N.A.E.

R. & M. No. 2641
(11,462)
A.R.C. Technical Report

MINISTRY OF SUPPLY

AERONAUTICAL RESEARCH COUNCIL
REPORTS AND MEMORANDA

Towing Tank Tests on a Large Six-engine Flying Boat Seaplane, to Specification 10/46 Princess

PART I

General Porpoising Stability, Trim and Spray Clearance

By

A. G. SMITH, B.Sc., D.I.C.,
G. L. FLETCHER, D.L.C.,
T. B. OWEN, B.A.,
D. F. WRIGHT

LONDON: HER MAJESTY'S STATIONERY OFFICE
1953

EIGHT SHILLINGS NET

Towing Tank Tests on a Large Six-engine Flying Boat Seaplane, to Specification 10/46 Princess

PART I[*]

General Porpoising Stability, Trim and Spray Clearance

By

A. G. Smith, B.Sc., D.I.C.,
G. L. Fletcher, D.L.C.
T. B. Owen, B.A.,
D. F. Wright

Communicated by the Principle Director of Scientific Research (Air),
Ministry of Supply

Reports and Memoranda No. 2641[†]
January, 1948

Summary.—This report gives the results of the first series of towing tank tests made at the Royal Aircraft Establishment Towing Tank (up to May 1947) on a powered dynamic model of a six-engine transport flying boat, later named the *Princess* class, and designed to specification 10/46, on the basis of which full-scale hull construction was started; later tests have been made to further improve the hull step and afterbody and test the effect of modifications to the aerodynamic superstructure and power units.

By contemporary flying boat standards the final form evolved in these tests is hydrodynamically good up to a take-off weight of 310,000 lb and probably satisfactory up to an overload weight of 340,000 lb. It is good in landing at the proposed weight of 240,000 lb, and satisfactory up to 280,000 lb, the highest weight tested.

The porpoising stability is generally good at high speeds in take-off and landing in calm water and across waves up to about 150 ft in length. Above 310,000 lb the stability deteriorates in the mid-planing speed range with increase of weight because of afterbody interference, such that porpoising is likely to persist in this range if take-offs and landings are necessary across waves of the order of 150 ft length or more. In take-off such porpoising will damp out before take-off speed is reached, without the aircraft being thrown off the water to any excessive height. There should be no difficulty using the ' parallel to waves ' technique in cross-winds up to the order of 25 knots, when any danger of instability can be avoided.

There is considerable broken spray impact on propellers, tailplane leading edge and flaps above 310,000 lb. Damage to the propellers is considered likely to be small in calm and choppy water up to 340,000 lb but continuous taxying with middle propellers at full speed should be avoided between 20 and 30 knots, especially across long waves. The flap in retracted positions and tailplane have been adequately stengthened against the contemplated water loads up to 340,000 lb, this solution being considered to be more economic on large seaplanes than undue raising of the wing or tail surfaces. The use of flap below 60 knots in take-off over 310,000 lb is not recommended in rough water conditions. There is little change of trim from water to airborne conditions, except for ground effect.

Improvement of the overload conditions was obtained as a result of a later major redesign of the aerodynamic superstructure to suit larger power units. Model technique improvements to obtain increased wing lift and damping more comparable with full-scale also showed the present model results to be pessimistic. These results and tests, also made to improve the hull step and detailed hull afterbody design are to be published as Part II of this report.

---

[*] Part II, R. & M. 2834.

[†] R.A.E. Report Aero. 2240, received 8th May, 1948.

1. *Introduction.*—Tank tests were required on a dynamic powered model of a large six-engine flying boat for the further development of satisfactory porpoising stability, trim and spray clearance characteristics. The dynamic model tests described in this report are those made between May 1946 and May 1947 in the Royal Aircraft Establishment Towing Tank on the basis of which full-scale construction was started on the hull. Later the aircraft superstructure was partially redesigned for bigger power units to give improved performance at greater all-up weight and also lower hull air drag. Tests on the revised layout will be published as Part II of this report—(R. & M. 2834).

1.1. *Description of Seaplane.*—The 10/46 specification is for a civil transport flying boat suitable for operation on long range routes in sub-arctic, temperate and tropical climates. The passenger accommodation will vary with the length of stage but the minimum accommodation will be for 70 sleeping passengers and the boat must be capable of conversion for carrying over a 100 day passengers. The passenger accommodation and the flight deck are to be pressurised, the hull being designed for a working differential pressure of $8\frac{1}{2}$ lb/sq in. The operating height will vary up to 39,000 ft.

The Saunders-Roe S.R.45 *Princess*, designed to the 10/46 specification is a high-wing flying boat with single fin and rudder. It is to be powered by six gas-turbine units driving propellers of which the outer on each wing will be of reversible-pitch type for manœuvring on the water.

Accommodation is arranged in two decks, and the hull form is of a figure-of-eight section for ease of pressurisation. The lateral stabilising floats are fully retractable. A three-view general arrangement is given in Fig. 1 and leading particulars in Table 1.

1.2. *Description of Hull Lines.*—Various hull lines had been provisionally tested and modified in earlier R.A.E. tank tests on unscreened resistance hulls, using a generalised method of testing at planing speeds in terms of draft and attitude[1]. Using these generalised methods it has been found possible to gain considerable information on hull efficiency, particularly on the vital problem of hull afterbody interference. The case for such preliminary tests on this hull was further strengthened by the necessity of providing the firm with some tested hull lines as quickly as possible and also because a limiting design factor was likely to be the drag maximum at low speeds.

The lines developed in the preliminary tests (Fig. 2) were the result of the firm's compromise between the best hydrodynamic lines and structural and aerodynamic requirements, based on the original design weight of 280,000 lb. The lines were a logical development of British flying boat practice, but with a modified form of step designed for low air drag and good porpoising stability at high water speeds. The original forebody was lengthened to four times the beam for low speed and performance, as much as the firm thought desirable considering the associated aerodynamic directional stability and hull structure weight. The step was faired in plan form and elevation but with the latter kept very conservative to ensure high-speed water stability. The afterbody was kept fairly strong to keep down the hump attitude and resistance, although, according to the resistance model tests, at some cost in increased afterbody interference.

1.3. *Purpose of Tests.*—The purpose of the dynamic model tests was to test the seaworthiness in the presence of slipstream and waves. The spray clearance requirements were different from those of past tests in that experience had shown that it is almost impossible to avoid some spray impact on propellers, wing trailing edge and tailplane in the presence of high slipstream velocities and rough water, but so long as the spray was broken up and did not consist of green water, little or no damage occurred. It was, therefore, decided to design as far as possible for freedom from green-water spray in both calm water and waves and strengthen up the structure to take spray rather than to go to prohibitive lengths to raise the wing and tail units out of the way. Experience had also shown that it was more important to obtain very good porpoising stability near the take-off and landing speeds particularly under disturbance (wave conditions) than at lower speeds. Porpoising at mid-planing speeds could be uncomfortable and cause local damage, but porpoising near take-off and landing speeds could be dangerous. Therefore, tests were extended from the steady speed runs in calm water to include steady and accelerated runs in waves up to take-off speed, so that the effect of disturbance could be correlated more exactly with possible operational conditions.

2. *Methods of Tests.*—All tests were made in the R.A.E. Towing Tank on a powered dynamic model of 1/28-th scale. The model was towed from the wing tips, free to pitch about the centre of gravity and rise vertically with respect to the water surface, as described in R. & M. 2620[2].

2.1. *Steady Speed on Calm Water.*—Porpoising stability, trim and spray measurements were made over a range of weights and flap positions with and without slipstream to represent take-off and landing conditions respectively. In the first instance the standard form of tests was followed, stability and trim diagrams being obtained from a series of steady speed runs in calm water with constant elevator angles. The stability was observed with and without the effect of an artificially applied nose-down disturbance, and the amplitude of the latter required to start any instability noted. During these tests, observations were made in rather more detail than usual of the impact of the spray on the propellers, wing, tailplane, etc. and whether the impact was of broken spray or green (more solid) water and the results plotted out as spray sketches in terms of impact conditions against speed and attitude. Still photographs were also taken from forward at low speeds.

2.2. *Steady Speeds into Waves.*—Secondly the standard form of tests was repeated in waves, but without an artificially applied disturbance. The tests were made at steady speeds for a range of weights and zero flap position only, and for elevator angles restricted to those giving reasonable trim curves for operational conditions. All runs were made directly across the wave systems for zero wind conditions and high-speed ciné photographs (130 frames/sec) were taken of the behaviour in addition to the usual observations. These ciné records were projected at the standard speed of 24 frames/sec to give the full-scale time scale ($1\sqrt{28}$ times the model time scale), so that an excellent impression of the likely operational behaviour was obtainable from the pilot's viewpoint and time was available to see what was happening in terms of stability, afterbody interference and spray impact. The waves generated represented swells of length to height ratios of 50 : 1 and 30 : 1 and a wave height of 3 ft full scale. These were chosen as arbitrary standards, pending a fuller investigation and were dictated more by the limitations of the tank apparatus than the most severe cases to be considered full scale. It is known that the most severe conditions correspond to cross wave take-offs or landings, but the response of the seaplane in trim will depend on the frequency of wave impacts (speed) and the amplitude (height), there probably being critical values for a given seaplane. Large wave impacts are not likely to be encountered full-scale if the latest recommendations are observed for 'parallel to the wave-crests' take-offs and landings in all but excessive cross-winds.

2.3. *Accelerated Speeds into Waves.*—Finally the behaviour was examined under combined acceleration and wave-impact conditions. The dynamic model was accelerated up to take-off speed, allowed to fly off, and high-speed ciné records taken. No flaps were used and the elevators were fixed at angles giving approximately zero change of trim between water and airborne conditions for the take-off case. The acceleration was that of the carriage, the mean value being $0 \cdot 14g$, which is double the correct value at medium speeds for overload take-offs. Analysis of the results was made by direct observation and from the ciné films.

3. *Model, Wing Lift and Propeller Thrust Characteristics.*—3.1. *Model Design.*—The limiting factor in the choice of model scale was the span. In the R.A.E. tank the largest that can be accommodated is $7 \cdot 5$ ft, which corresponded to a 1/28-th scale model. The take-off speed at this scale was within the limiting carriage speed of 40 f.p.s. but the scale weight (density) of the model was much lower than had hitherto been experienced, being only 10 lb complete with power units

for the original estimated landing weight of 220,000 lb. In the past, the use of relieving loads by a pulley system to relieve excess weight has been employed, but results are open to doubt since the ratio of the masses moving vertically to the moment of inertia is altered. Therefore, the scale weight was attained by cutting down on all model wall thicknesses and the result probably represents the limit to which weight reduction is possible for adequate strength. The hull was made of a 3/16-th in. thick balsa shell, the wing leading and trailing edge spars hollowed out, the ribs lightened, and the balsa skin made thinner than usual. The model propellers were made of balsa with nylon reinforced leading edges. They were designed for simplicity as six-bladed single-rotating instead of reproducing the contra-rotating 15-ft diameter propellers then proposed full-scale. Each was driven directly by a three-stage axial-flow compressed-air turbine of a new type[2] designed for this model.

3.2. *Wing Section and Lift Measurements.*—From consideration of wind-tunnel tests on aerofoil sections at low Reynolds numbers and low turbulence it was considered that a NACA 6418 section (root chord) on the model would give a lift curve closest to the estimated full-scale characteristics. The trailing edge was maintained at the correct height to give the appropriate spray clearance, but the setting to the hull datum was changed from $+4\cdot5$ to $+2$ deg to take into account the difference in no-lift angle.

Lift measurements were made on the complete model with the main step well clear (order of 7 in.) of the water surface where ground effect is nil.

The results without slipstream, propellers windmilling, Fig. 4, showed that not only were the expected lift values far from being obtained but also that they were considerably less than those obtained on the actual full-scale section in tests in the R.A.E. tunnel, although the latter discrepancy was in part due to the combined effects of increased Reynolds number and turbulence delaying the breakaway on the wing upper surface. Full-scale, it is expected that the maximum slope would extend to much higher attitudes. With slipstream there was considerable recovery of lift and for $T_c = 0\cdot5$, the tank results on the complete model were in fair agreement with the wind-tunnel results (Figs. 5, 6). It is possible that these results are more comparable with full-scale, but the present method[3] for estimating full-scale increased lift due to slipstream is of very doubtful validity for the high T_c and attitude values required on this aircraft at low speeds.

It follows that in all the test results which are described later in this report, the possible effect of considerably increased air lift must be kept in mind, although the order of the increase is unknown.

3.3. *Thrust Measurements.*—Measurements of thrust showed that the model propellers would give approximately the design propulsive thrust required for the original design, but not those anticipated as a result of a later design change in the type of power unit to be used and the propeller diameter. The scaled model thrusts were then considerably below those anticipated full scale, although the maximum power input available was fed into the model turbines. The thrust and T_c relationships obtained are shown in Fig. 7. These values are high by past standards.

4. *Porpoising Stability and Trim (calm water, steady speeds).*—4.1. *Original Lines.*—Table 1 gives the leading dimensions of the boat and Fig. 2 the hull lines for the original form. Two take-off weights were investigated, 280,000 lb which at the time of testing was the anticipated normal all-up-weight, and 310,000 lb, representing an overload figure which might be reached during the development life of the boat. The tests were made without flaps. Results for the porpoising stability and trim are given in Fig. 8. At 280,000 lb the stability was good but at 310,000 lb the porpoising stability deteriorated and from 60 knots to 80 knots there was a band of instability extending over all attitudes. The porpoising was of a mild type although of fairly large amplitude such as has been encountered just above the hump speed on models of some contemporary designs. A disturbance of the order of 7 deg nose down was required to start

instability near the limits but only 3 to 4 deg in the middle of the unstable range. In the similar but stable region at 280,000 lb there was very light damping. Above 80 knots there was still an ample margin of stability.

