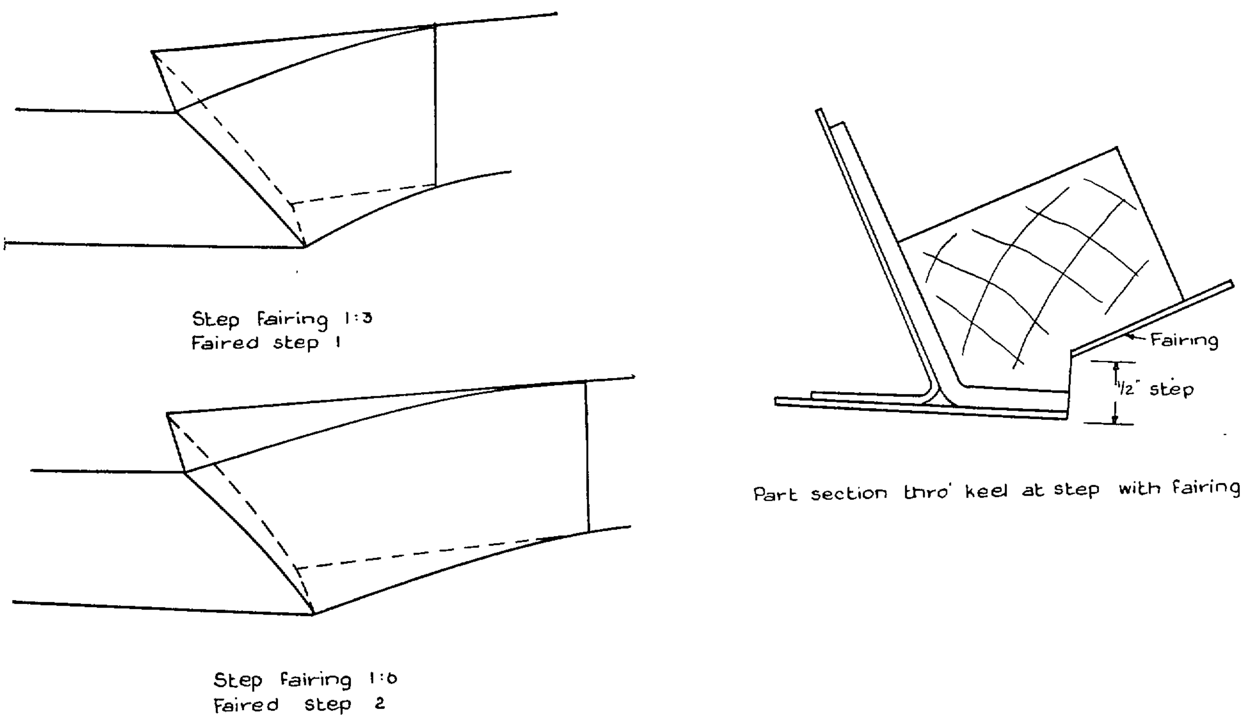


FIG. 2. Experimental step fairings.

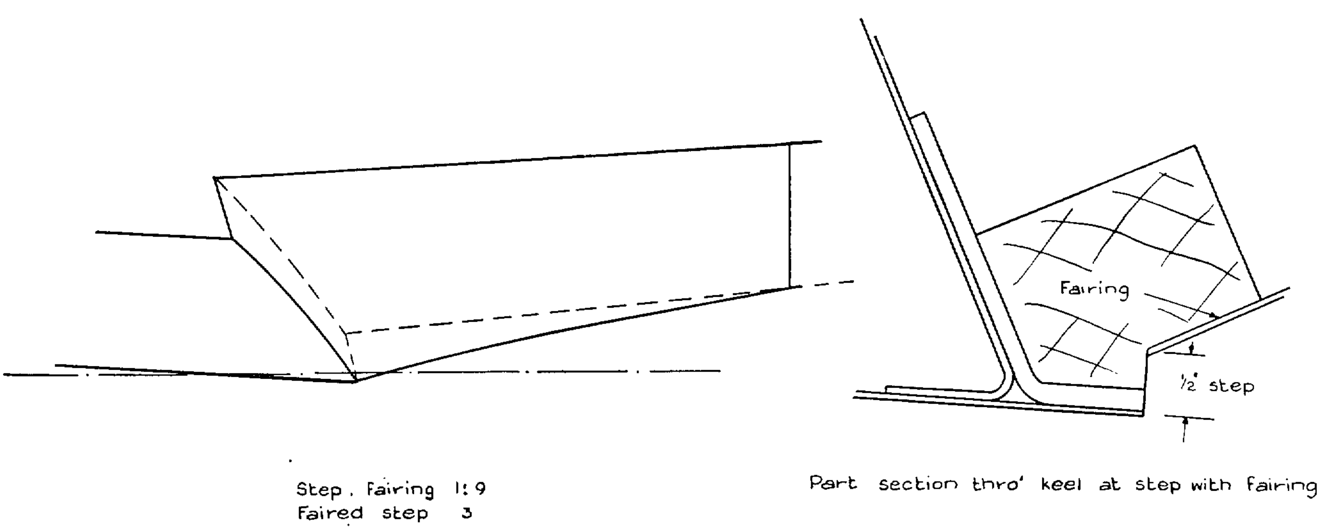
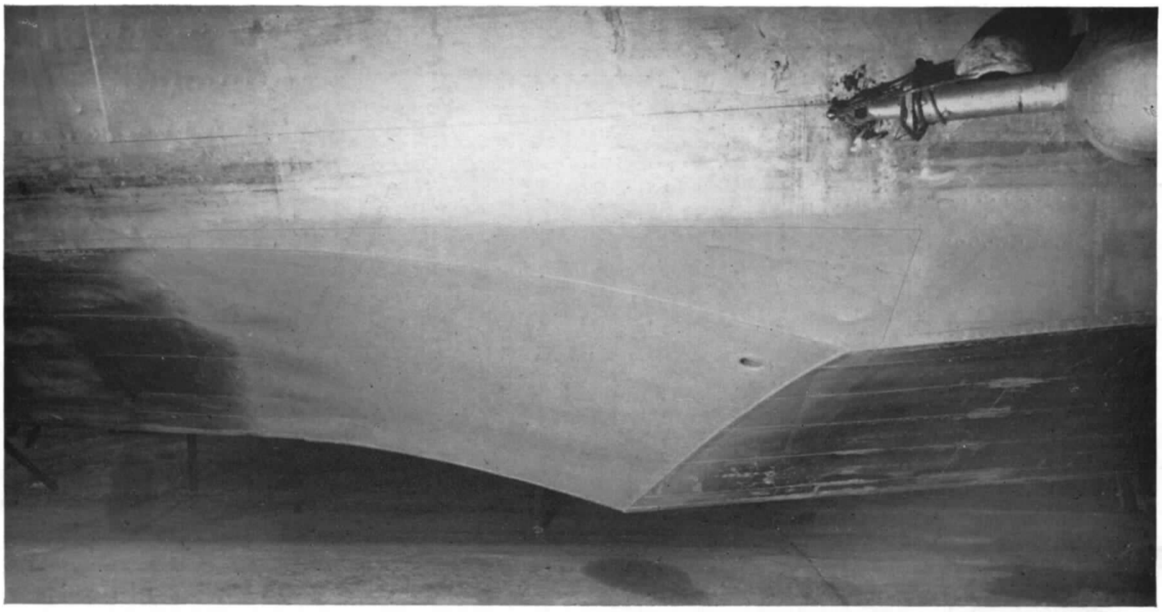
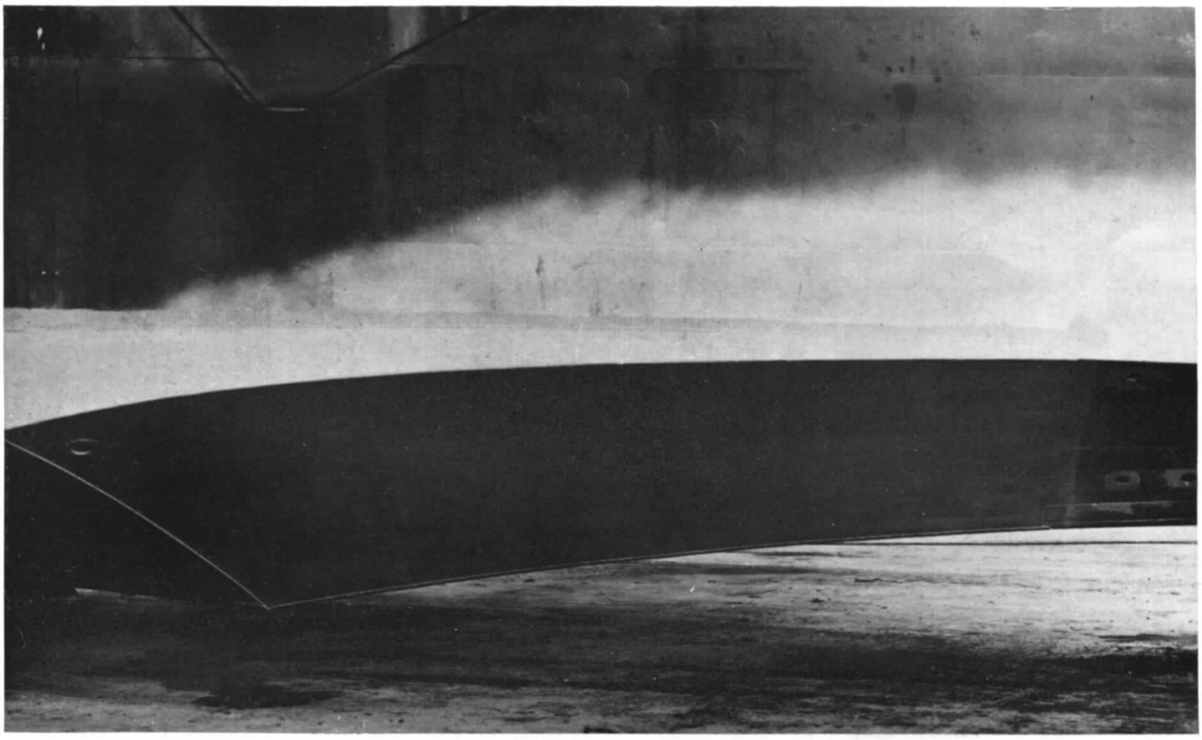


FIG. 3. Experimental step fairing.



Fairing 2 (1 : 6).



Fairing 3 (1 : 9).

FIG. 4. Step fairings 2 and 3.