For the landing cases three weights were considered, 220,000 lb which at the time was the design landing weight with half fuel expended, and also 250,000 lb and 280,000 lb. Fig. 9 shows the porpoising stability and trim at 220,000 lb and 280,000 lb. In both cases there was good stability above 90 knots but the stick had to be kept about a third back as in the take-off case to avoid trimming below the lower stability limit. At 220,000 lb stability was good throughout the landing run, no evidence being found of the upper stability limit even with elevator angle 30 deg up.

At 250,000 lb (not illustrated) there was a narrow band of stability (about 1 deg wide) between 78 and 65 knots following the free-to-trim curve. At 280,000 lb there was an unstable band covering all attitudes between 90 and 70 knots similar to that found in the overload take-off.

4.2. *Modifications*.—Some modifications were next tried to reduce the deterioriation of stability just above the hump speed with increase of weight, and to raise the free-to-trim attitude with respect to the lower limit without interfering with the lower deck pressurisation. A complete list of modifications with a brief outline of their effect is given in Table 2. The more important ones concerning stability and trim are discussed below.

Modification A.—The point of the step was moved forward by changing its planform to a circular arc. The stability so far as investigated appeared to be considerably improved. There was also no effect on the hump trim, and the high-speed trim was considerably lowered. This was attributed to the circular step planform being a more efficient lifting surface than the original elliptical planform.

Modification C.—The modified step was moved forward but this made little difference to the high-speed free-to-trim and lower limit attitudes. There was a small reduction of hump angle and some further improvement in mid-planing stability. It was still necessary on the model to hold the stick nearly one third back in take-off and landing to avoid lower limit instability, but further movement of the step position was considered inadvisable.

Modification N.—The wing and tailplane were raised to provide greater spray clearance at the increased design weights and the propellers were moved forward to accommodate new engines, Figs. 1, 3. Step design was as in modification C and bow line and deadrise distribution as in original condition. The estimated normal all-up weight of the boat was increased to 320,000 lb and it was decided to do tank tests up to 340,000 lb. The results are given in Figs. 10, 11, 12.

The basic stability characteristics were unaltered but the unstable band on the original form at 310,000 lb was considerably reduced in extent, leaving a 1 deg stable region between 65 and 72 knots. Most of the gain was due to the step modifications. Increasing the weight to 340,000 lb caused this instability band to spread once more completely over the attitude range from 65 to 80 knots.

Modification S.—The step fairing was removed but this made no difference to the stability or trim.

Modification T.—The step fairing was replaced, and the afterbody chines just aft of the step given a small radius to give slightly better air entry conditions to the afterbody. The propellers were also moved aft. The aircraft was then in the final form agreed with the firm at that time, Figs. 1, 3, and tests were made with the then estimated maximum take-off weight of 320,000 lb with a take-off flap setting of 20 deg, and at a landing weight of 240,000 lb with a flap setting of 45 deg.

The effect of the flaps on stability, Fig. 12, proved to be negligible, but the elevator-up angle required to trim was slightly increased.

5. *Spray Clearance* (*calm water*).—The results of the spray clearance tests in calm water are sketched in Figs. 13 to 17 and photographs are given in Figs. 18 to 21.

5.1. *Displacement Region* (*low speeds*).—Tests in calm water on the original lines showed that slight propeller interference occurred from 20 to 30 knots during take-off at 280,000 lb and this was correspondingly worse at higher weights. Several modifications, listed in Table 2, were made, and it became evident that the severity of main spray* could be lessened only at the expense of high forward spray* and that the original lines probably represented the best compromise for the given forebody strength (buoyancy and leverage about the c.g.). When the all-up weight of the aircraft was increased the wing was raised 2 ft full-scale to increase the water clearance. Conditions at 310,000 lb, Fig. 14, were then found to be substantially the same as they were previously at 280,000 lb (Fig. 13).

The basis for the series of modifications made to improve buoyancy was to reduce the effect of the main spray by decreasing the deadrise angle forward of station 10, *i.e.*, where the chines start to rise and the main spray originates at low speeds, and increase the chine turn down in the same region to keep down the forward spray. Any modification which reduced the buoyancy had a bad effect on the main spray—a harder chine impact resulting where the chine was rising. Too much turn down was bad because it tended to disperse forward spray and increase main spray. In waves (section 6) hard impacts were obtained right forward (*i.e.*, forward of station 6) and in this region any hard turn down was bad.

Some tests were made with a bow hydrofoil (16 × 2·9 ft full-scale) to give added lift forward, Fig. 19. The additional lift gained was sufficient to clear the propellers from main spray at all speeds in calm water despite separation of water flow from the top surface because of too high a hydrofoil incidence. Tests with the hydrofoil in waves were however somewhat disappointing, the lift being insufficient at low speeds to prevent the pitching into waves and the subsequent throwing of water through the propellers.

Vertical chine strips, 0·03 beam deep, were tried to break down the pressure gradient at the chines and so spoil the main forward spray. At low speeds the propellers were then clear except for a fine mist, Fig. 19, but at higher speeds the wing trailing edge near the root was badly pounded by heavy spray reflected from the water surface.

A combination of spray strips and front hydrofoil gave pactically no spray interference up to 30 knots, Fig. 19.

Photographs of the modification N tests for take-off at 310,000 lb and 340,000 lb are given in Fig. 20, and the effect of taxying with different engines cut shown in Fig. 21. Spray interference was mostly in the middle propellers* but was reduced the most by throttling the inners. Throttling the middles only was also useful in reducing interference and eliminating possible damage.

5.2. *Hump and Planing Regions*.—The hump region is here defined as the speed range of approximately 30 to 60 knots, and the planing region 60 knots to flying speed.

Comparative spray clearances in calm water are sketched in Figs. 13, 14 for take-off without flaps and Figs. 16, 17 for landing without flaps, showing the improvement between the original and final forms.

Generally speaking, for the same spray clearance, the maximum all-up weight was increased by the order of 30,000 lb. In the design take-off condition, 320,000 lb with flaps 20 deg, Fig. 15, there was main spray impact on the deflected flaps between 40 and 50 knots. The tailplane was hit by loose spray detached from the main spray by the slipstream from 40 to 60 knots, stick central, and by the main spray up to 70 knots if the stick was held back.

During take-off at 340,000 lb with flaps 0 deg, Fig. 15, the wing trailing edge was hit by light spray only but the tailplane was likely to be hit by main spray stick back from 50 to 80 knots.

In the landing condition, 240,000 lb with 45 deg flaps, Fig. 16, the only spray interference was due to forward spray hitting the flaps.

---

* See definitions.

6. *Tests across Waves.*—6.1. *Steady Speed Tests.*—Steady speed tests were made on Modification T, the final form of this report, at 300,000 lb, 320,000 lb, and 340,000 lb in the take-off condition without flaps. The waves used were 3-ft high full-scale and of length/height ratios 50 and 30 : 1 at 300,000 lb and 30 : 1 at 320,000 lb and 340,000 lb. The steady speed tests across waves without wind represent the severest conditions to be expected since time is allowed for any instability and pitching to develop and the load on water is a maximum.

Comparative tests were made on *Seaford* and *Sunderland* dynamic models in the same full-scale waves 3-ft high and also in waves scaled down from the 10/46 according to the maximum beams of the hulls. The *Seaford* was tested at 75,000 lb, its operating all-up weight. The *Sunderland* was tested at 52,000 lb a typical operating weight, and also 60,500 lb which is equivalent to the 10/46 at 300,000 lb on a beam loading basis.

6.1.1. *Spray and Stability.*—Preliminary tests had shown that it was necessary to carry a hard chine right forward to the bow to prevent bow spray being flung up vertically over the bow and back onto the windscreen and inner propellers when the boat pitched to waves.

Results for Modification T are tabulated in Tables 3 to 6.

A large deterioriation of stability and spray clearance was found compared with the calm water case, which was rather surprising in view of what is known of the performance full-scale of contemporary flying boats. However the comparative tests on the *Seaford* and *Sunderland* confirmed this deterioriation and in fact showed this deterioriation to be considerably worse for these boats under some conditions.

The disturbances in pitch caused by the waves were such that the stability limits closely resembled those found in the calm water tests with the nose-down disturbance technique. The boat did not however leave the water. It might require a series of disturbances in the unstable with disturbance region before porpoising persisted on its own accord, and the time required was considerably less for the 50 : 1 than the 30 : 1 length/height ratio waves. No instability was found at high speeds with these waves.

Similar tests on the *Sunderland* implied that the boat was unstable taking off across waves for all conditions above the hump speed, and on the *Seaford* that the boat was unstable in the mid-planing region and at high attitudes up to take-off speeds. In both these cases the boat was thrown off the water model scale below the flying speed, *i.e.*, the resulting instability was more severe than on the 10/46.

At displacement speeds the boat pitched to the waves below 35 knots, with the result that main spray was thrown periodically into all the propellers and over the wing. This spray was very broken up compared with the calm water case. The middle propellers were worst affected. These conditions were however not so bad as in the comparative *Sunderland* and *Seaford* across scaled-down waves.

The main and forward spray impact on the wing trailing edge and tailplane leading edge was also worse in the respective speed ranges of 30 to 50 knots and 30 to 90 knots, any pitching or wave impacts throwing up higher forward and main spray and also lowering the tailplane into that spray. As in the low speed case, however, this spray, although very heavy at times was broken up and spasmodic. The corresponding conditions on the *Sunderland* and *Seaford* were similar, and worse at higher speeds because of the greater instability.

6.2. *Accelerated Speed Tests.*—Accelerated runs were made with the same two wave conditions as the steady runs at weights of 300,000 lb, 320,000 lb and 340,000 lb.

The forced instability and spray interference were much less severe than in the steady speed tests, mainly because of the limited time under any one disadvantageous condition. There was only time for one or two oscillations at low speeds and in the calm water mid planing unstable band disturbance porpoising instability only persisted if a sufficiently nose-down disturbance happened to occur when the boat was still in that region. With long waves this happened frequently, but in the shorter waves not more than half as frequently. In all cases any instability damped out completely in take-off before the boat reached flying speed, and the boat was not flung off the water. Tail and wing spray interference was correspondingly reduced.

7. *Interpretation Model to Full-Scale Operating Conditions.*—7.1. *Porpoising Stability.*—The porpoising stability is generally better than found in contemporary seaplanes. The deterioriation of stability with increase of weight above 310,000 lb to nil at 340,000 lb in the 60 to 80 knots speed range is probably the effect of a too powerful afterbody at increased draft as indicated by the earlier generalised force tests. It is, however, only likely to be found full-scale if take-offs have to be made across swells of length of the order of 150 ft and then only occasionally. The margin between stability and instability is not so pronounced as appears from the figures, since even when stable the damping was very light and pitching will in any case occur in waves. It is evident, however, from the take-off tests across waves that even a small positive stability makes the chances of violent pitching persisting much more remote, and full-scale the damping is expected to be increased because of better wing and tail aerodynamics. The pitching died out, model-scale, before take-off and should do so more quickly full-scale. Such take-off or landing conditions are only likely to be met in open water (not shallow water seadromes) when the wind is too high (say 25 knots) and blowing in such a direction that take-off or landing parallel to the crests is not possible. When the wind is much higher the waves will, however, tend to be very long in deep water, say 1,000 ft, and the water speed reduced so that the pilot should have a better chance of making a cross-wave take-off or landing, given good judgement. The superimposed very short choppy seas should have very little effect on stability.

These conclusions are based on general full-scale experience, and in particular on that of the comparative types tested, the *Sunderland* and *Seaford*[4]. Although more unstable model-scale, full-scale tests at the Marine Aircraft Experimental Establishment have shown that both boats are stable under normal sheltered water operating conditions. The similar mid-planing instability with severe disturbance found model-scale[6] on the *Seaford* was not found full-scale[5] even in steady runs, probably because the severe disturbance required to start it was not encountered. Model high attitude instability, however, was found on the *Seaford* full-scale, but only in steady runs and in some slight degree in landing in rough water. Instability in long cross-wave conditions has not yet been investigated at Marine Aircraft Experimental Establishment but some verbal reports from airline boat pilots indicate that across certain long swells these instability regions may be present. Also tests made by the U.S.A. Coastguards with a *Mariner* confirm the overwhelming advantages of take-offs and landings parallel to long swells, lateral control being good in cross-winds up to the order of 20 knots. The scaled-up wind for the 10/46 on the basis of beam would be of the order of 25 knots.

One difficulty in the model technique is that it is not possible, so far, to simulate the effect of possible attempts at control by use of the elevators. On a boat of this size, the period of the porpoising is of the order of 5 seconds, so that there is ample time for control movements, although again the lag in response might be of the order of 2 seconds. But it is conceivable that some control, especially of airborne conditions, might be possible full-scale on a boat of this size.

7.2. *Spray Clearances.*—The problem to be faced is the extent to which spray could be allowed to pass through the propeller discs and hit the wing trailing edge and tailplane. It is well known that full-scale spray does enter the propeller discs on practically all boats in service, and the general opinion is that provided the spray does not take the form of green water the damage is likely to be small. This is because of the characteristic scale effect on spray form, the spray blisters, found model-scale, being broken up into drops, full-scale, very soon after leaving the chine. This break up is particularly rapid in choppy water. However to further the knowledge of the operational damage sustained, tests have been made full-scale on the *Seaford* to study the effect of continuous running in spray in various sea conditions. Results[7] are encouraging and it is considered that on the 10/46 the risk of pitting should be less than on the *Seaford* both because of better seaworthiness and a smaller propeller tip speed. In calm water the middle propellers are worst hit but in waves all propellers are likely to be hit, and in heavy seas major damage may result if the wave impacts happen to coincide with pitching frequency.

In calm water the wing trailing edge and the tailplane clearances are reasonable, but in waves the tailplane in particular is badly hit. Parallel tests on contemporary boats, however, show the spray wetting to be of the same order and it is considered that with the strengthened wing trailing edge and tailplane leading edge designed by the firm on the basis of full-scale experience[8] on the *Sunderland*, the risk of damage is small up to 320,000 lb.

7.3. *Trim.*—The model tests showed that there was likely to be little change of trim between water and air conditions with ground effect at high speed, when trimmed to run at about 6 deg keel datum attitude, a suitable condition from both stability and resistance standpoints. The presence of flaps increased the up elevator required. The tank tests gave the elevator required as between 10 and 15 deg up (including ground and slipstream effects) whereas R.A.E. wind-tunnel tests showed that the angle is between 0 deg and 5 deg. It is possible that the difference is because of the large loss in lift on the tank model at more than about 8 deg incidence from no-lift and that the elevator angles will be satisfactory full-scale.

7.4. *Wing Lift Characteristics.*—The full-scale lift characteristics should be considerably better than on the tank model both because of reduced air flow separation and increased slipstream velocity. The load on water at the hump speed may be reduced full scale by the order of 20,000 lb, which would in effect postpone the present deterioriation in spray and stability from 310,000 lb up to 330,000 lb. A different distribution of downwash behind the wing will also affect the tailplane efficiency, recovery of top surface lift decreasing the up elevator required.

8. *Conclusions.*—The 10/46 Seaplane, *Princess*, porpoising stability and spray characteristics as tested model-scale up to the final form of this report (Modification T) are good hydrodynamically by contemporary flying boat standard up to a take-off weight of 310,000 lb and probably satisfactory up to an overload of 340,000 lb. It is good at the landing weight of 240,000 lb satisfactory up to 280,000 lb, the highest weight tested. The model results are probably somewhat pessimistic, mainly because of scale effects on wing lift.

8.1. *Porpoising Stability.*—There is good stability above 80 knots in take-off and landing in both calm water and across waves up to 150 ft in length. Above 310,000 lb in take-off and 280,000 lb in landing there is a deterioriation of stability with increase of weight between 65 and 80 knots. A severe nose-down disturbance in this region will start instability of high amplitude, which is, however, not dangerous in that the seaplane is unlikely to leave the water and porpoising will damp out after 80 knots before take-off (100 to 120 knots). Such a disturbance is only likely to be encountered in a cross-wave take-off or landing in waves at least 150 ft in length. These conditions should only be met in emergencies. Take-off or landing parallel to the crests of long waves should be straightforward hydrodynamically in cross-winds up to the order of 25 knots, provided lateral aerodynamic control is adequate.

8.2. *Spray Clearances.*—There is spray interference with the propellers during take-off with high T_c between 20 and 30 knots but comparison with contemporary full-scale seaplanes indiindicates that major damage is not likely below 340,000 lb take-off weight. This spray becomes worse in waves because of pitching response below 30 knots, it being thrown over the wing and liable to enter the air intakes but this is more broken up and not so bad as on contemporary boats.

The tailplane is hit by heavy spray at 50 knots and up to 80 knots with the stick back in calm water or stick central in 3-ft high waves at 310,000 lb, and more so at 340,000 lb, but again no major damage is expected full-scale under normal operating conditions, the leading edge being sufficiently strengthened.

The wing trailing edge is almost clear during take-off at 310,000 lb but at 340,000 lb is hit by loose spray detached from the main spray from 35 to 50 knots and at higher speeds stick back or in waves. In landing it is clear of heavy spray up to 280,000 lb. Flaps 20 deg in take-off will be hit by heavy spray at 40 to 50 knots above 310,000 lb, but only by light spray in landing at 240,000 lb with 45 deg flaps. Flaps, if not strengthened, are likely to be damaged in take-off in waves if lowered before 70 knots at weights above 310,000 lb.

Further improvement in stability characteristics and flap and tailplane clearances would be advisable for open water and emergency operation above 310,000 lb, and is obtained as a result of the modifications reported in Part II.

8.3. *Trim.*—There is little change of trim between water to airborne conditions. Model-scale, the seaplane trims rather nose heavy but some improvement is expected full scale.

8.4. *Further Design Changes and Tests.*—Major stability and trim improvements require increase of the afterbody chine heights but this is difficult without interfering with the pressurisation structure. Major spray improvement is only possible by lengthening the forebody at the expense of directional stability and structure weight.

Some reduction of the extent of instability and spray interference and also of the elevator up angle to trim is expected as a result of increase of wing lift with the redesign of the aerodynamic superstructure for larger power units. There may also be changes in damping in pitch, increase of which is desirable on this model.

Further tests will be made to investigate the effect of (1) the design changes (2) improved representation of full-scale lift and damping (3) improvement of the afterbody design.

Symbols and Definitions.

b	Maximum beam of bottom chine (ft)
Δ_0	Static load on water (lb)
$C_{\Delta 0}$	Static beam loading coefficient $\Delta_0/\omega b^3$
ω	Density of seawater (64 lb/cu ft)
ω_s	Wing loading (lb/sq ft)
η	Elevator angle
$\left\{ \begin{matrix} \alpha_k \\ \text{Hull datum} \end{matrix} \right\}$	Angle between the tangent to the keel at the main step and the undisturbed water surface
Afterkeel angle	The angle between the tangent to the forebody keel at the main step and that at the afterbody step
Heel-to-keel angle	The angle between the tangent to the forebody keel at the main step and the line joining the points of the main and rear steps
Deadrise angle at keel	The angle of the planing bottom to the horizontal measured at the keel, on a section normal to the keel datum
Main Spray	The spray which originates from the leading edge of the intersection of the chine with the disturbed water surface. (Sometimes called main blister)
Forward Spray	The spray which originates from the line intersection of the planing bottom with the disturbed water surface. (Sometimes called lateral or side spray)
Outer Propeller	The propeller furthest out from the hull on each wing
Inner Propeller	The propeller adjacent to the hull on each wing
Middle Propeller	The propeller between the inner and outer on each wing

REFERENCES

No.	*Author*	*Title, etc.*
1	A. G. Smith	An Examination of Some Problems of Large Seaplane Design and Methods of Investigation. A.R.C. 9405. January, 1946. (Unpublished.)
2	D. I. T. P. Lewellyn-Davies, W. D. Tye and D. C. Macphail	Design and Installation of Small Compressed Air Turbines for Testing Powered Dynamic Models in the R.A.E. Seaplane Tank. R. & M. 2620. April, 1947.
3	R. Smelt and H. Davies	Estimation of Increase in Lift due to Slipstream. R. & M. 1788. February, 1937.
4	A. G. Smith and H. G. White	A Review of Porpoising Instability of Seaplanes. A.R.C. 7741. February, 1944. (To be published.)
5	J. Stringer	Full Scale Water Stability Tests with Special Reference to Hull Pounding Seaford I. A.R.C. 10851. July, 1947. (Unpublished.)
6	S. Raymond and W. Reiners	Tank Tests on the Water Performance of a Four-engined Flying Boat at Overload (Seaford I). A.R.C. 9719. February, 1946. (Unpublished.)
7	J. E. Allen	Full Scale Spray Tests of a Four-Engined Flying Boat (Seaford) with special reference to Propeller Damage. A.R.C. 11,237. December, 1947. (Unpublished.)
8	A. G. Smith and J. L. Hutchinson	Strength of Leading Edge of Tailplane of Sunderland. A.R.C. 5812. January, 1943. (Unpublished.)

TABLE 1

Leading particulars of flying boat.

Hull	*Original form*	*Modification N*
Maximum beam (b)	16·5 ft	16·6 ft
Forebody length w.r.t. point of step	66·0 ft $= 4\cdot0b$	63·7 ft $= 3\cdot84b$
Afterbody „ „ „ „ „	55·0 ft $= 3\cdot34b$	57·3 ft $= 3\cdot47b$
Counter length	22·0 ft	22·0 ft
Afterkeel angle	7° 0′	7° 0′
Heel to heel angle	8° 41′	8° 20′
Forebody deadrise angle at step	25° 0′	25° 0′
Step depth unfaired (at keel)	1·63 ft $= 0\cdot10b$	1·50 ft $= 0\cdot09b$
Cove depth	0·16 ft $= 0\cdot01b$	0·16 ft $= 0\cdot01b$
Fairing	Approx. 2 : 1	Approx. 2 : 1
Hull maximum height	24·25 ft	24·25 ft
Maximum radius of upper circles	5·7 ft	5·7 ft
Maximum radius of lower circles	7·3 ft	7·3 ft

Wing	
Span	220 ft
Area (gross)	4850 sq ft
Root chord	26 ft
Tip chord	11 ft
Aspect ratio	10
Taper ratio	0·42
Section (full scale)	Low Drag
Section (model scale)	NACA 6418
T/C ratio (root chord to tip chord)	18 to 12 per cent
Dihedral from root to outboard engine	0°
Dihedral from outboard engine to tip	2° 12′
Wing setting to keel datum: Full scale	4° 30′
Wing setting to keel datum: Model scale	2° 0′

TABLE 1—*continued*

C.G. Position (Model)

Modifications A to M inclusive
57·2 ft aft of F.P.
19·0 ft above hull datum } 30 per cent of S.M.C.
Modifications N onwards
57·2 ft aft of F.P.
20·2 ft above hull datum } 30 per cent of S.M.C.

Spray Clearance Data	*Original form*	*Modification N*
Height of bottom tips of 16-ft diameter propellers above hull datum ..	12·8 ft	15·3 ft
Height of wing trailing edge above hull datum	18·5 ft	20·5 ft
Height of tailplane leading edge at root above hull datum	23·1 ft	25·6 ft
Height of tailplane leading edge at tip above hull datum		32·6 ft

Flaps

Type	Model scale	Plain split
	Full scale	Slotted
Chord	.. ..	20 per cent of root chord
Span	.. ..	54 per cent of overall span

TABLE 2

List of Modifications with effects

Modification	Nature of Modification	Effects of Modification
A	Point of step moved forward (0·106b) by making step planform circular arc. Step fairing modified to suit.	Above 60 knots trim ($\eta = 0$ deg) and lower limit lowered together up to 2 deg near flying speed. Mid-planing stability considerably improved.
B	Chine turndown removed for approx. 2b forward of step.	Forward spray worse above hump speed.
C	Step moved forward 0·25b model scale.	Little change in trim ($\eta = 0$ deg) and lower limit at high speeds. Some reduction of hump trim and improvement in mid-planing stability.
D	Heavy turndown put on chines for approx. 2b forward of step.	Chine turndown too heavy for best forward spray.
E	Chine line raised forward of station 10. Deadrise also increased by lowering keel line. Chine turndown reduced.	Main spray pick-up by propellers worse at 25 and 31 knots. Some interference of forward spray and main spray at 25 knots.
F	Keel line almost as Mod. E made to drawings supplied by firm. Deadrise altered to give lower chine forward, no turndown forward of station 4.	Main spray clearance as good as original lines but forward spray worse.
G	Chine lowered and flared out forward of station 8 to give spoon-type bow.	Heavy main spray pick-up by propellers at 25 knots. Forward spray clear, but some interference by reflection from water surface at 31 knots.

TABLE 2—*continued*

Modification	Nature of Modification	Effects of Modification
H	Lines proposed by firm. Very little turndown forward, keel as Mod. F but new deadrise distribution.	Heavy main spray pick-up by propellers at 31 knots.
I	Turndown reduced at stations 7, 8, 9 increased forward.	Main spray better, forward spray at 25 knots much worse
J	Original keel line and deadrise distribution. Chine lifted at stations 6, 7, 8 and slightly modified. Mod. D chine line aft.	Inner and middle propellers pick up main spray at 25 and 31 knots, small forward spray pick-up at 31 knots.
K	Chine weakened at station 9 starboard side only, 0·55*b* radius chine turndown running out at 7 deg for stations 10 to 12.	Comparison of port and starboard side shows all round improvement on Mod. J.
L	Starboard chine further weakened in vicinity of station 9 to be nearer to original lines.	Some improvement but forward spray tending to run back into main spray.
M	Port side as original lines starboard side as Mod. L. Aft of station 9, chines as Mod. K.	Comparison of sides shows that original lines still the best tested.
N	Original bow lines, Mod. K turndown. Wing raised 2 ft, full scale. New tailplane, dihedral 12 deg, 2·5 ft higher at root chord. Propellers moved forward and slightly downwards.	No change in basic stability characteristics, but increased operating weight of 310,000 lb reduces available stable margin. Spray conditions about the same at 310,000 lb as at 280,000 lb on original form, Spray situation deteriorates in 3-ft waves.
O	Nose hydrofoil fitted.	Propeller and wing clear at all speeds at 310,000 lb. Some improvement in waves, but slight.
P	Chine spray strip 0·03*b* deep extending from nose to step fitted starboard side only. No hydrofoil.	Propellers clear except for fine mist. Spray very broken up, hitting wing trailing edge hard above 30 knots.
Q	As Mod. P. with hydrofoil fitted.	Everything clear to 30 knots, then as Mod. P (hydrofoil clear).
R	Spray strip fitted port side also. No hydrofoil.	Propellers clear but wing trailing edge hit locally above 30 knots.
S	Forebody as firm's final offsets, step fairing removed.	No change in stability.
T	Afterbody chines rounded just aft of step, and step fairing reproduced to firm's offsets. Propellers moved back due to engine change. (Hull to Drg. No. 45 PD 133 and 134).	No change in stability.