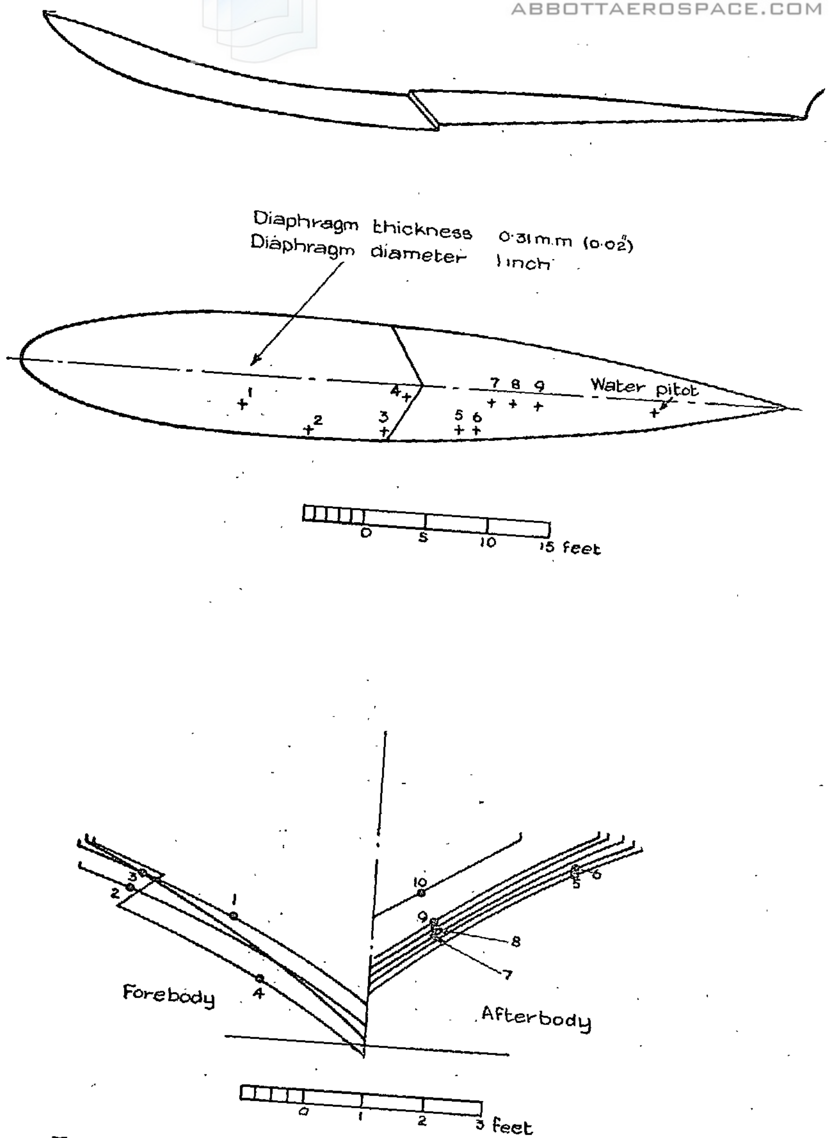


FIG. 5. Position of pressure diaphragms. No fairing.

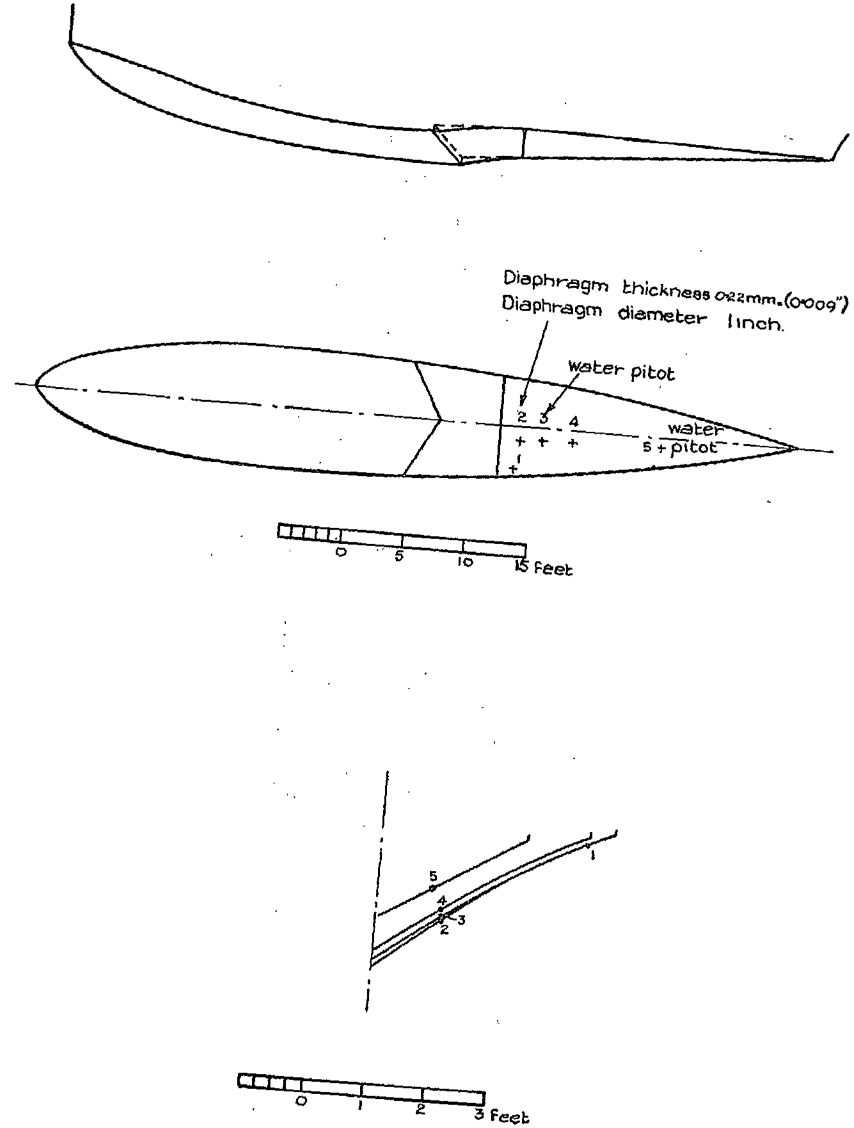


FIG. 6. Position of pressure diaphragms. Faired step 2.

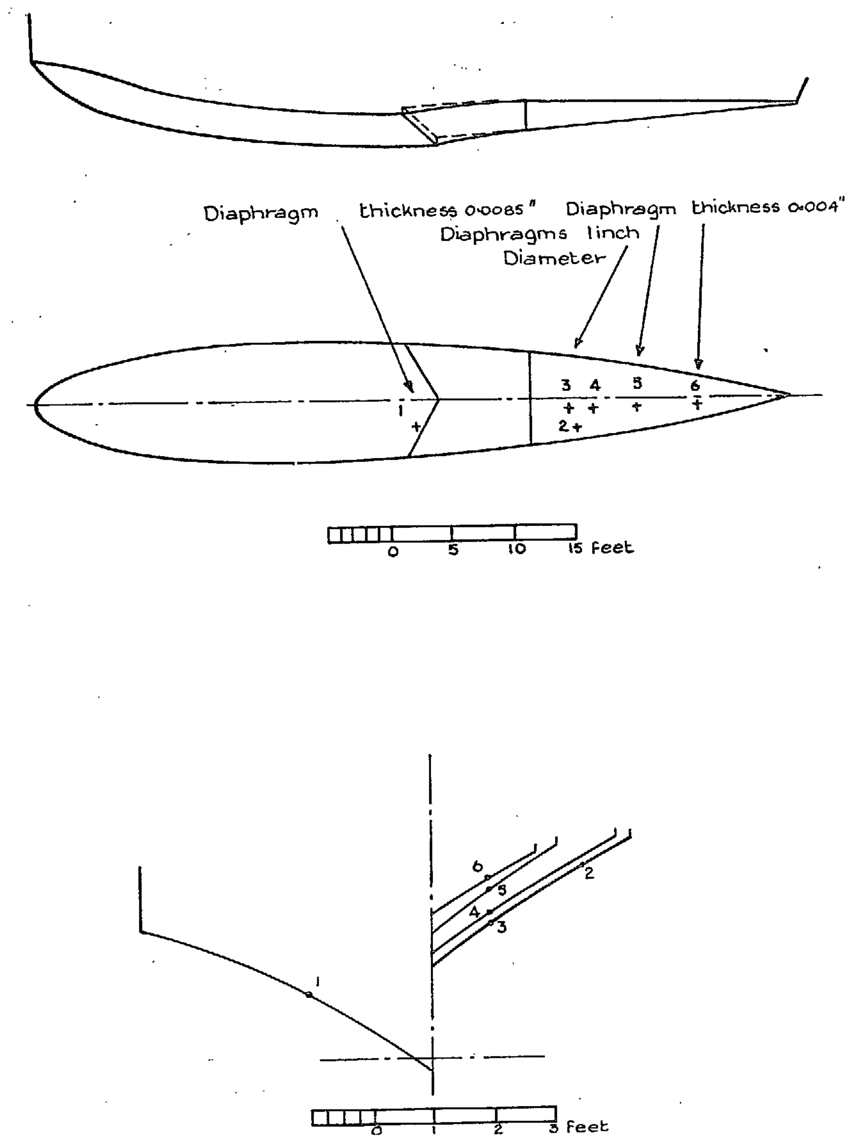


FIG. 7. Position of pressure diaphragms. Faired step 3.

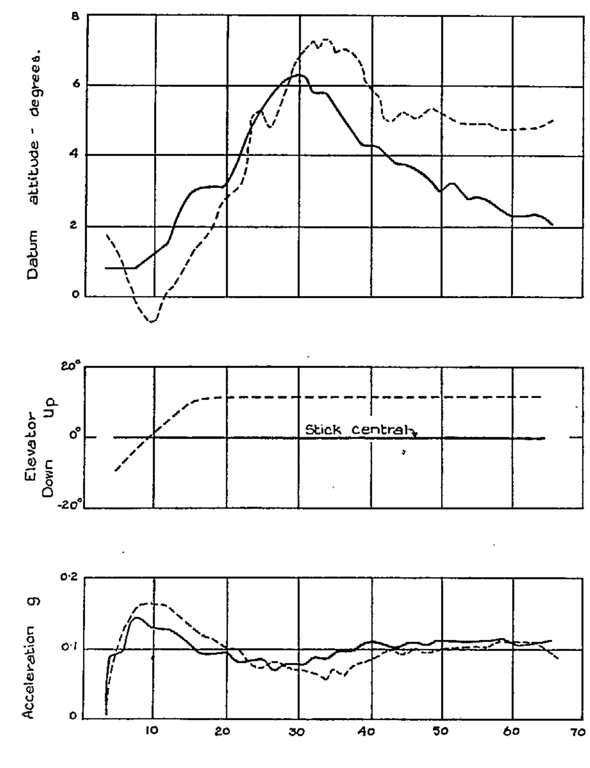


FIG. 8. Take-offs with faired step 1.
43,000 lb. 0 deg flap. Wind speed 5 knots.

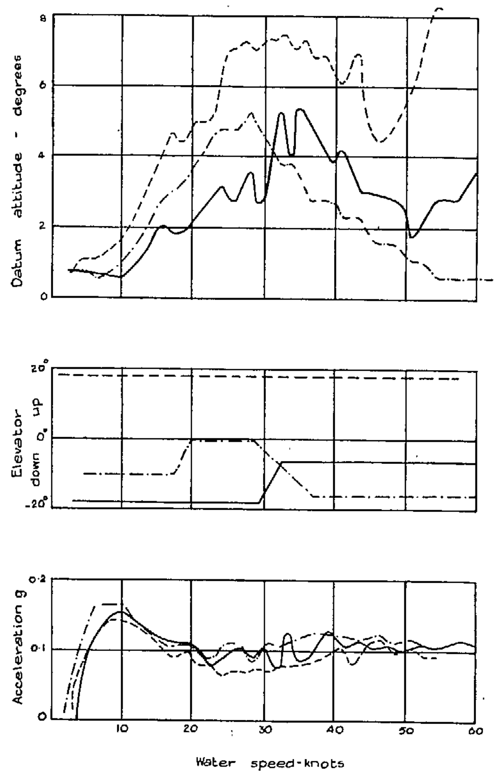


FIG. 9. Take-offs with faired step 1. 43,000 lb. 1/3rd flap. Wind speed 5 knots.