TABLE 3

Tests Across Waves (steady speeds), Modification T

Take-off, weight = 300,000 lb Wave height 3 ft Length/Height = 50

Speed knots	Spray Clearances			Other Remarks
	Propellers	Wing	Tailplane	
12·5	Clear	Clear	Clear	Riding to waves
18·8	Clear	Clear	Clear	Riding to waves
25·1	Middles and inners catching main spray	Clear from main spray, wet by mist from propellers	Clear	Riding the waves but bow burying slightly
31·3	All propellers caught by main spray, middles worst	Main spray just catching trailing edge	Undersurface just touched by main spray	Riding partially to waves with bow ploughing through
37·6	Just clear	Main spray catching trailing edge. Forward spray clear	Broken water from main spray on both surfaces	Bow high. Attitude fairly steady. Forebody ploughing
43·8	Clear	Borderline clearance	Heavy broken main spray over both surfaces	As 37·6 knots
50·1	Clear	Forward spray just catching trailing edge	Well into main spray	
56·4	Clear	Just clear	Well into main spray	
62·6	Clear	Just clear	Well into main spray	
68·9	Clear	Just clear	Soaked by heavy spray at high attitudes	Porpoising
75·2	Clear	Clear, but trailing edge caught during porpoising	Soaked by heavy spray at high attitudes	Porpoising
87·6	Clear	Clear, but trailing edge caught during porpoising	Broken water intermittently over both surfaces	Porpoising gently
94·0	Clear	Clear	Hit lightly and intermittently by broken spray	Stable
100	Clear	Clear	Clear	Almost flying

TABLE 4

Tests Across Waves (steady speeds), Modification T

Take-off, weight = 300,000 lb Wave Height 3 ft Length/Height = 30

Speed knots	Spray Clearances			Other Remarks
	Propellers	Wing	Tailplane	
12·5	Clear	Clear	Clear	Ploughing
18·8	All propellers caught	Clear except for mist	Clear	Ploughing
25·1	All propellers caught	Broken up main spray catching trailing edge	Clear	Ploughing with forebody. Bow up
31·3	Just Clear	Main spray catching trailing edge	Clear	Ploughing with bow well up
37·6	Clear	Main spray just catching trailing edge	Intermittent main spray over both surfaces	Not so severe as 31·3 knots due to less draft
43·8	Clear	Just Clear	Intermittent heavy main spray	Attitude constant-ploughing with forebody
50·1	Clear	Just Clear	Hit by intermittent heavy main spray	Slight impact pitch (*not* porpoise)
56·4	Clear	Just Clear	Hit by intermittent heavy main spray	Medium impact pitch—not serious
62·6	Clear	Just Clear	Hit by continuous broken main spray	Gentle porpoise
68·9	Clear	Clear	Hit by heavy main spray at high attitudes	Gentle porpose
75·2	Clear	Clear	Undersurface periodically hit	Limiting stability
94·0	Clear	Clear	Flicked occasionally by drops	Stable
100	Clear	Clear	Clear	Almost flying

TABLE 5

Tests Across Waves (steady speeds), Modification T

Take-off, weight = 320,000 lb Wave Height 3 ft Length/Height = 30

Speed knots	Spray Clearances			Other Remarks
	Propellers	Wing	Tailplane	
12·5	Clear	Clear	Clear	Ploughing
18·8	Middles and inners in main spray, outers occasionally	Clear, but for fine mist	Clear	Ploughing
25·1	Middles and inners in heavy main spray, outers occasionally	Broken up main spray just catching trailing edge	Clear	Ploughing
31·3	Intermittent puffs of spray into centres and outers	Rising part of main spray catching trailing edge	Clear	Bow up. Forebody ploughing
37·6	Clear	Main spray just catching trailing edge but main body of spray further aft	Hit intermittently by broken up main spray	Same as 31·3 knots
43·8	Clear	Trailing edge just touched occasionally	Heavy main spray intermittently thrown over both surfaces	Attitude high and steady
50·1	Clear	Trailing edge just touched occasionally	Tail continuously in main spray	Slight impact pitching
56·4	Clear	Clear, but forward spray near trailing edge	Continuously in main spray	Up on step. Mid-planing
62·6	Clear	Forward spray near trailing edge	Undersurface in main spray, periodic water over top surface	Porpoising
68·9	Clear	Just clear	Main spray periodically breaking over, not so severe	Porpoising
75·2	Clear	Clear	Main spray touching undersurface only	Stable but trying to porpoise
87·6	Clear	Clear	Light main spray only	Stable
100	Clear	Clear	Almost clear	Stable
114	Clear	Clear	Clear	Almost flying

TABLE 6

Tests Across Waves (steady speeds), Modification T

Take-off, weight = 340,000 lb Wave Height 3 ft Length/Height = 30

Speed knots	Spray Clearances			Other Remarks
	Propellers	Wing	Tailplane	
12·5	Clear	Clear	Clear	Ploughing
18·8	Main spray into all propellers. Outers fairly light	Clear, but for fine mist	Clear	Ploughing
25·1	Very heavy main spray into middles and inners, outers occasionally	Drops from broken up main spray on trailing edge	Clear	Severe ploughing
31·3	Main spray into middles and some into inners	Main spray fairly solidly on to trailing edge	Clear	Severe bow up impacts

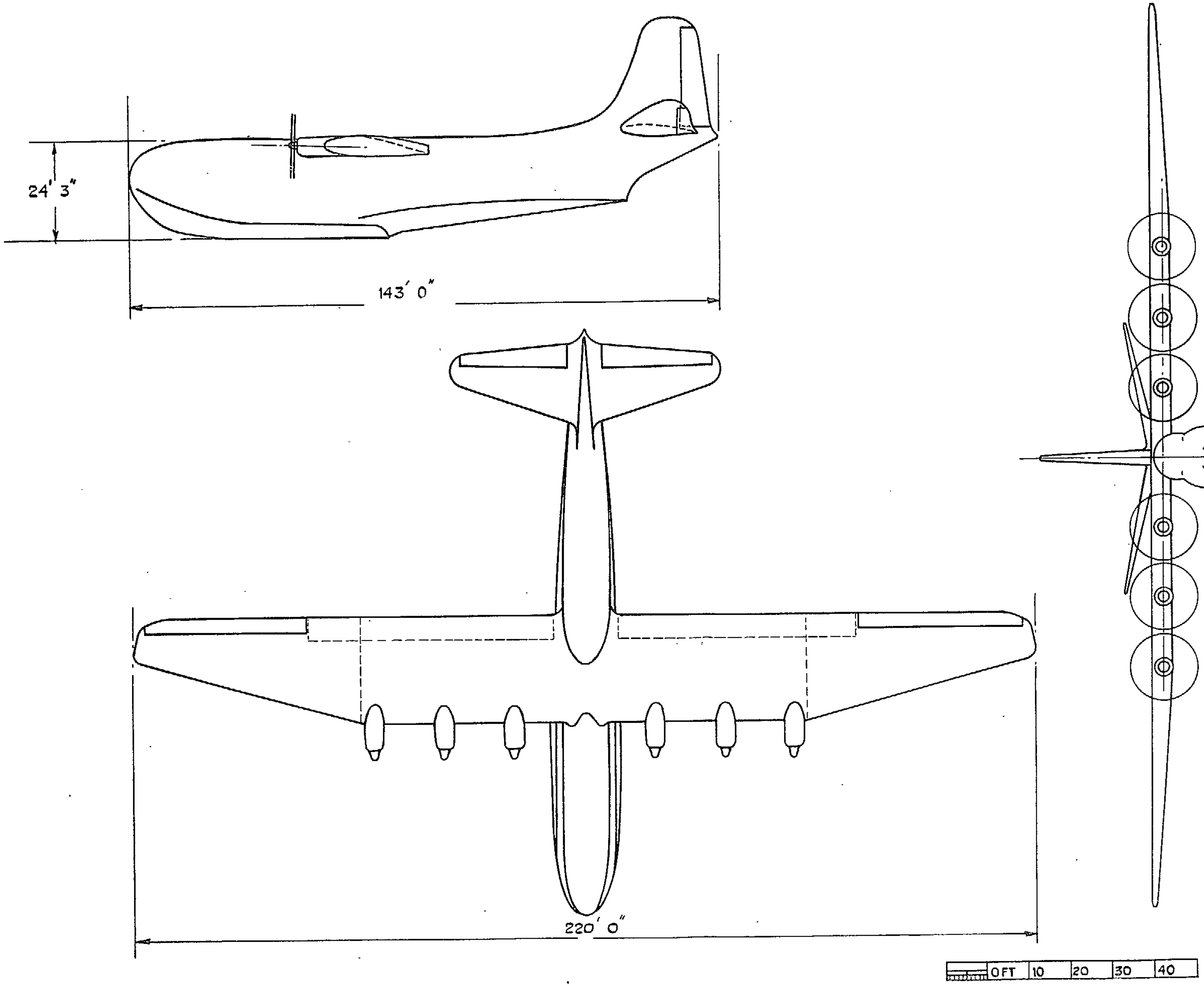
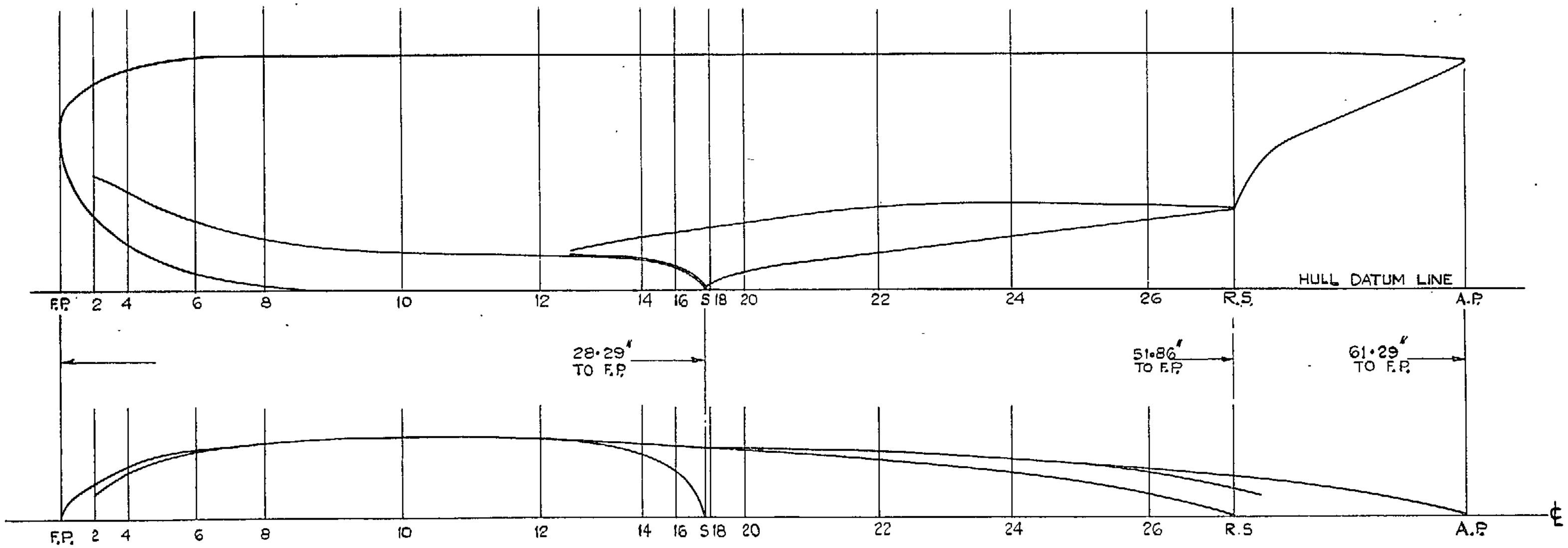
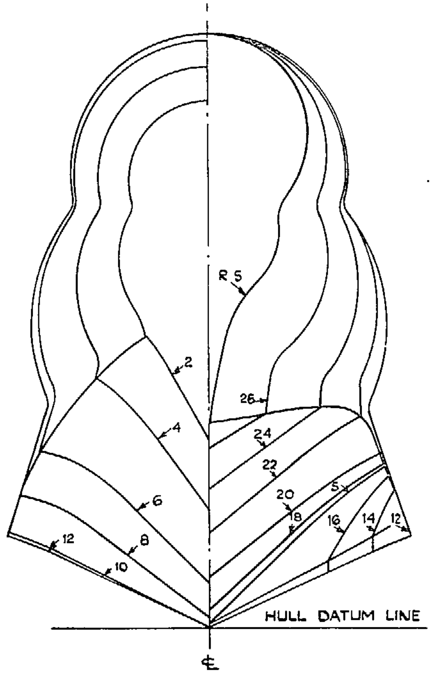


FIG. 1. General arrangement of 10/46, modification N.

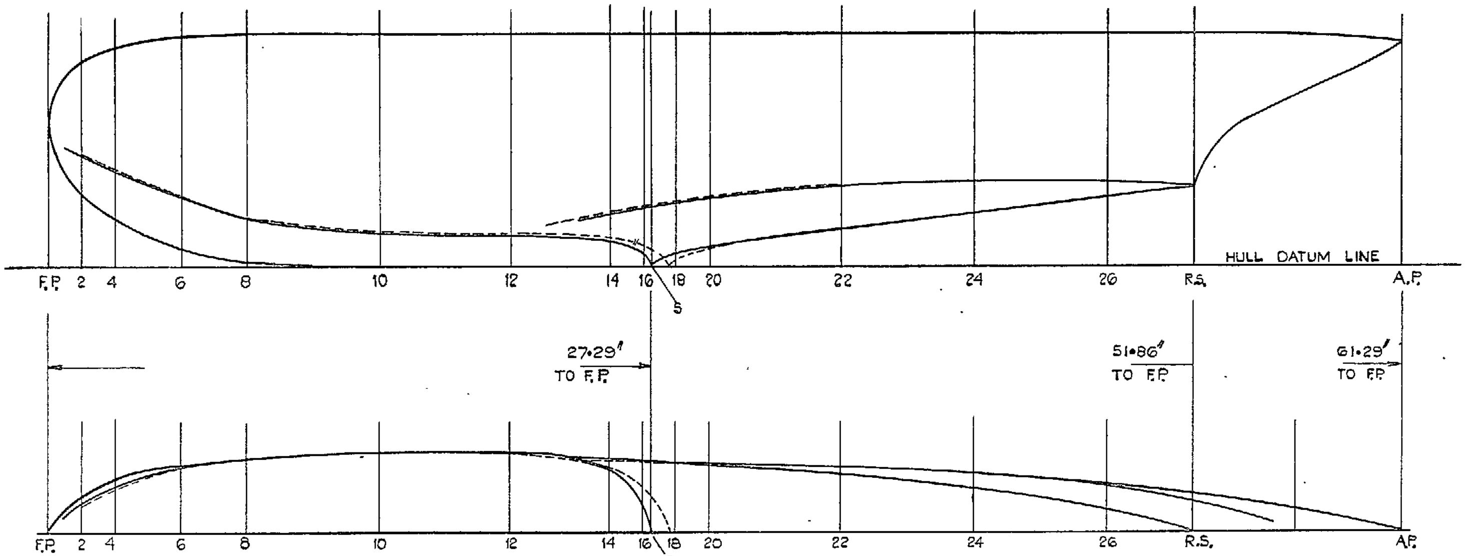


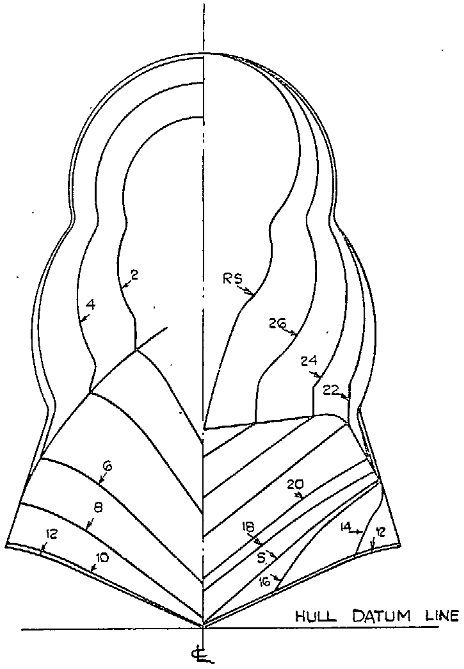


STATION NUMBER	DISTANCE FROM F.P.	KEEL HEIGHT	FORWARD CHINE HEIGHT	AFT CHINE HEIGHT	FORWARD CHINE HALF BREADTH	AFT CHINE HALF BREADTH	UPPER CIRCLES RADII	LOWER CIRCLES RADII	PROFILE HEIGHT	BOTTOM PRODUCED TO 3·54″ LINE HEIGHT	BOTTOM RADIUS	LOWER INTER-SECTION HEIGHT	COVE RADIUS	LOWER INTER-SECTION HALF BREADTH	INTER-SECTION RADIUS
F.P.	0	6·95	—	—	—	—	—	—	—	—	—	—	—	—	—
2	1·50	3·28	5·12	—	1·11	—	1·39	1·57	9·22	9·65	3·52	—	1·66	—	0·43
4	3·00	2·06	4·36	—	1·99	—	1·93	2·30	9·82	6·95	3·08	4·66	0·50	—	0·43
6	6·00	0·79	3·08	—	2·97	—	2·36	3·01	10·30	4·27	2·57	4·02	0·43	—	0·43
8	9·00	0·19	2·28	—	3·32	—	2·41	3·11	10·39	2·86	3·25	3·91	0·43	—	0·43
10	15·00	0	1·65	—	3·52	—	2·41	3·11	10·39	1·73	6·14	3·91	0·43	—	0·43
12	21·00	0	1·58	—	3·52	—	2·41	3·11	10·39	1·65	6·42	3·91	0·43	—	0·43
14	25·50	0	1·32	2·40	2·84	3·21	2·41	3·11	10·39	1·65	6·42	3·91	0·43	—	0·43
16	27·00	0	0·97	2·61	2·07	3·12	2·41	3·11	10·39	1·65	—	3·91	0·43	—	0·43
S	28·29	0 FWD 0·07 AFT	0	2·78	0	3·05	2·41	3·11	10·39	—	—	3·91	0·43	2·77	0·43
18	28·50	0·29	—	2·82	—	3·03	2·41	3·11	10·39	—	—	3·91	0·43	2·77	0·43
20	30·00	0·86	—	3·02	—	2·96	2·41	3·10	10·39	—	—	3·91	0·43	2·77	0·43
22	36·00	1·66	—	3·67	—	2·63	2·41	2·91	10·39	—	—	4·34	0·43	2·62	0·43
24	42·00	2·39	—	3·83	—	1·96	2·36	2·61	10·39	—	—	4·34	0·43	1·99	0·43
26	48·00	3·13	—	3·72	—	0·99	2·06	2·04	10·39	—	—	—	0·94	1·09	0·43
R.S.	51·86	3·60	—	3·60	—	—	1·74	1·22	10·39	—	—	—	2·12	0·39	0·78

ALL DIMENSIONS IN TABLE ARE GIVEN IN IN. MODEL SCALE

FIG. 2. 10/46 original hull lines for 1/28th scale dynamic model.





STATION NUMBER	DISTANCE FROM F.P.	KEEL HEIGHT	FWD. CHINE HEIGHT	AFT. CHINE HEIGHT	FWD. CHINE HALF BREADTH	AFT. CHINE HALF BREATH	UPPER CIRCLES RADII	LOWER CIRCLES RADII	PROFILE HEIGHT	BOTTOM PRODUCED TO 3·54 LINE HEIGHT	BOTTOM RAD.	LOWER INTER-SECTION HEIGHT	COVE RAD.	LOWER INTER-SECTION HALF BREADTH	INTER-SECTION RAD.
F.P.	0	6·95	—	—	—	—	—	—	—	—	—	—	—	—	—
2	1·50	3·28	5·02	—	1·25	—	1·39	1·57	9·22	9·65	1·52	—	1·16	—	0·43
4	3·00	2·06	4·29	—	2·07	—	1·93	2·30	9·82	6·95	2·08	4·66	0·60	—	0·43
6	6·00	0·79	3·08	—	2·97	—	2·36	3·01	10·30	4·27	2·57	4·02	0·43	—	0·43
8	9·00	0·19	2·28	—	3·32	—	2·41	3·11	10·39	2·86	3·22	3·91	0·43	—	0·43
10	15·00	0	1·56	—	3·56	—	2·41	3·11	10·39	1·73	3·65	3·91	0·43	—	0·43
12	21·00	0	1·49	—	3·58	—	2·41	3·11	10·39	1·65	3·25	3·91	0·43	—	0·43
14	25·50	0	1·27	2·38	2·74	3·28	2·41	3·11	10·39	1·65	—	3·91	0·43	—	0·43
16	27·00	0	0·60	2·63	1·28	3·20	2·41	3·11	10·39	1·65	—	3·91	0·43	—	0·43
S	27·29	0 FWD 0·07 AFT	0	2·67	0	3·16	2·41	3·11	10·39	—	—	3·91	0·43	—	0·43
18	28·50	0·67	—	2·84	—	3·08	2·41	3·11	10·39	—	—	3·91	0·43	2·77	0·43
20	30·00	0·92	—	3·04	—	2·99	2·41	3·10	10·39	—	—	3·91	0·43	2·77	0·43
22	36·00	1·66	—	3·67	—	2·63	2·41	2·91	10·39	—	—	4·34	0·43	2·62	0·43
24	42·00	2·39	—	3·83	—	1·96	2·36	2·61	10·39	—	—	4·34	0·43	1·99	0·43
26	48·00	3·13	—	3·72	—	0·99	2·06	2·04	10·39	—	—	—	0·94	1·09	0·43
R.S.	51·86	3·60	—	3·60	—	—	1·74	1·22	10·39	—	—	—	2·12	0·39	0·78

ALL DIMENSIONS IN IN. MODEL DIMENSIONS GIVEN

(ORIGINAL LINES SHOWN DOTTED)

FIG. 3. 10/46 hull lines, modifications N and T, for 1/28th scale dynamic model.

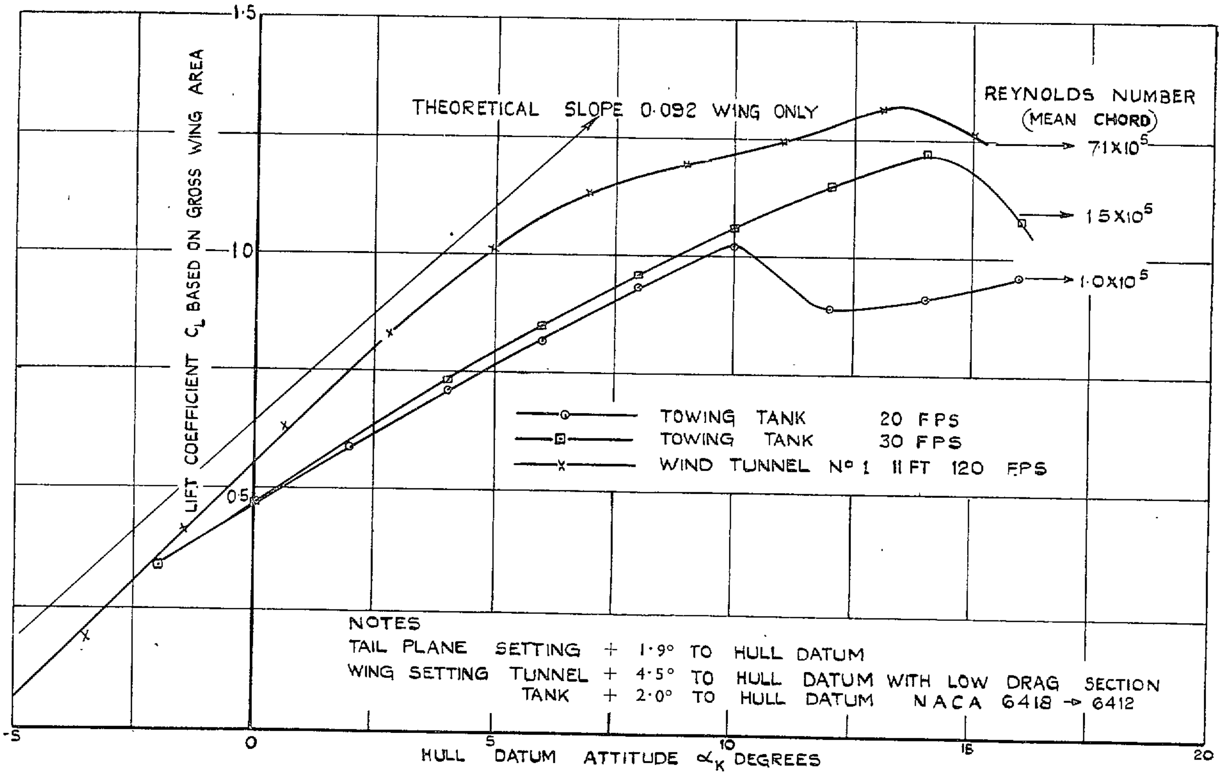


FIG. 4. Lift characteristics. Complete model modifications A to T, no flaps, no slipstream.

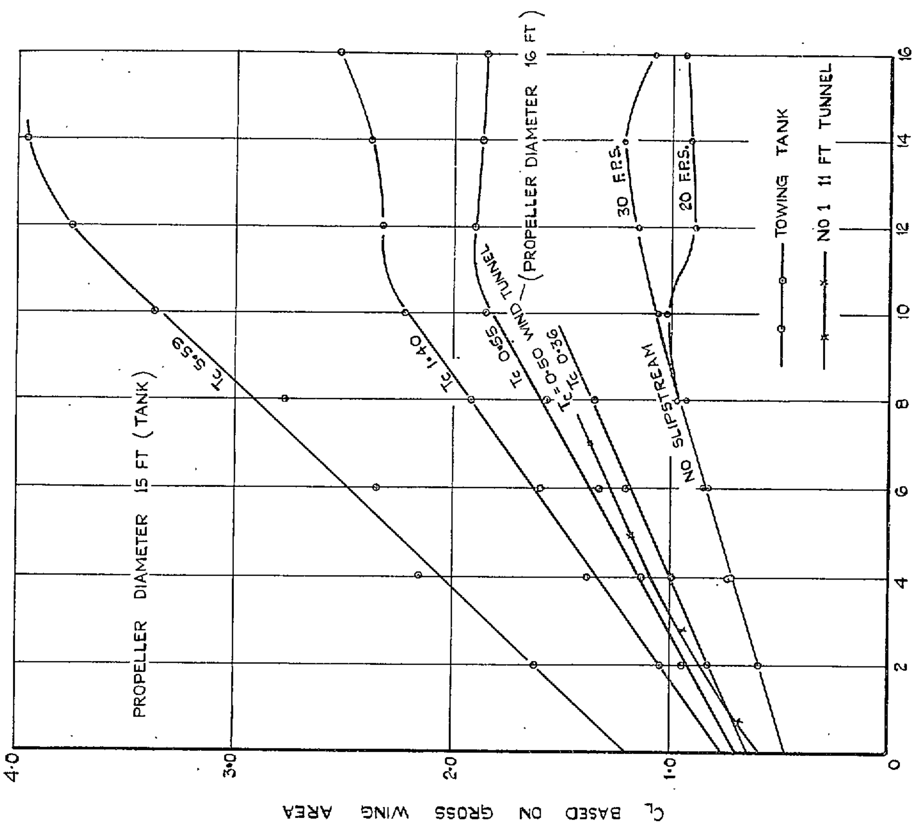


FIG. 5. Model lift characteristics.
Complete model, no flaps, with slipstream.