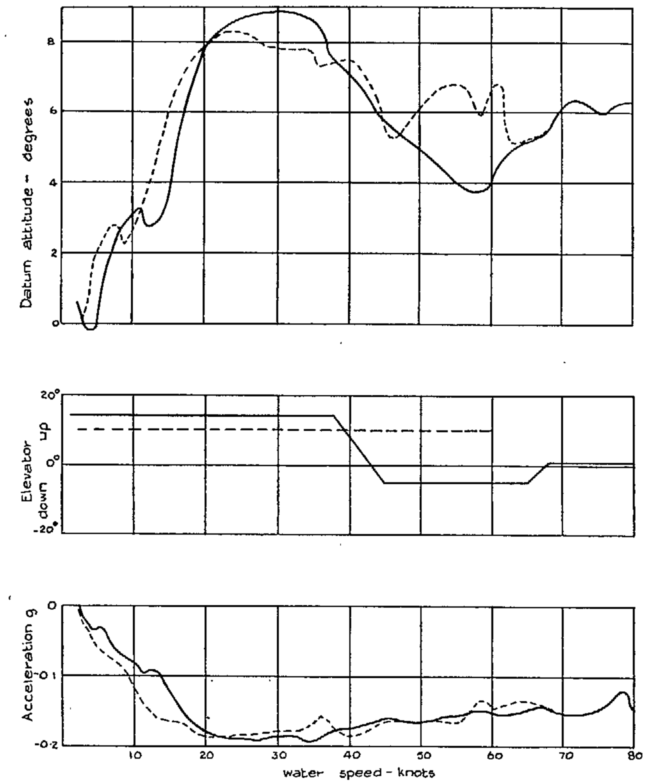


FIG. 10. Landings with faired step 1. 43,000 lb. 0 deg flap. Wind less than 5 knots.

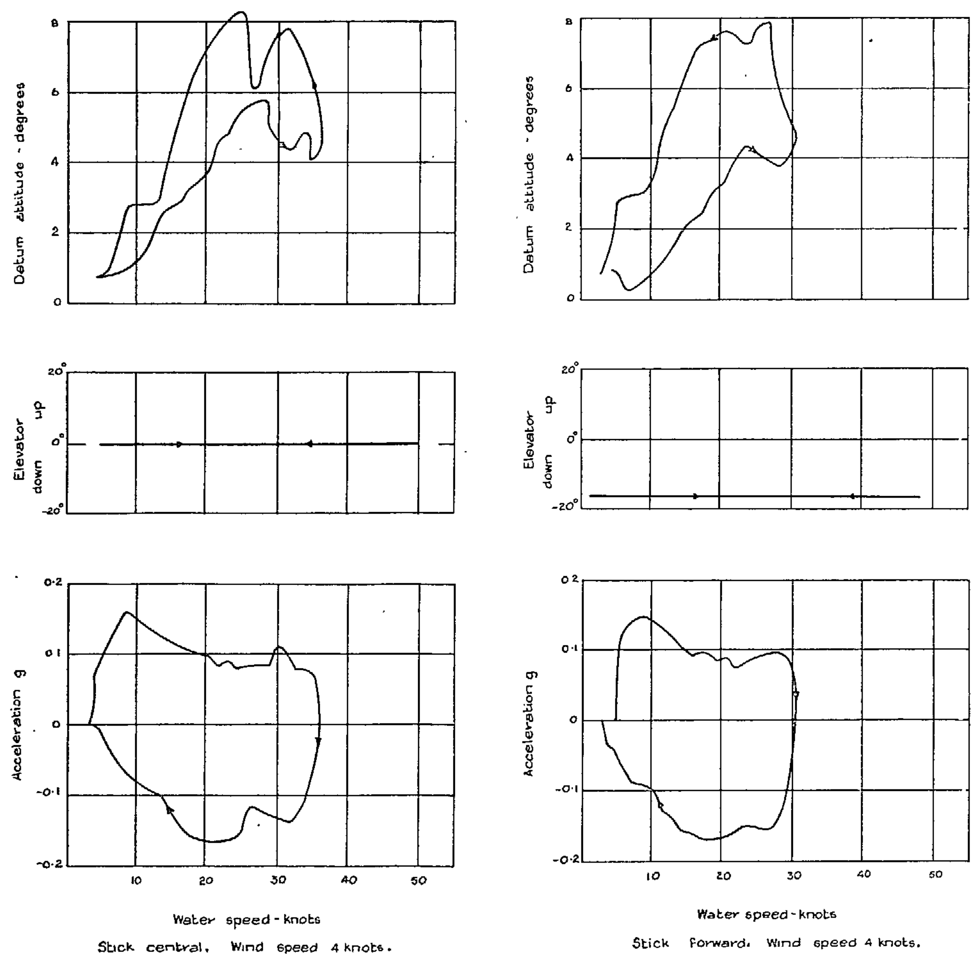


FIG. 11. Loop runs with faired step 1. 43,000 lb. 0 deg flap.

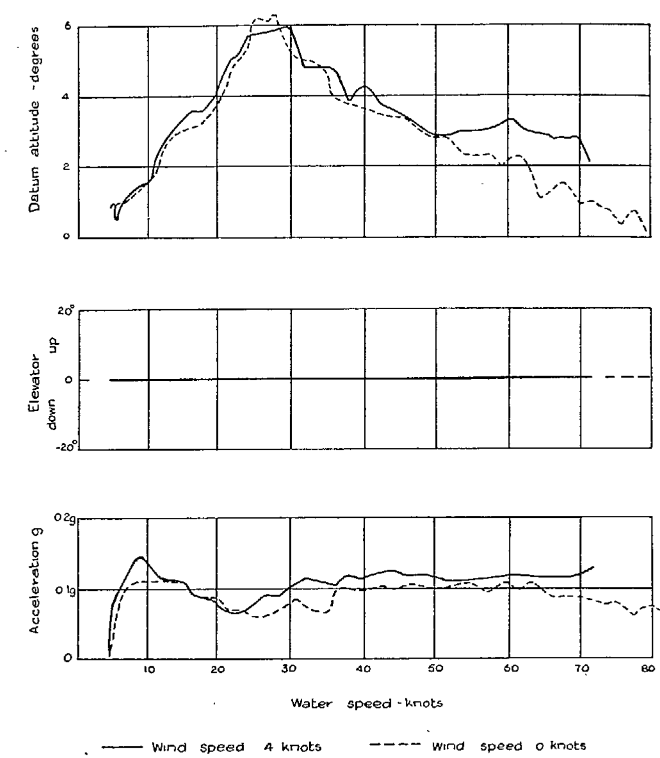


FIG. 12. Take-offs with faired step 2. 43,000 lb. 0 deg flap.

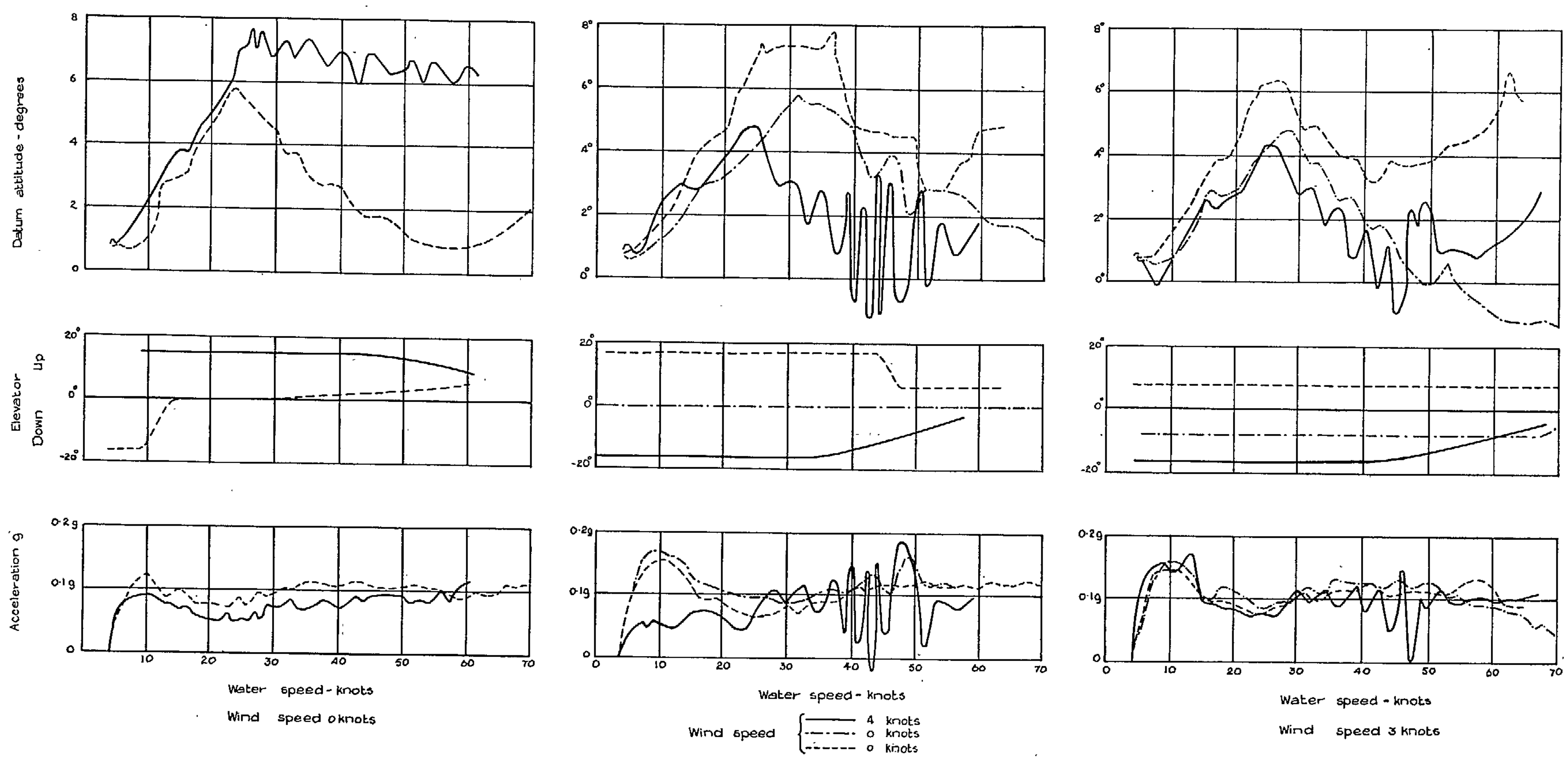


FIG. 13. Take-offs with faired step 2. 43,000 lb. 1/3rd flap.