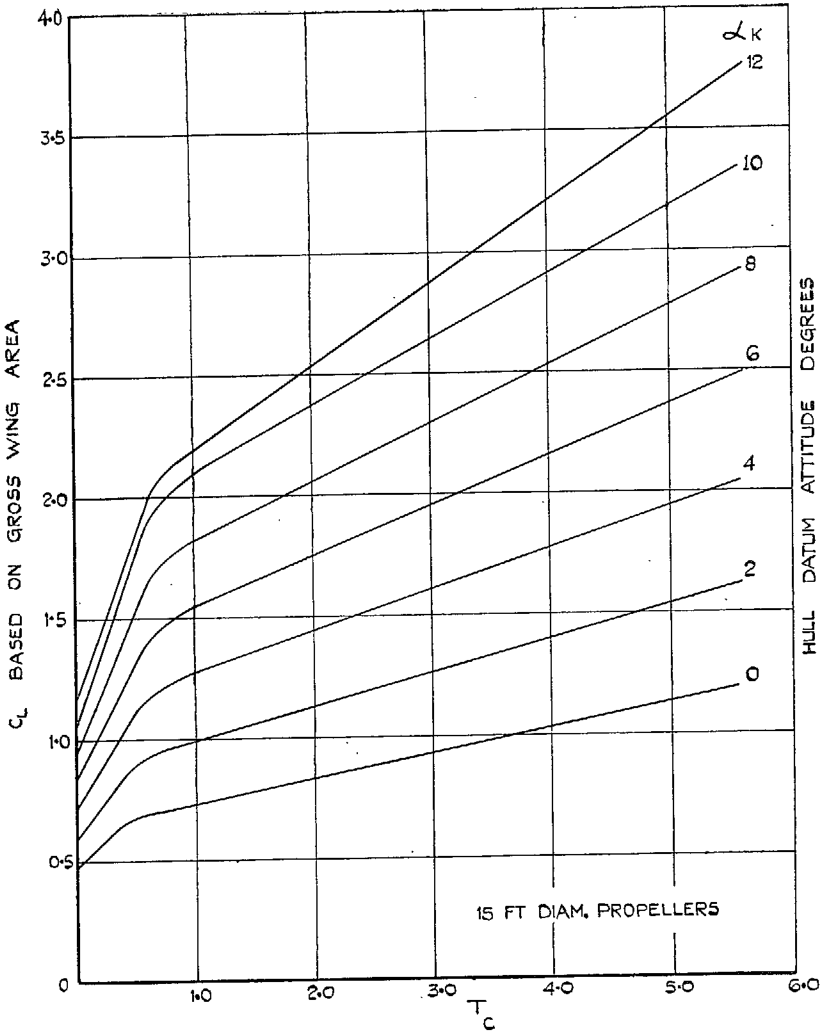


FIG. 6. Cross plot for C_L and T_c relationship.

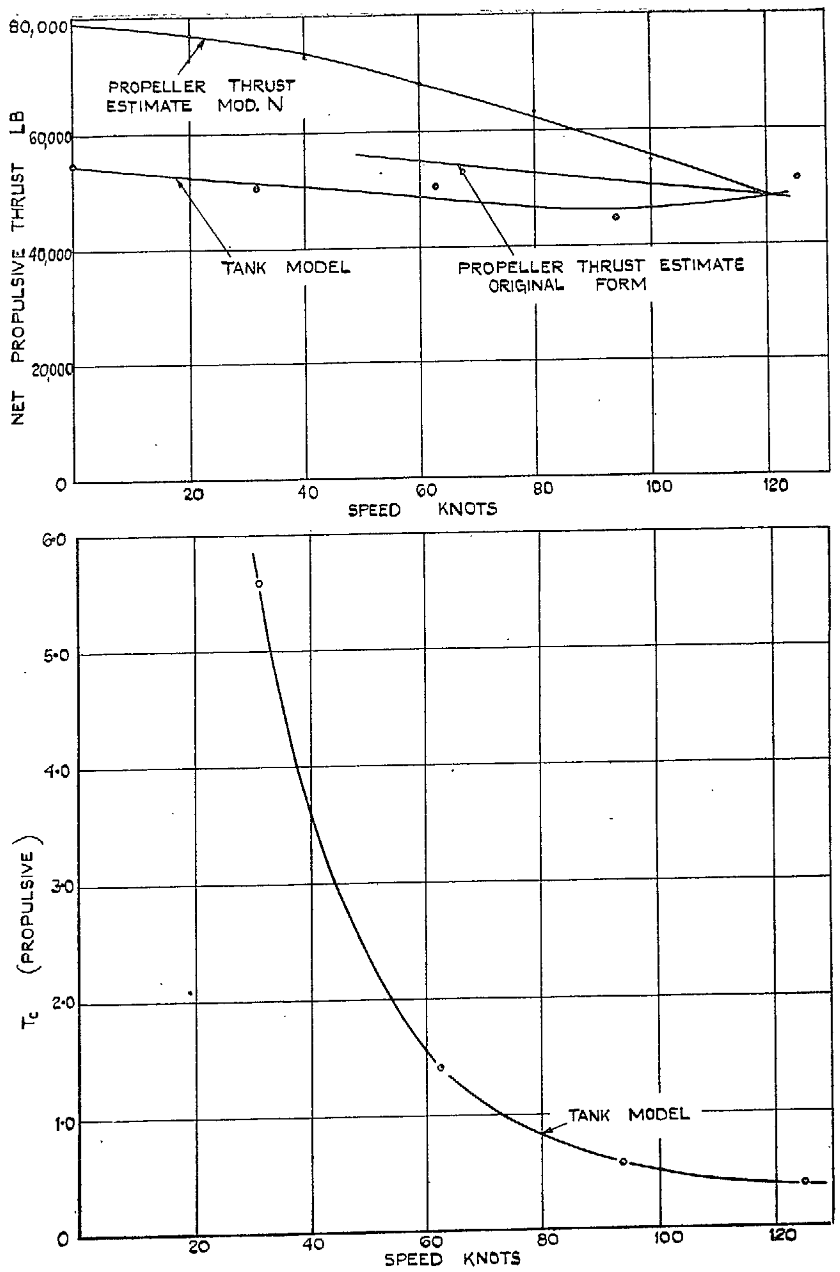
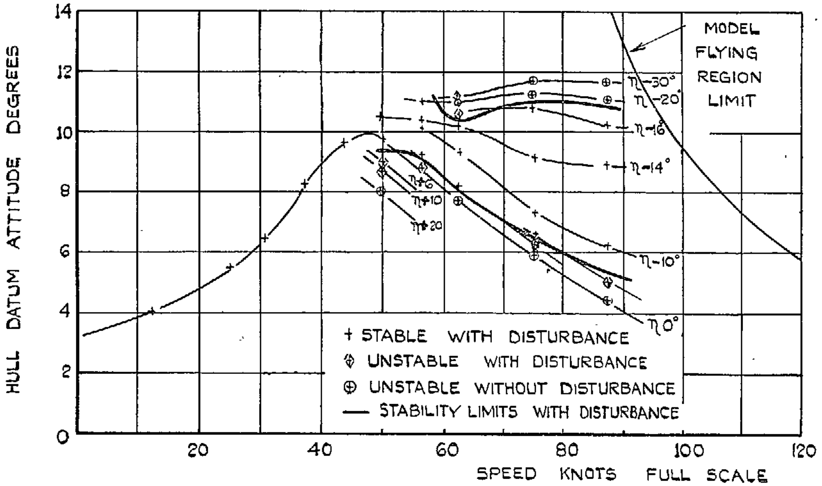
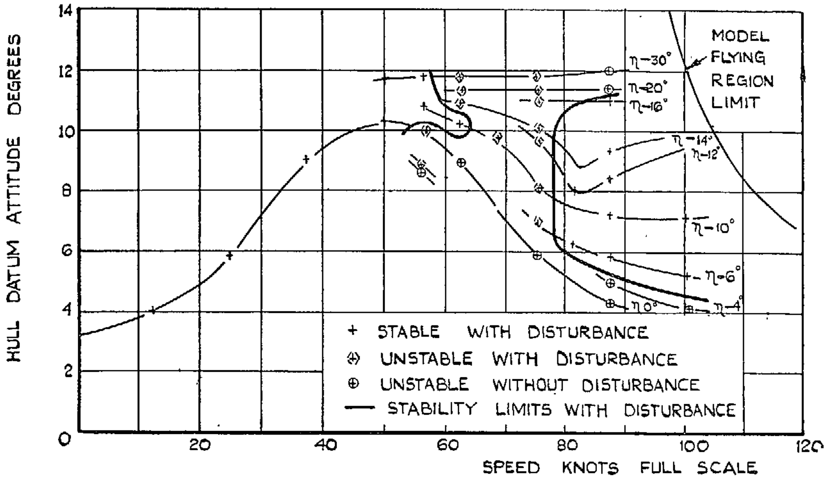


FIG. 7. Thrust and T_c-speed measured in tank on complete model propeller diameter 15 ft full scale.

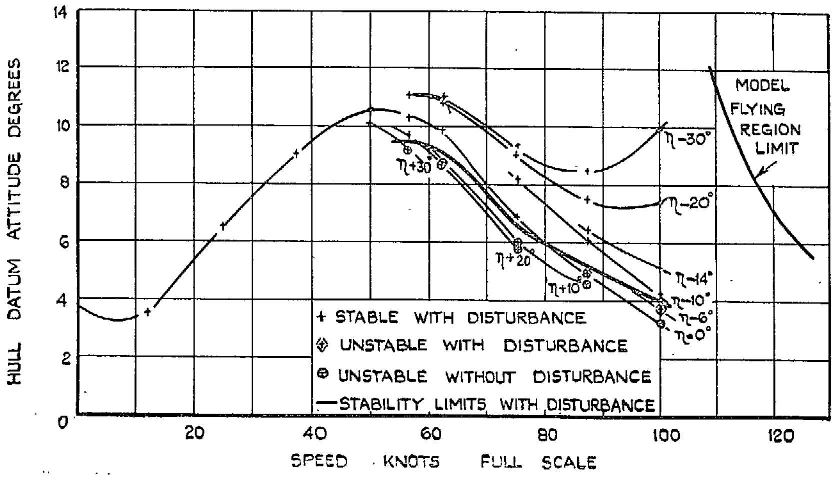


Take-off at 280,000 lb, flaps 0 deg.

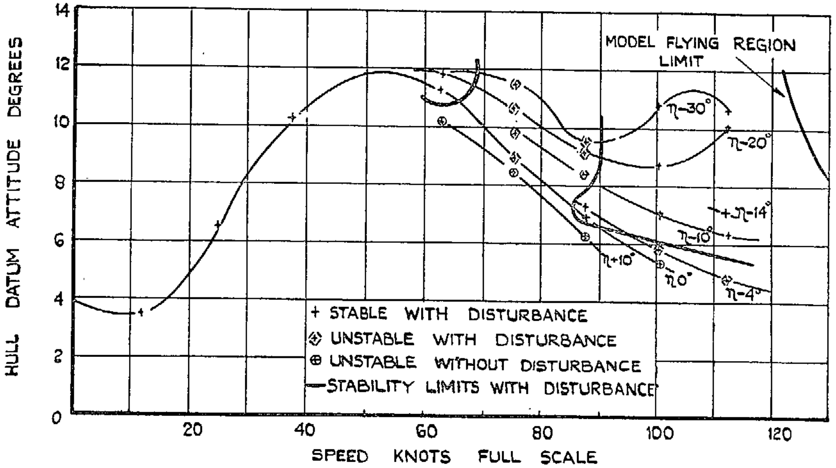


Take-off at 310,000 lb, flaps 0 deg.

FIG. 8. Stability and trim, original lines.

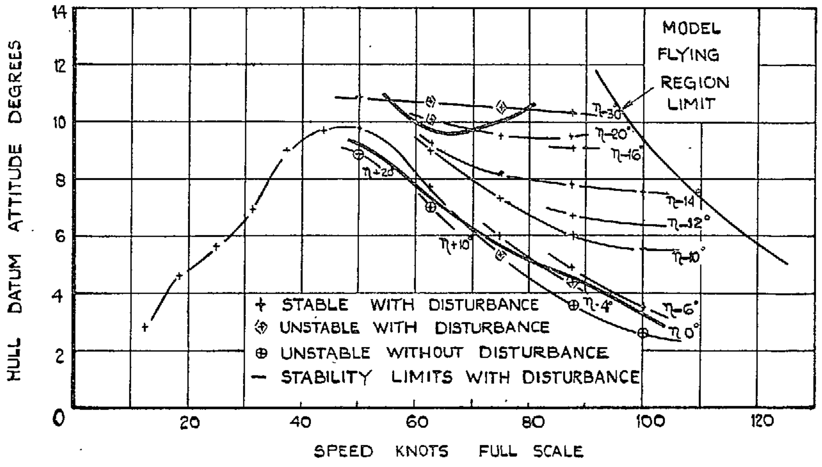


Landing at 220,000 lb, flaps 0 deg.