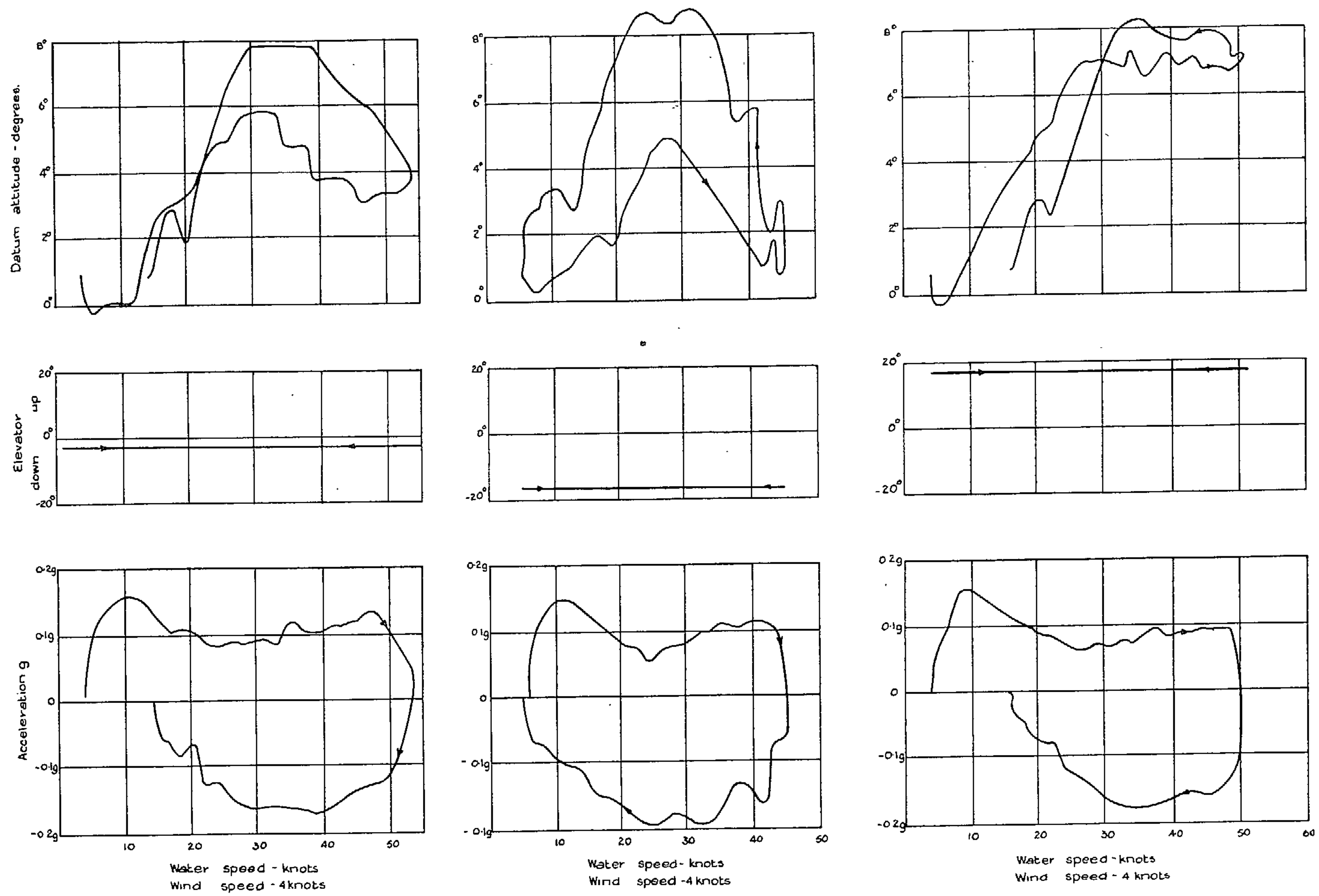


FIG. 14. Loop run with faired step 2. 43,000 lb. 0 deg flap.

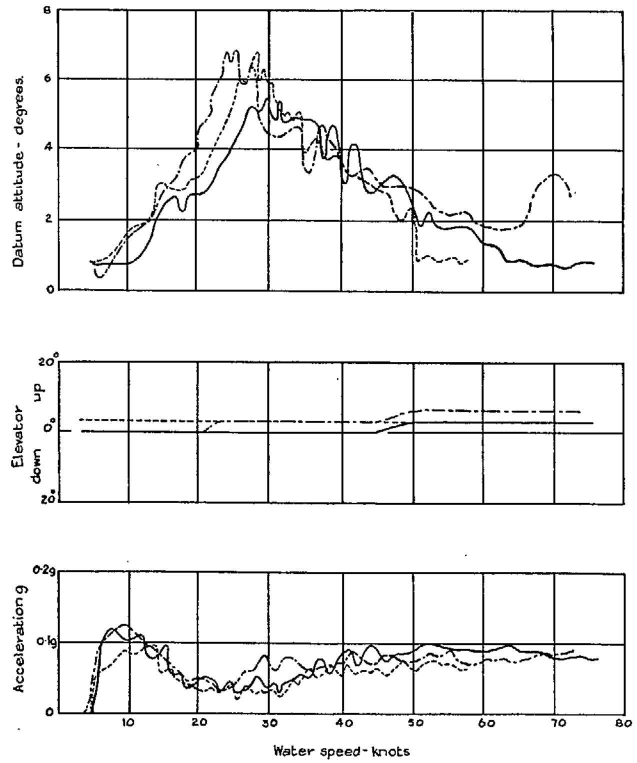


FIG. 15. Take-offs with faired step 2. 50,000 lb. 1/3rd flap. Wind speed 3 knots.

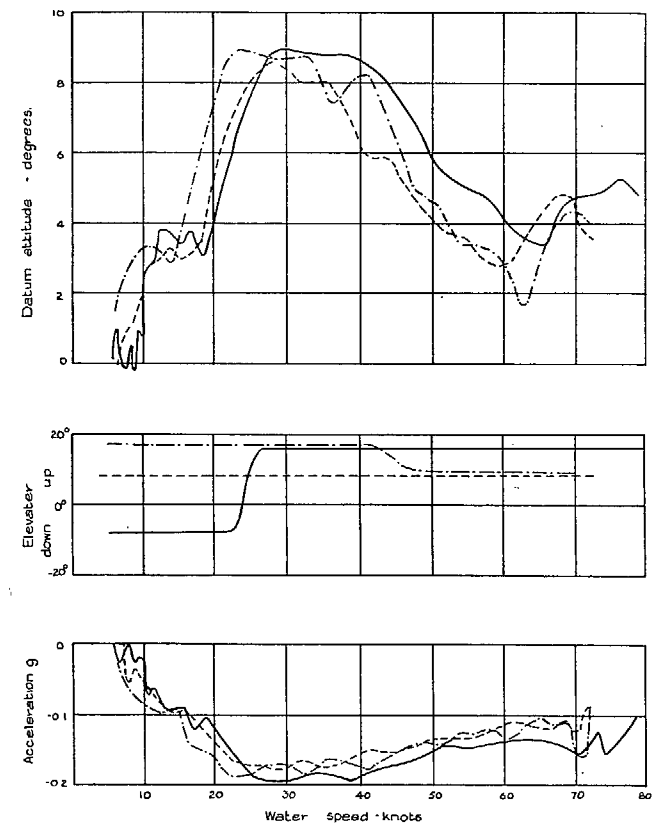


FIG. 16. Landings with faired step 2. 50,000 lb. Full flap. Wind speed 3 knots.

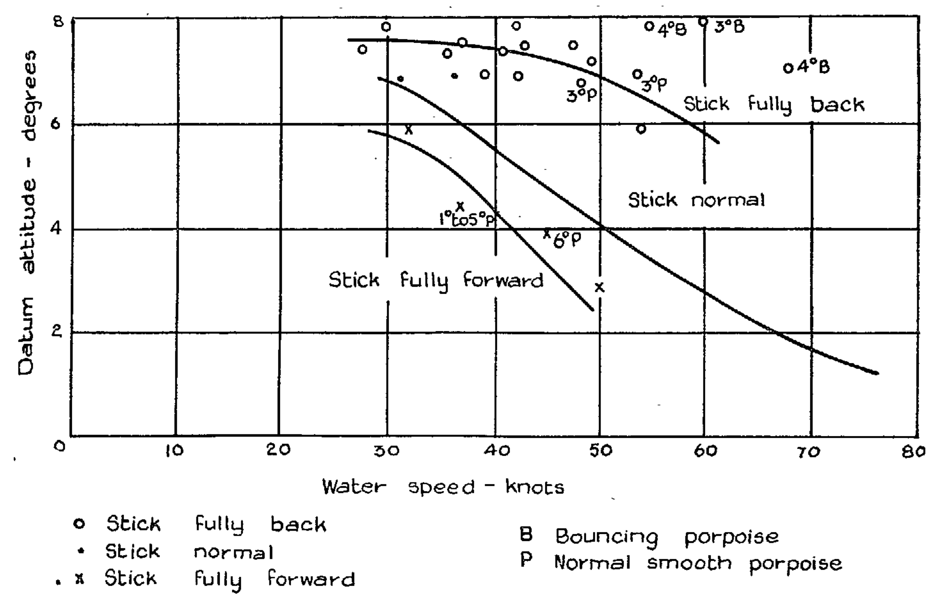


FIG. 17. Steady runs with faired step 2. 43,000 lb. 0 deg flap. Wind less than 4 knots. When porpoising occurred the amplitude reached is shown.

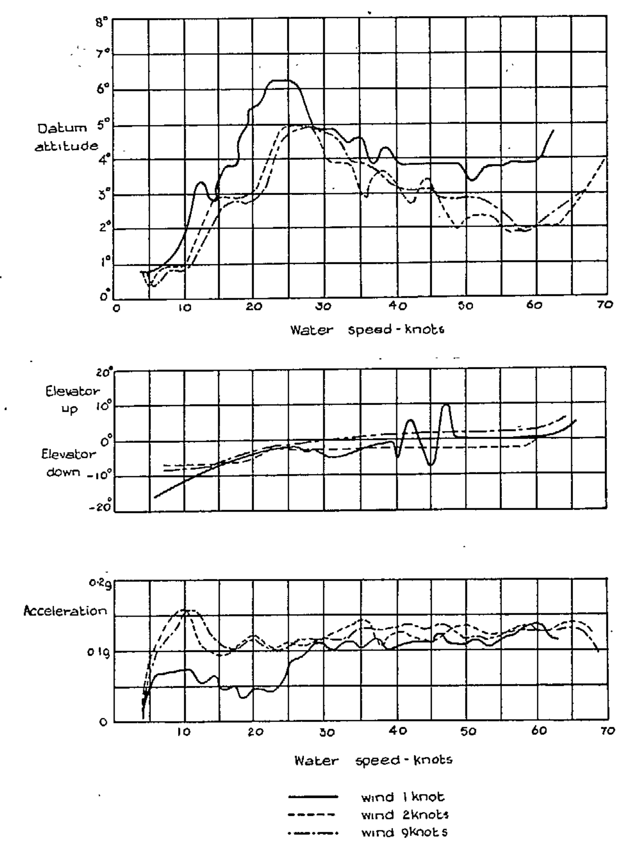


FIG. 18. Take-offs with faired step 3. 42,000 lb. 1/3rd flap.