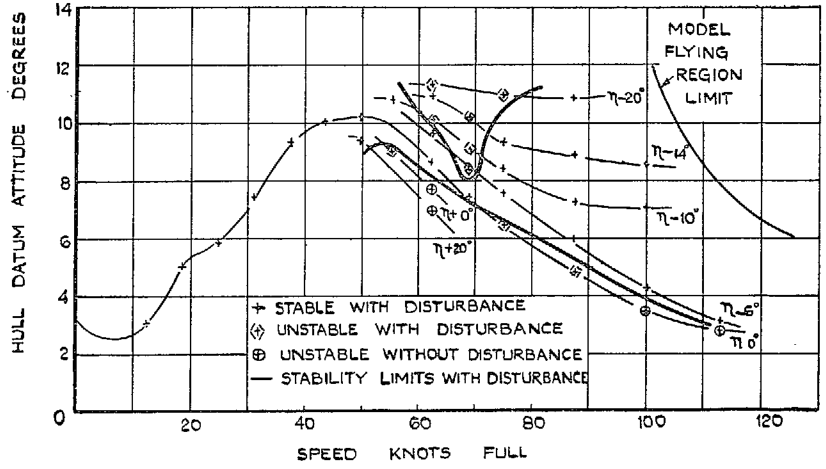


Landing at 280,000 lb, flaps 0 deg.

FIG. 9. Stability and trim, original lines.

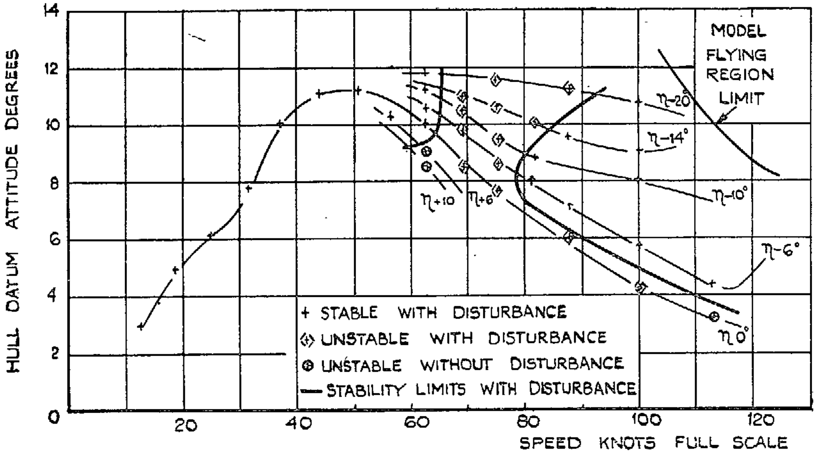


Take-off at 280,000 lb, flaps 0 deg.

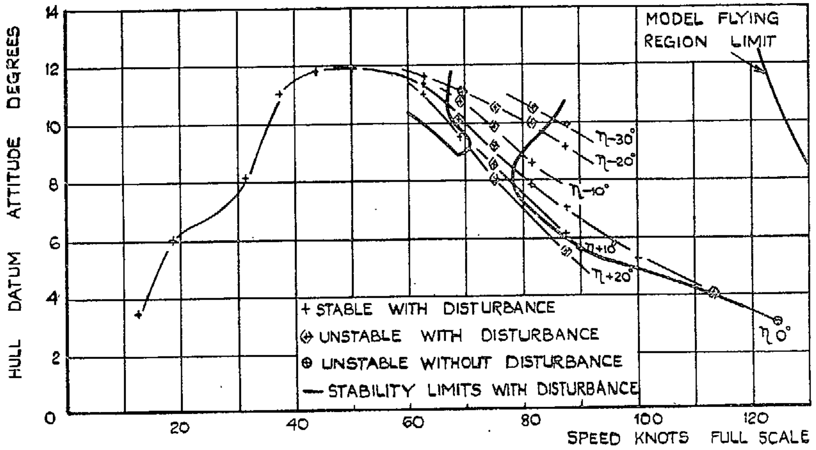


Take-off at 310,000 lb, flaps 0 deg.

FIG. 10. Stability and trim, modification N.

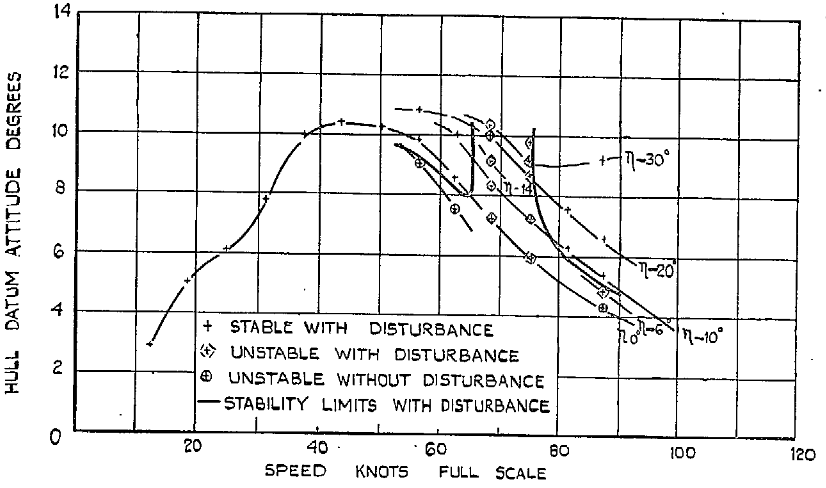


Take-off at 340,000 lb, flaps 0 deg.

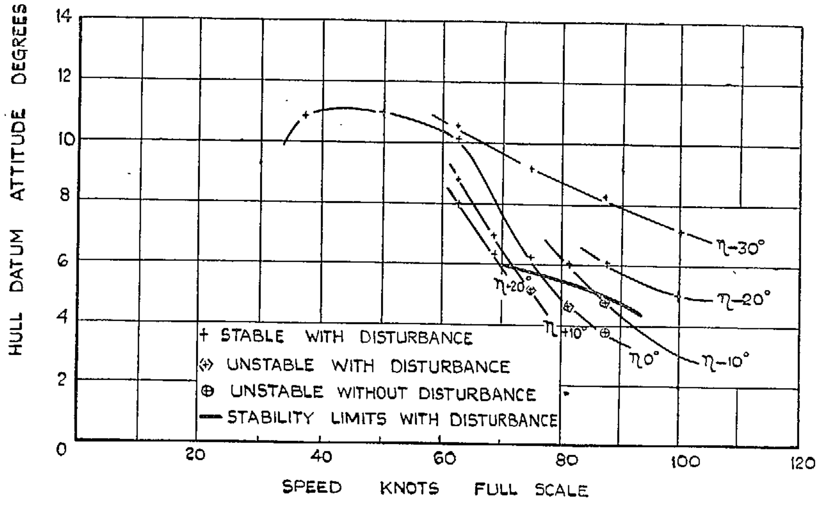


Landing at 280,000 lb, flaps 0 deg.

FIG. 11. Stability and trim, modification N.

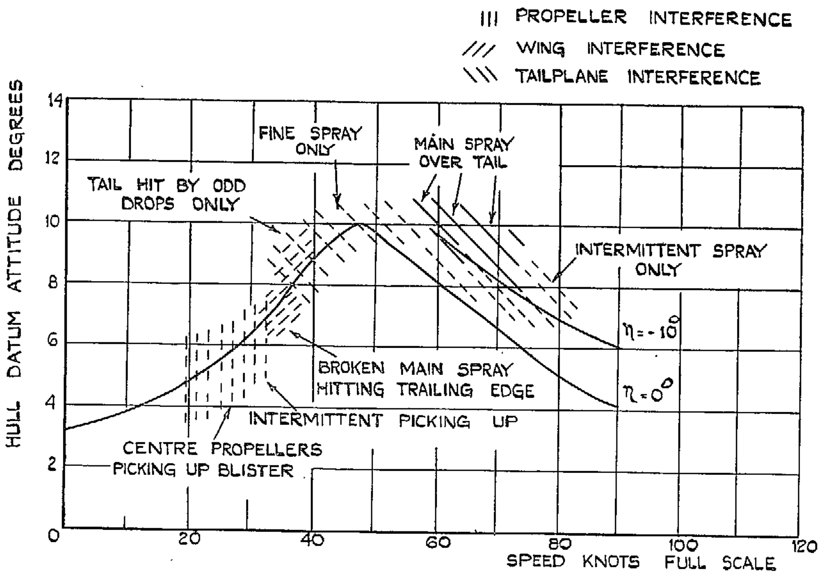


Take-off at 320,000 lb, flaps 20 deg.

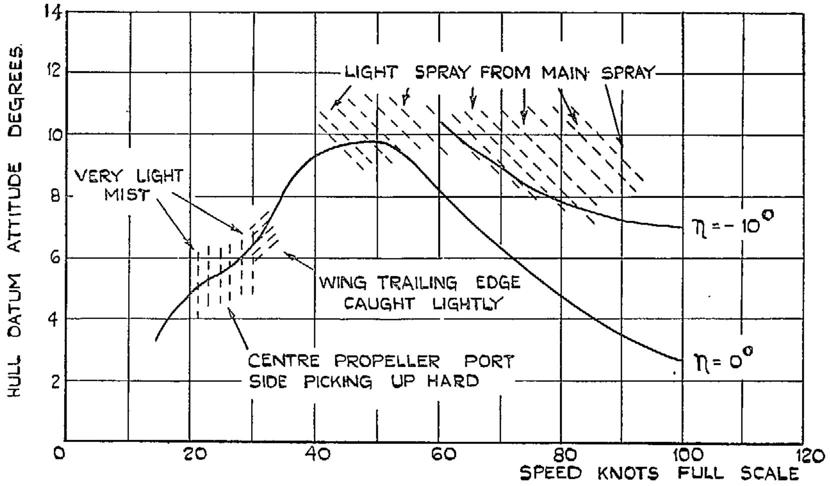


Landing at 240,000 lb, flaps 45 deg.

FIG. 12. Stability and trim, modification T.

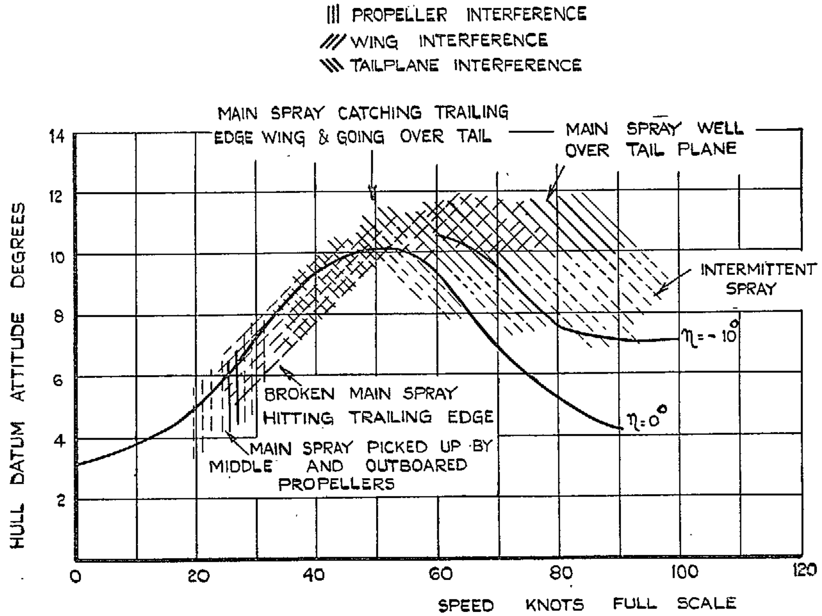


Take-off original form at 280,000 lb, flaps 0 deg.

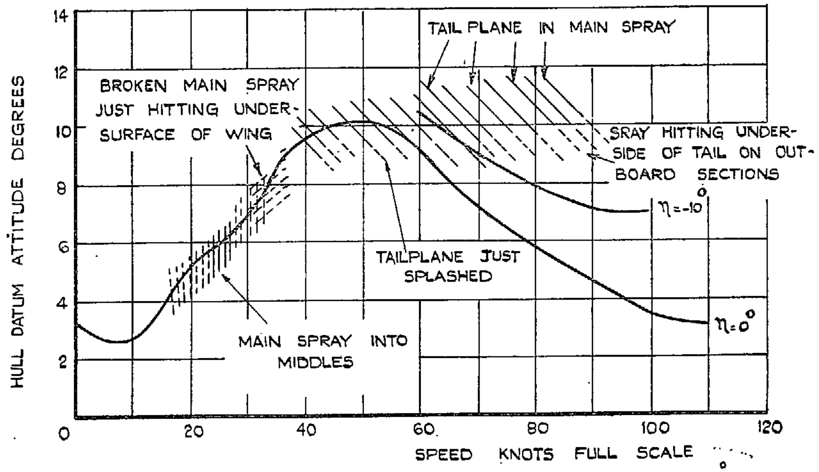


Take-off modification N at 280,000 lb, flaps 0 deg.

FIG. 13. Spray sketch for take-off at 280,000 lb.

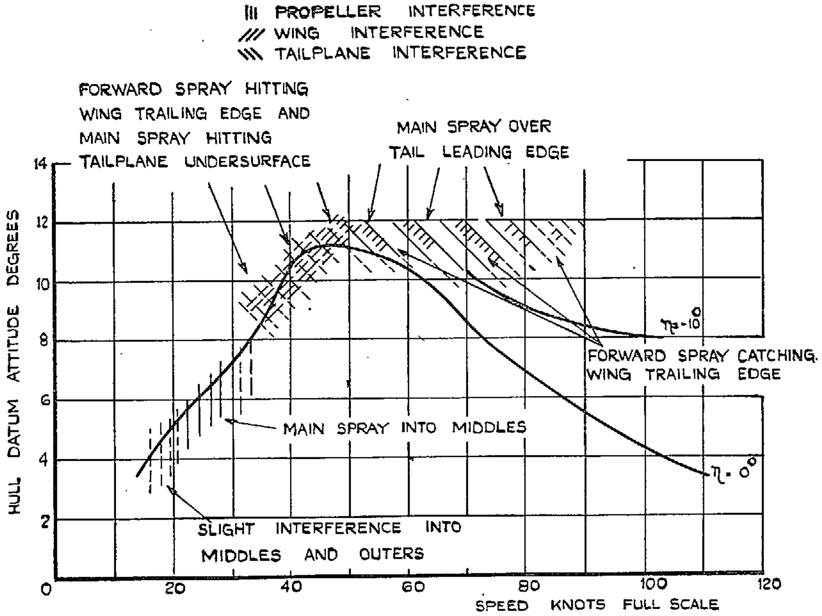


Take-off original form at 310,000 lb, flaps 0 deg.