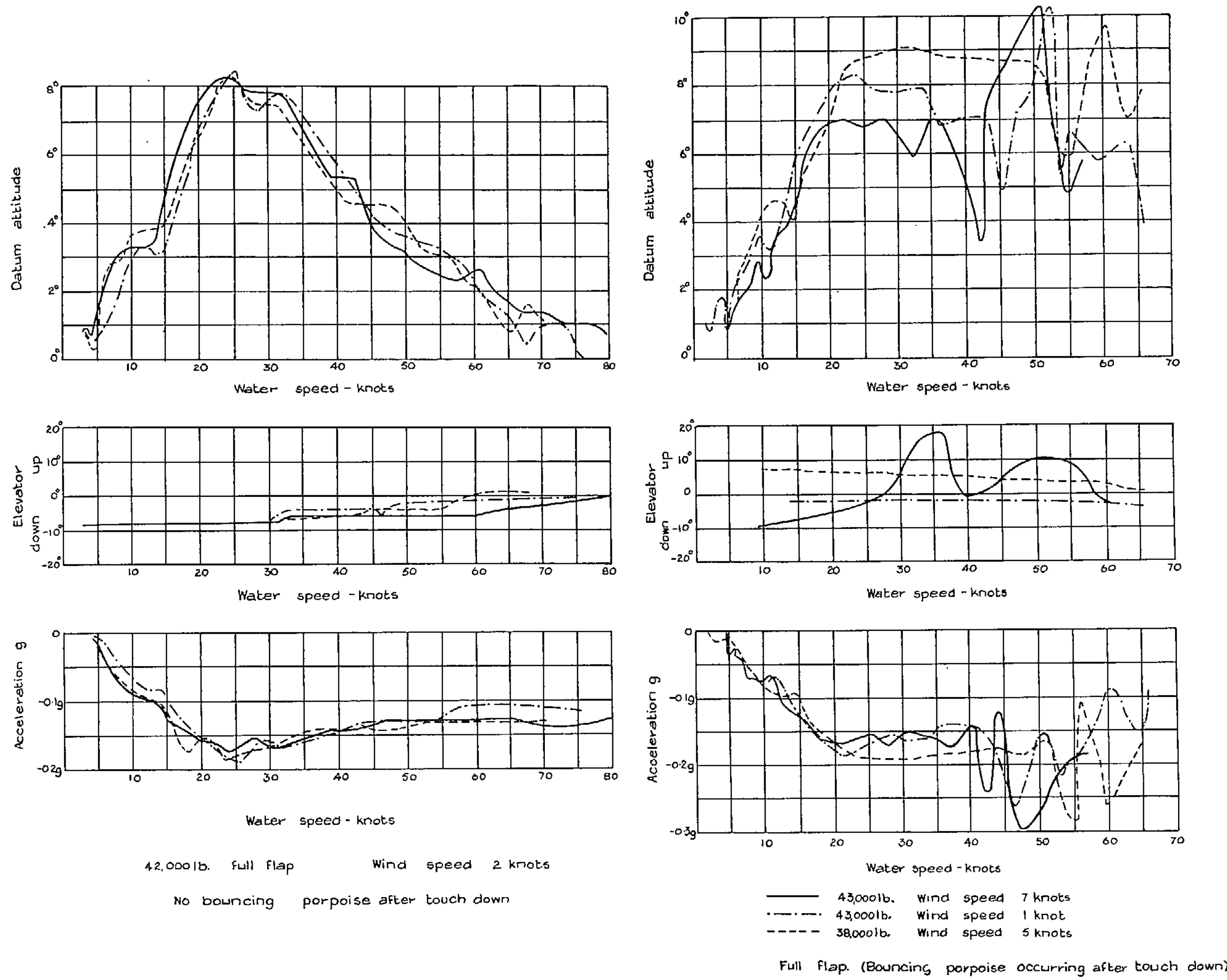


FIG. 19. Landings with faired step 3.

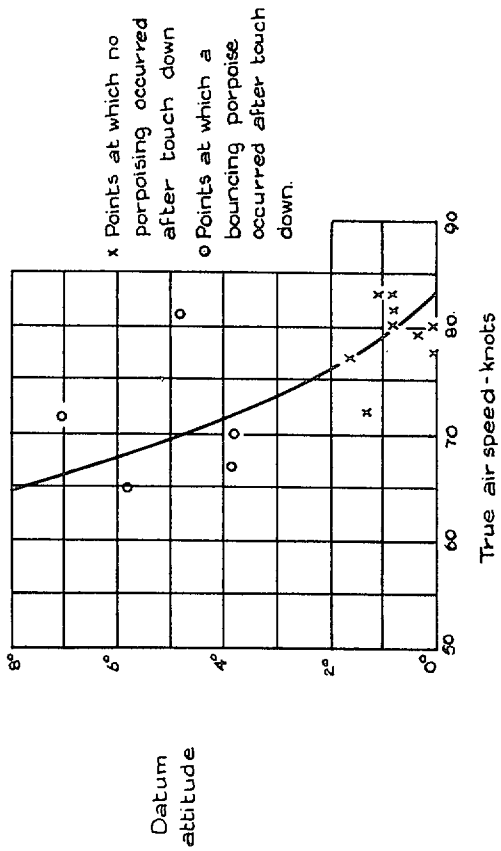


FIG. 20. Landing speed against attitude—landings with faired step 3. 38,000 to 43,000 lb. Full flap. Wind speed 1 to 7 knots.

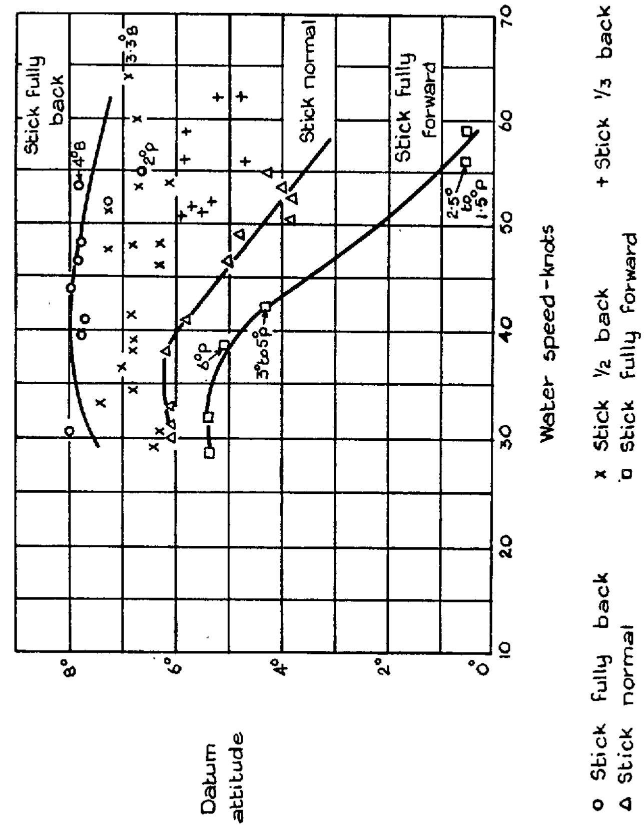


FIG. 21. Steady runs with faired step 3. 43,000 lb. 0 deg flap.

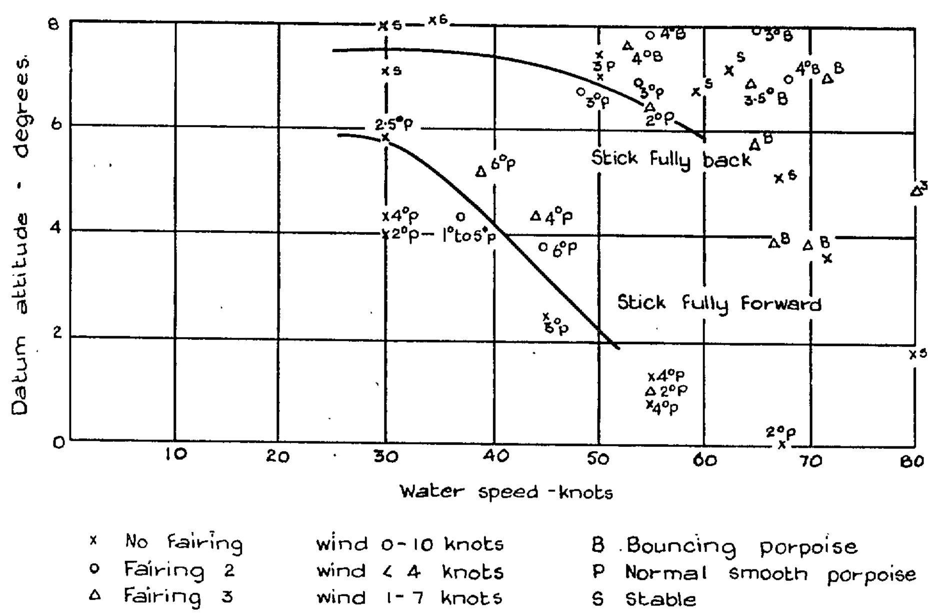


FIG. 22. Mean attitude curves with faired step 2. 43,000 lb. 0 deg flap. Porpoising points for no fairing and faired steps 2 and 3.

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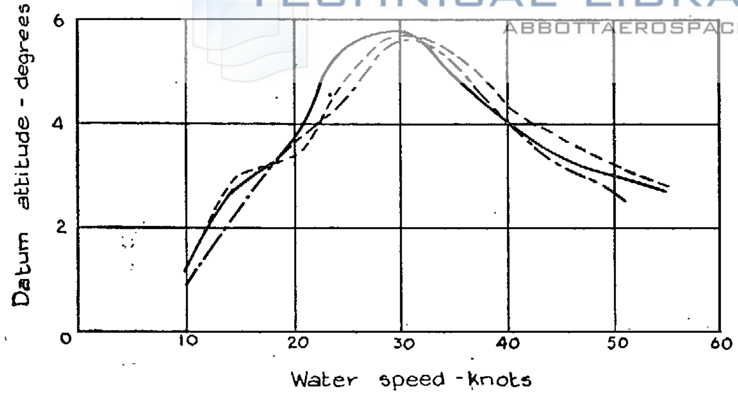
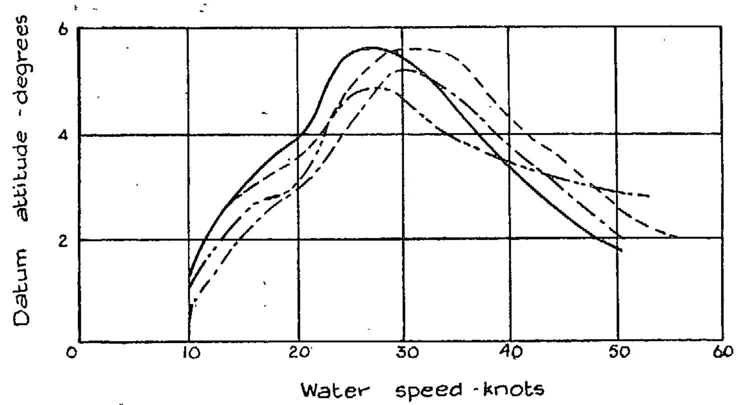


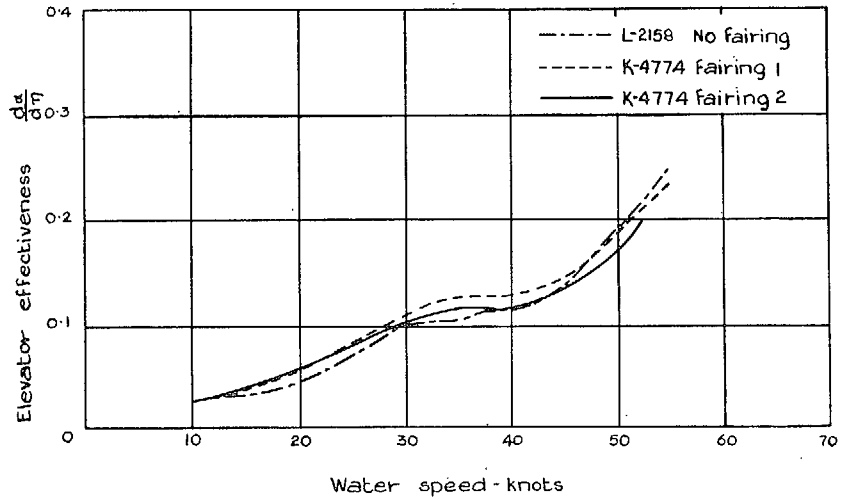
Mean take-off attitude with flaps 0° and elevator neutral
---- K 4774 faired step 1 wind 5 knots
—— K 4774 faired step 2 wind 0-4 knots
-·-·- L 2158 no fairing wind 9 knots



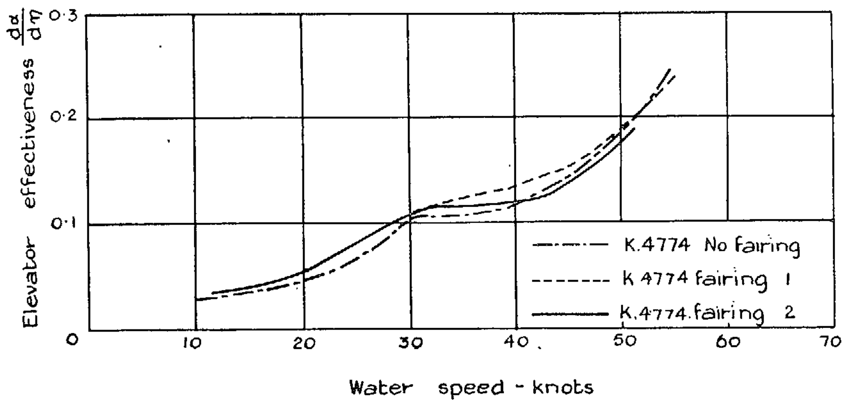
Mean take-off attitude with 1/3 flaps and elevator neutral

---- K 4774 faired step 1 wind speed 5 knots
—— K 4774 faired step 2 wind speed 0-5 knots
··-··- K 4774 faired step 3 wind speed 1-9 knots
·-·- L 2,158 no fairing wind speed 3 knots

FIG. 23. Take-off attitude comparisons with no fairing and fairings 1, 2 and 3 at 43,000 lb.



Elevator effectiveness - Zero flaps



Elevator effectiveness - 1/3 flaps

FIG. 24. Comparison of elevator effectiveness in take-off with no fairing and fairings 1 and 2 at 43,000 lb.

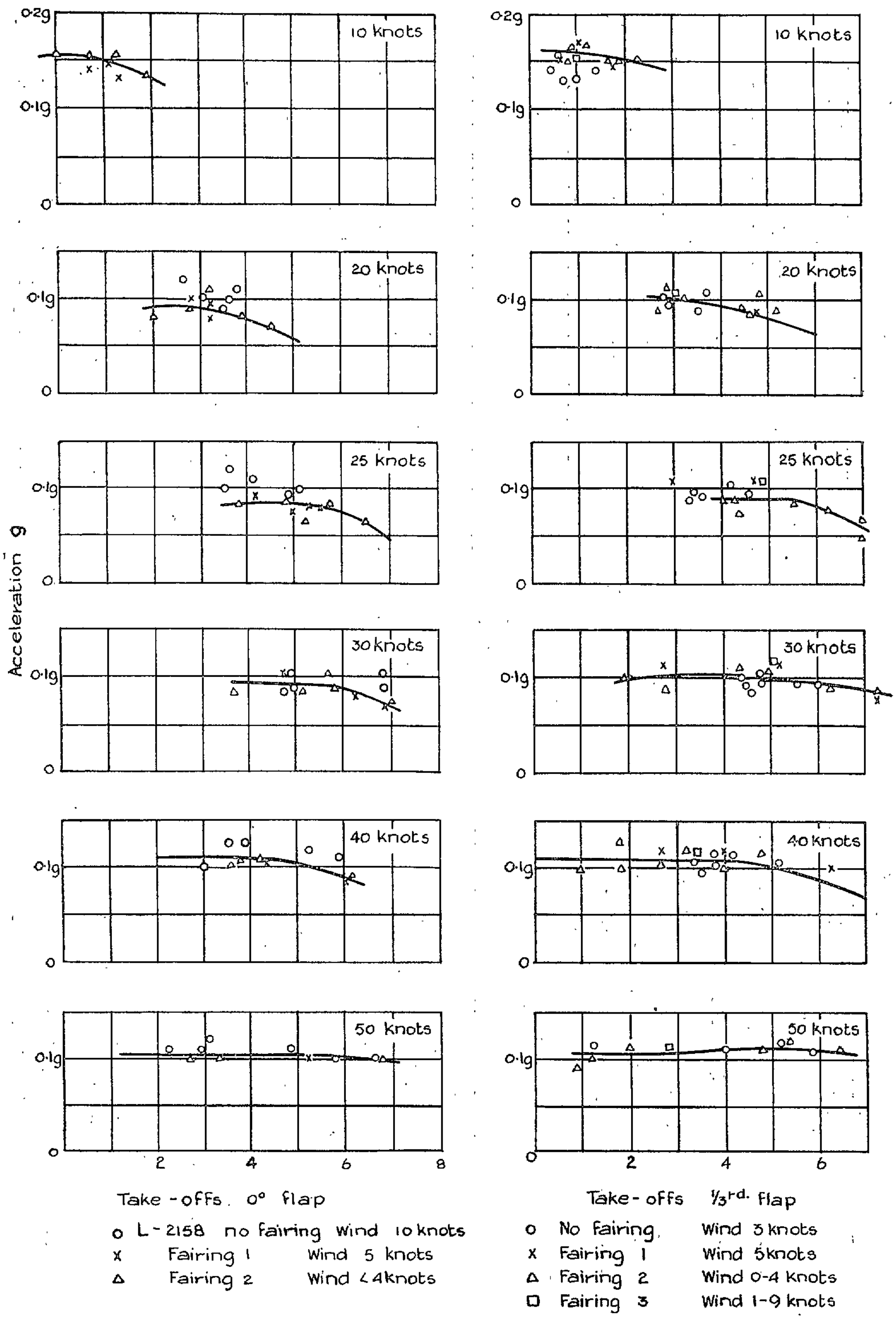


FIG. 25. Acceleration against attitude in take-offs with different fairings at 43,000 lb.

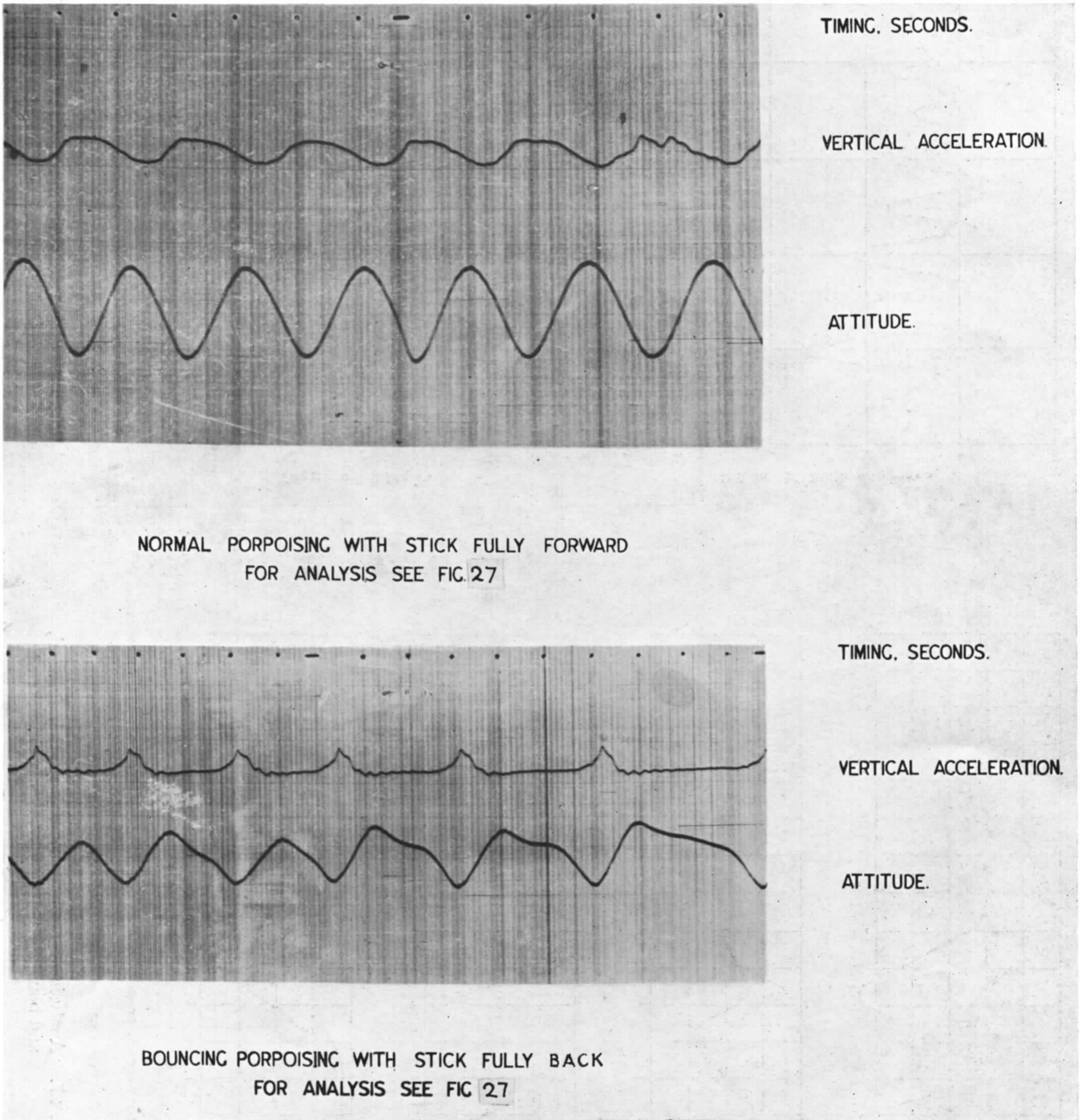


FIG. 26. Enlargements of gyro accelerometer records in porpoising runs with faired step 2. 43,000 lb. 0 deg flap.

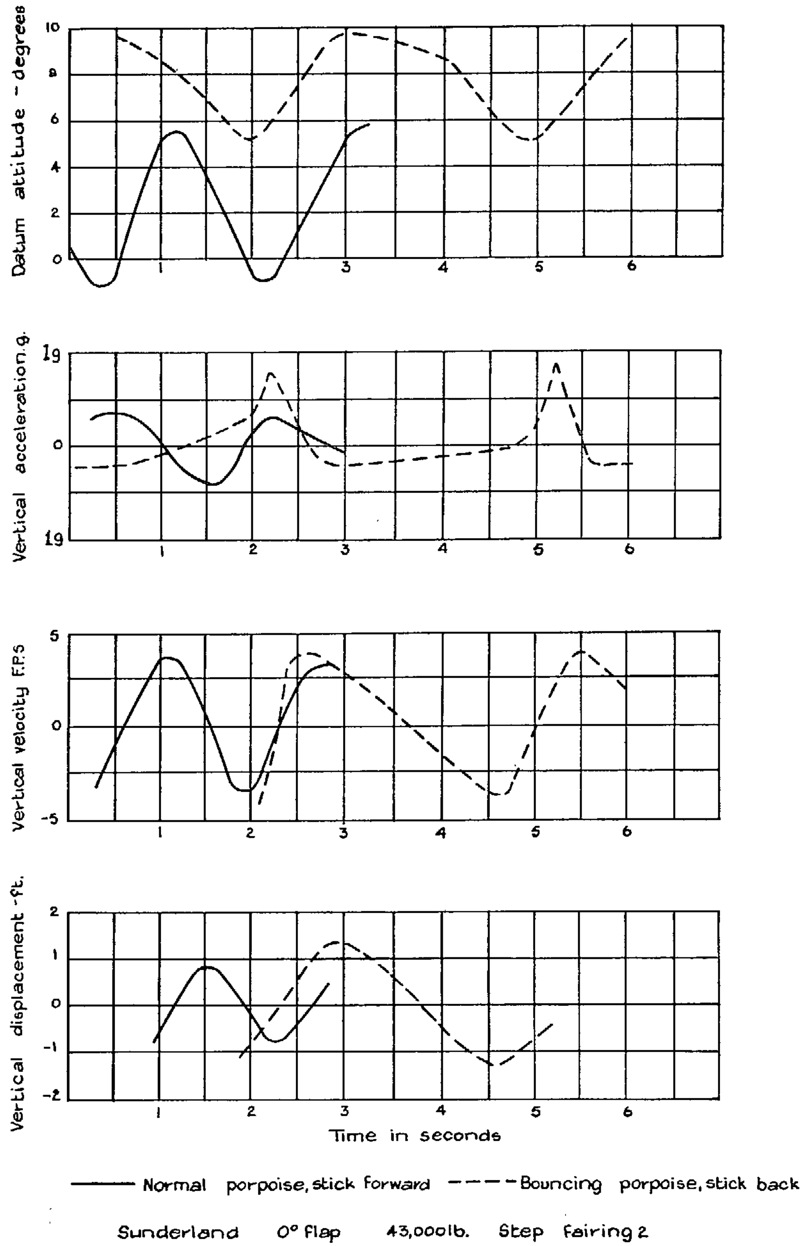


FIG. 27. Analysis of normal porpoising, stick forward, and bouncing porpoising, stick back.

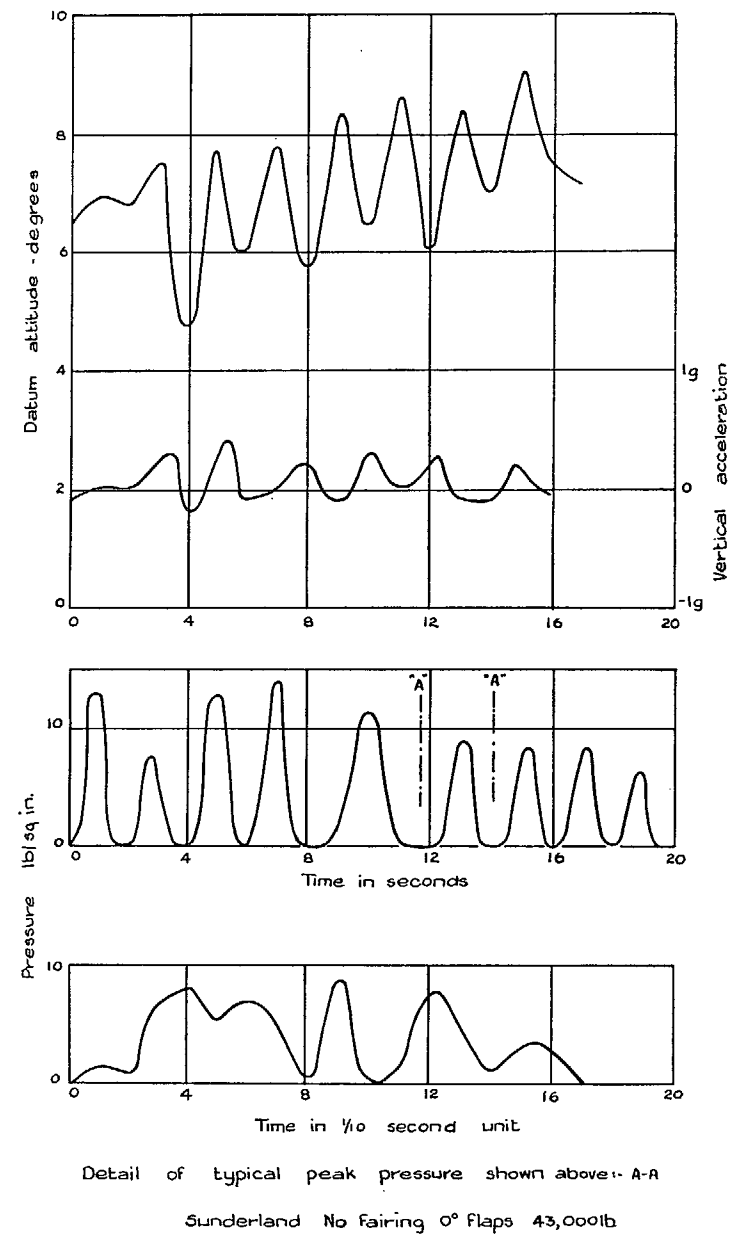


FIG. 28. Pressures on forebody at station 4 in normal porpoising run at 50 knots water speed. Stick fully back.

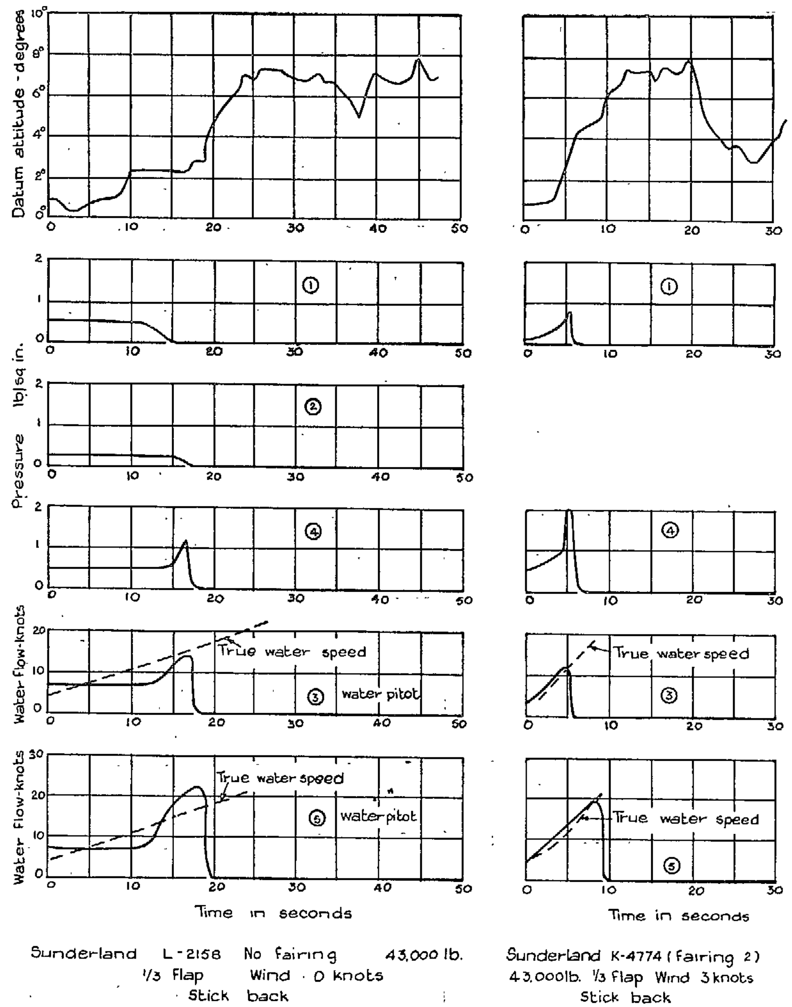


FIG. 29. Static and pitot records behind the step during take-off with and without step fairing.

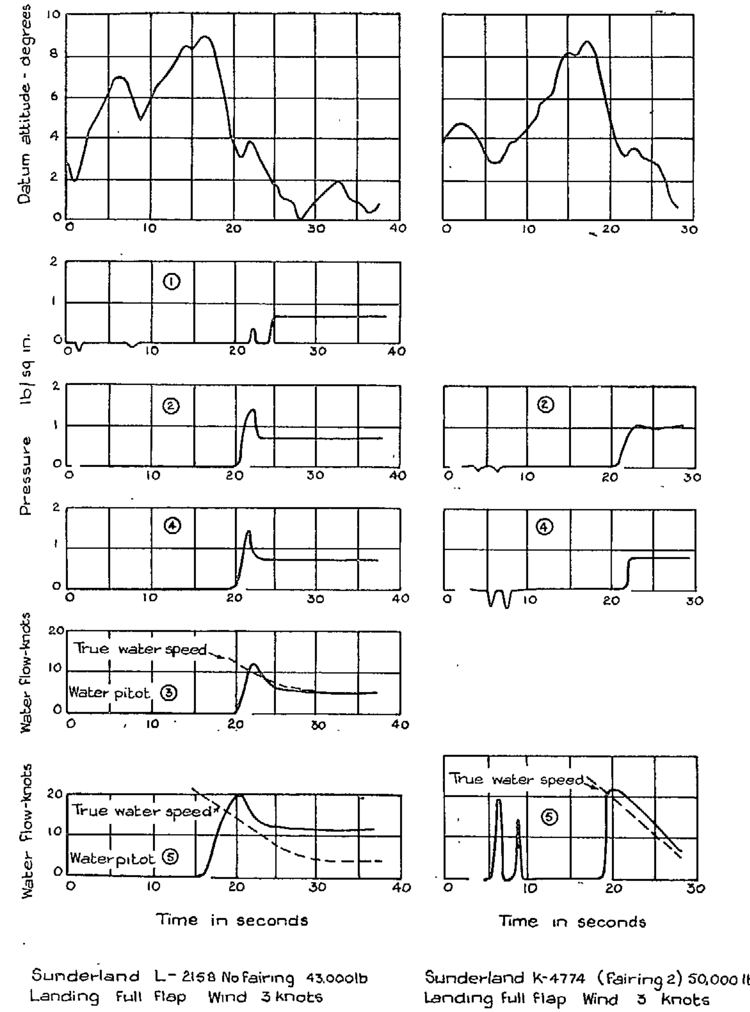


FIG. 30. Static and pitot records behind the step during landings with and without step fairing.

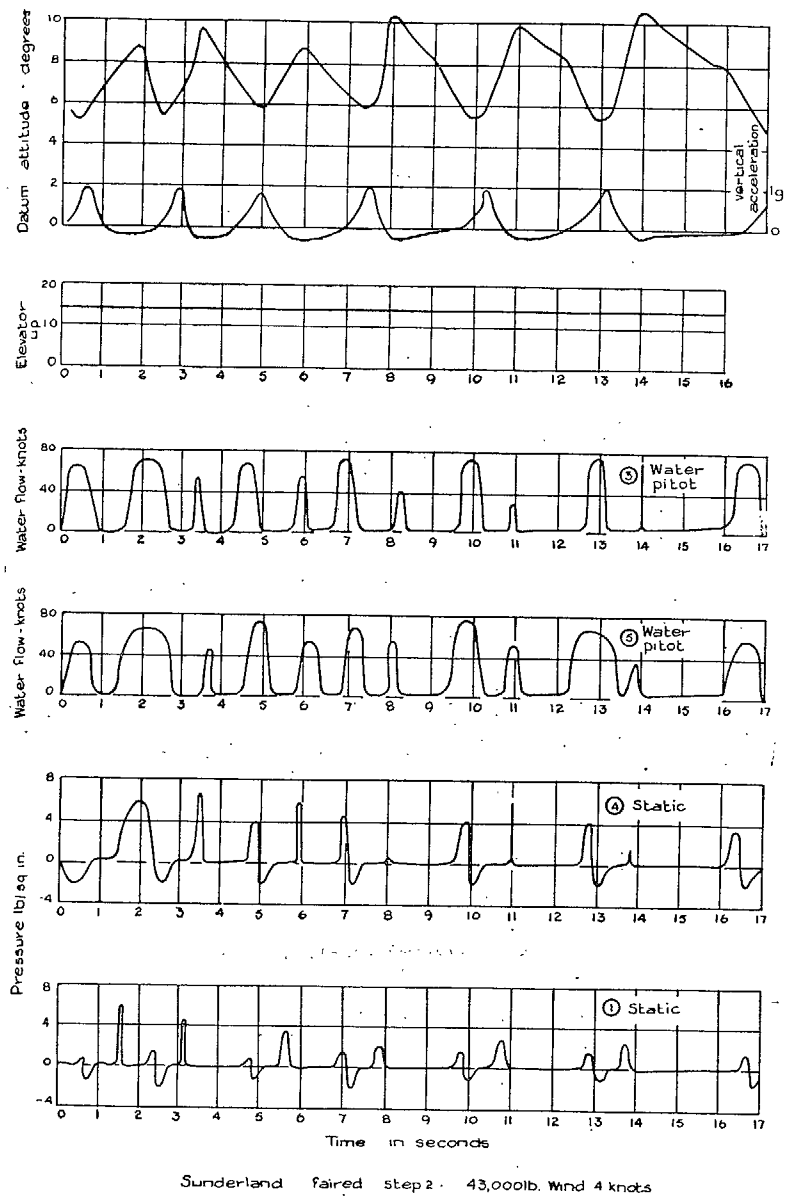


FIG. 31. Bouncing porpoise run. 0 deg flap. Water speed 55 knots. Stick back. Attitude and vertical acceleration curves with static and pitot records on afterbody.

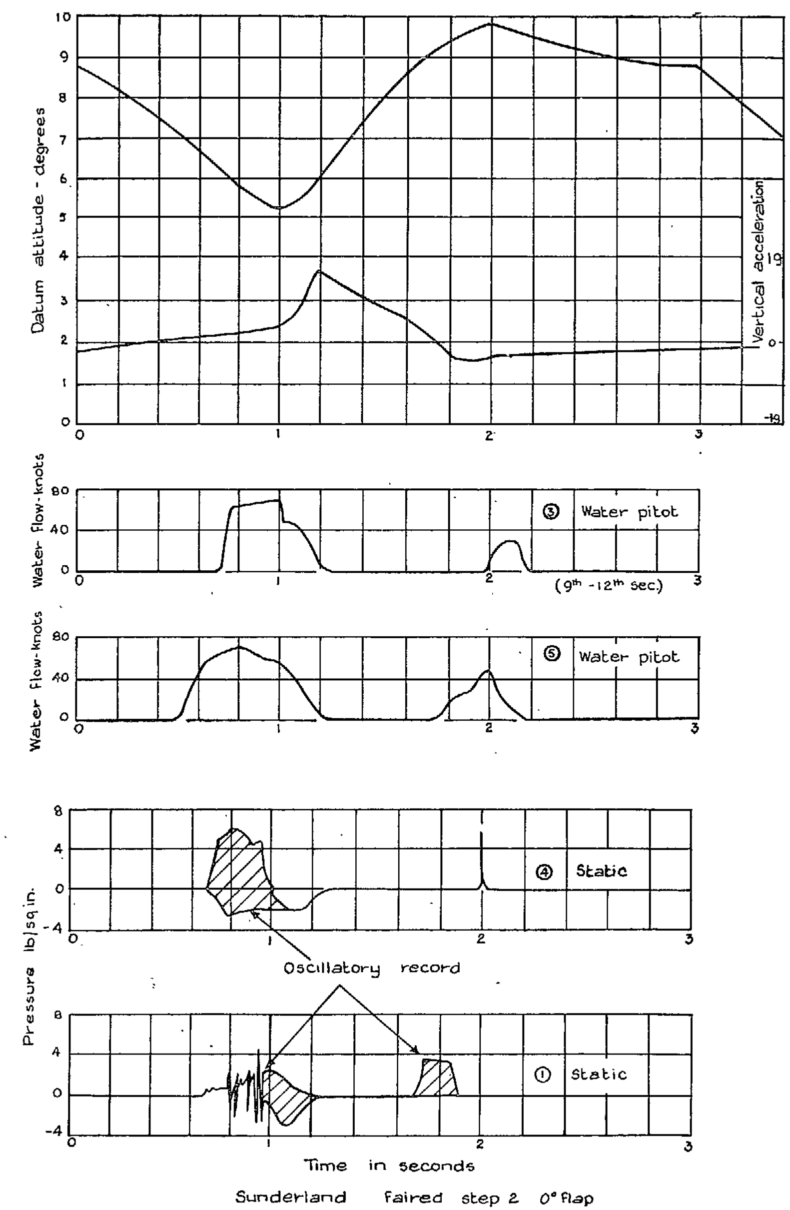


FIG. 32. Water flow over afterbody during bouncing porpoise from 9th to 12th sec period of Fig. 31.

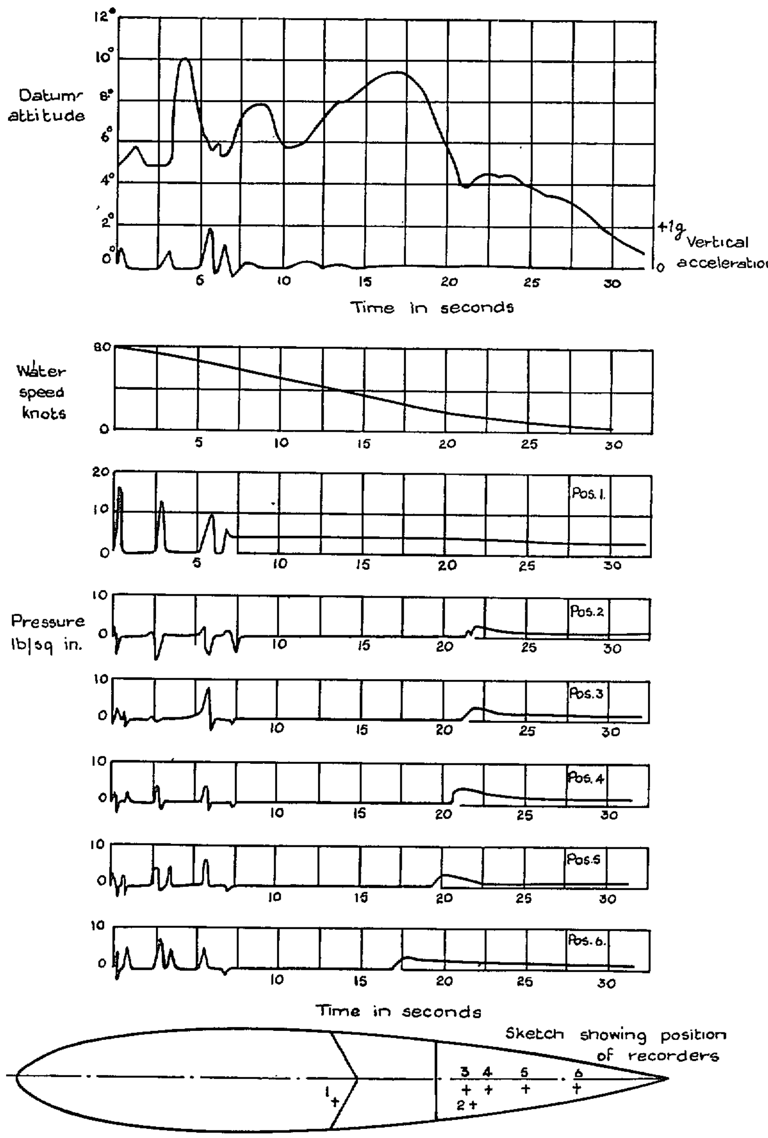


FIG. 33. Pressure records during a landing on which a bouncing porpoise occurred. Faired step 3. 43,000 lb. Full flap. Wind speed 1 knot.

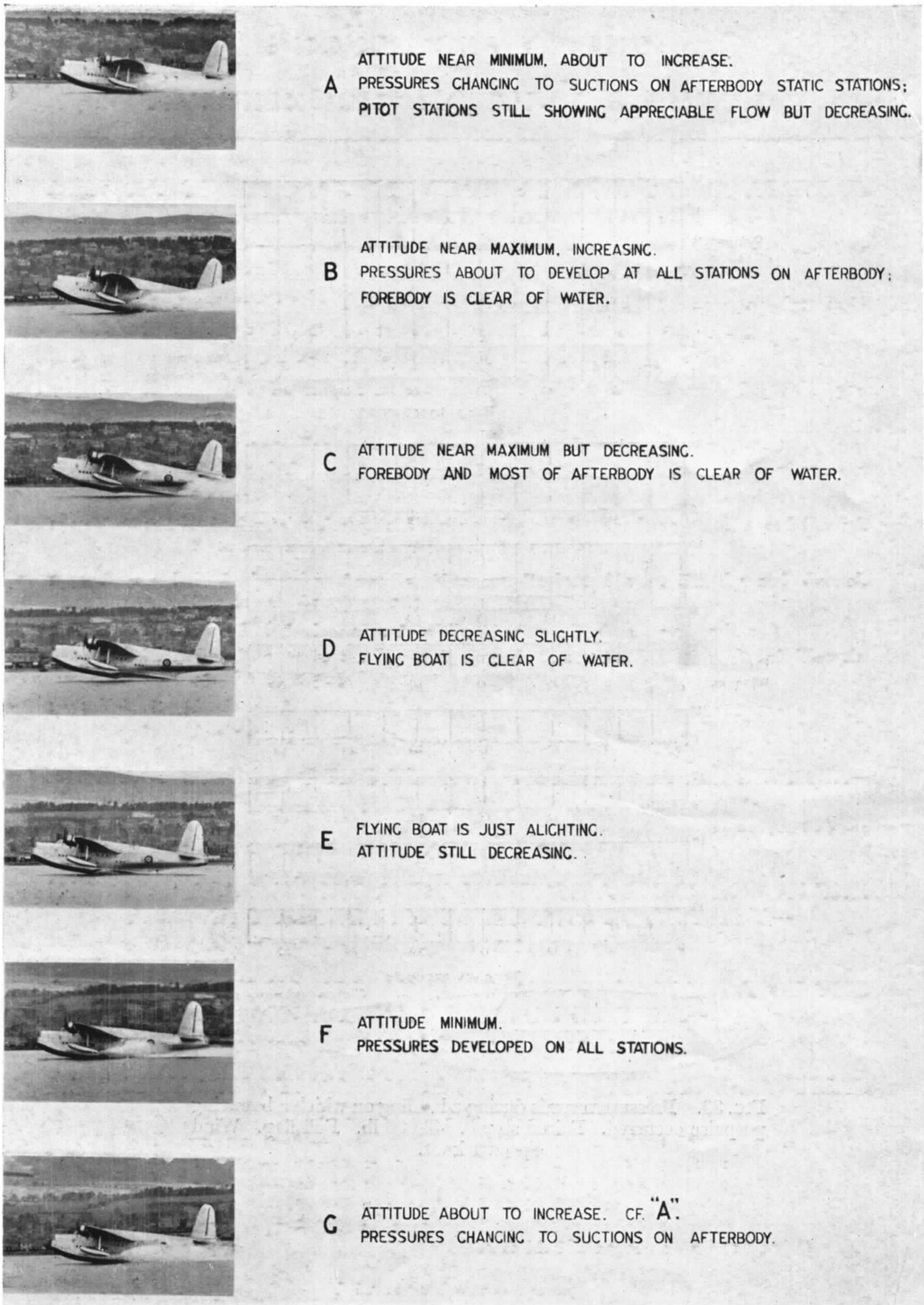


FIG. 34. Typical bouncing porpoise sequence with faired step 2. 43,000 lb. 0 deg flap. Started with stick fully back. Water speed 60 knots.

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