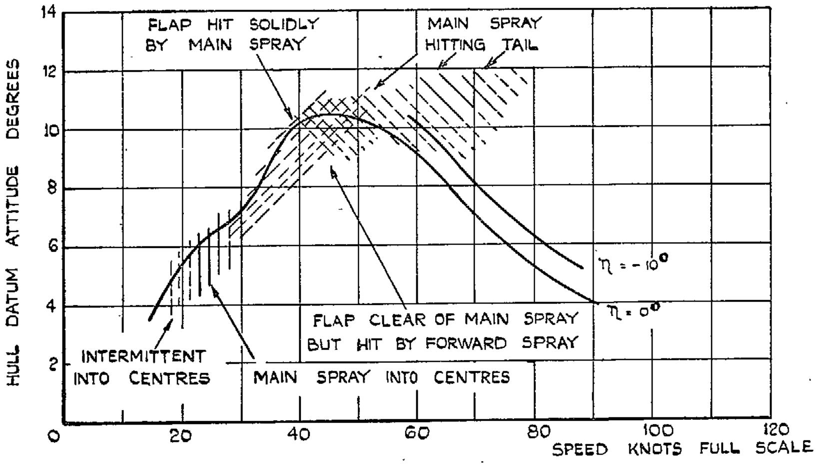


Take-off modification N at 310,000 lb, flaps 0 deg.

FIG. 14. Spray sketch for take-off at 310,000 lb.

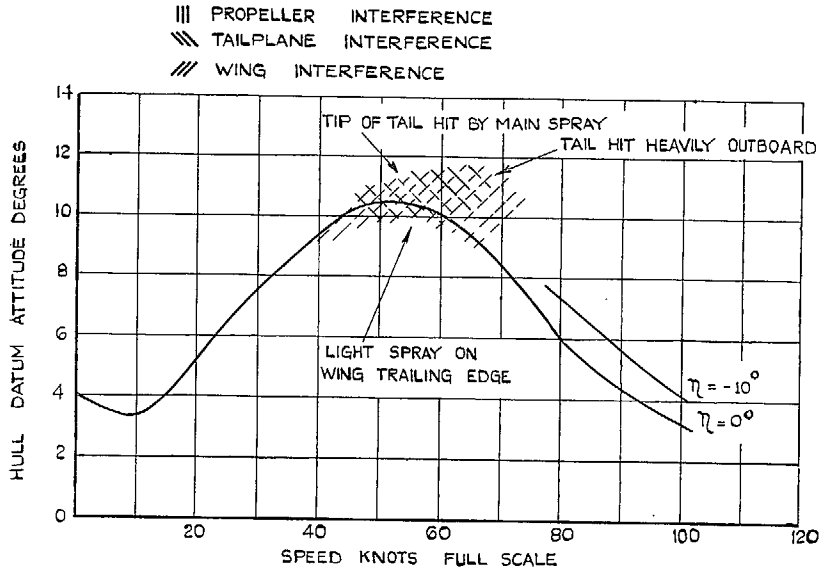


Take-off modification N at 340,000 lb, flaps 0 deg.

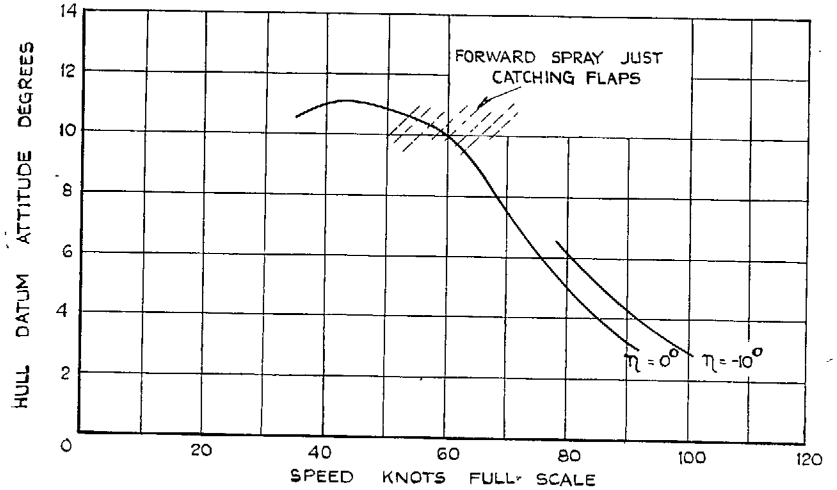


Take-off modification T at 320,000 lb, flaps 20 deg.

FIG. 15. Spray sketch for take-off with and without flaps.

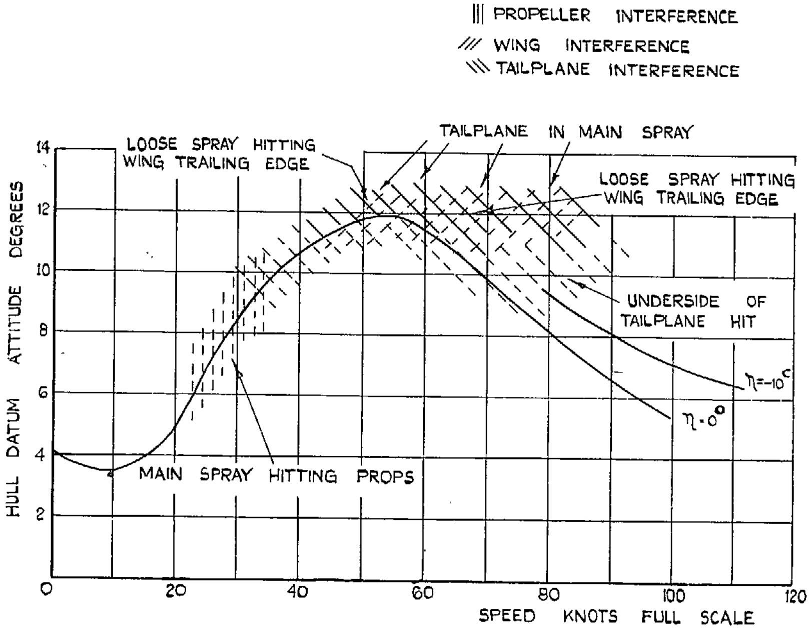


Landing original form at 220,000 lb, flaps 0 deg.

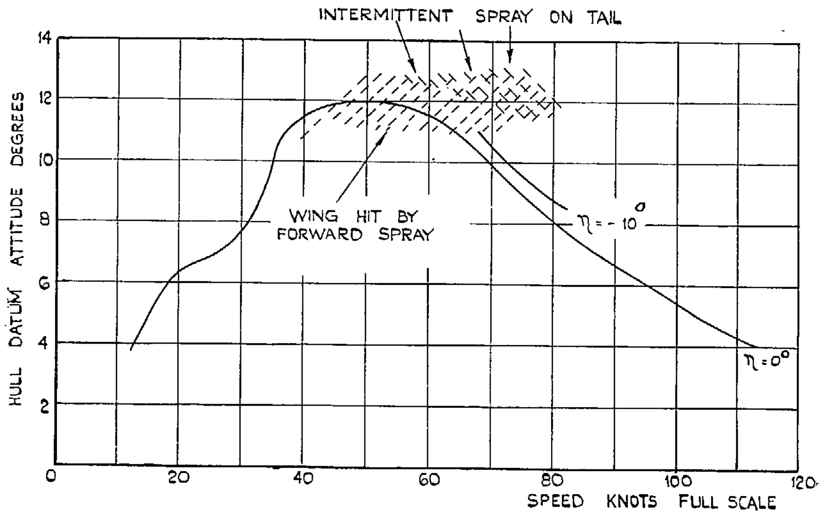


Landing modification T at 240,000 lb, flaps 45 deg.

Fig. 16. Spray sketch for landing with and without flaps.

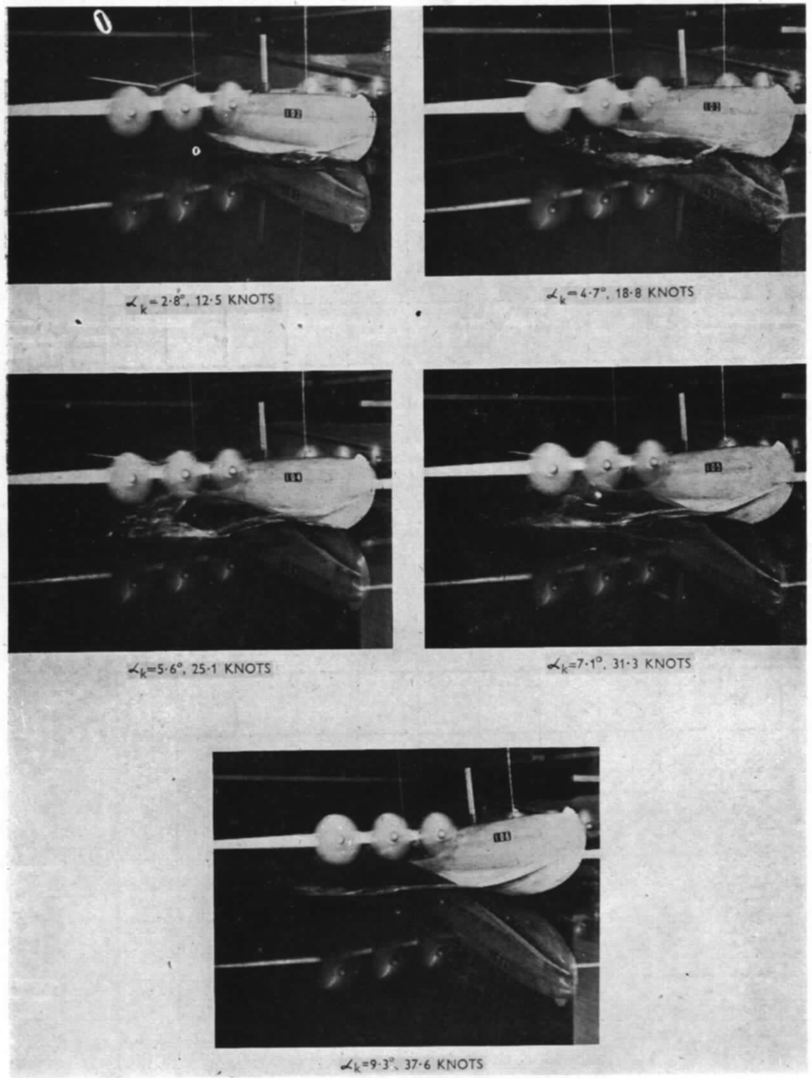


Landing original form at 280,000 lb, flaps up.



Landing modification N at 280,000 lb, flaps up.

Fig. 17. Spray sketch for landing at 280,000 lb.



$\alpha_k = 2\cdot8^\circ$, 12·5 KNOTS

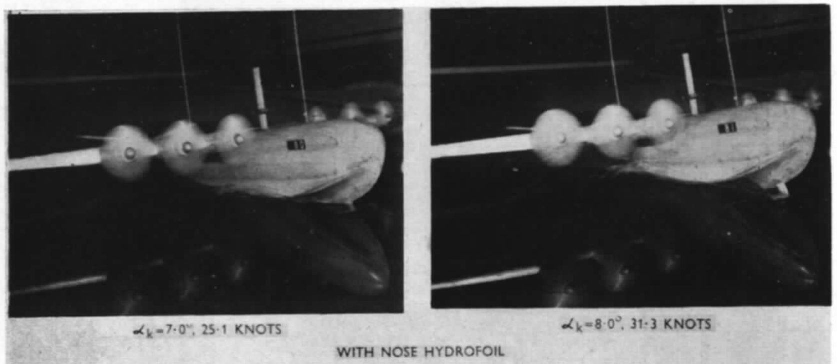
$\alpha_k = 4\cdot7^\circ$, 18·8 KNOTS

$\alpha_k = 5\cdot6^\circ$, 25·1 KNOTS

$\alpha_k = 7\cdot1^\circ$, 31·3 KNOTS

$\alpha_k = 9\cdot3^\circ$, 37·6 KNOTS

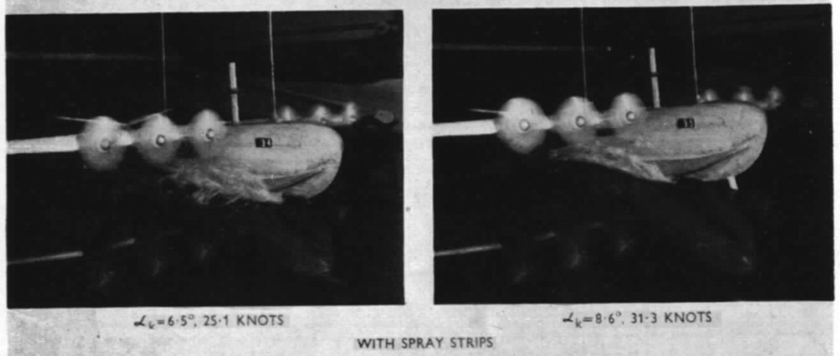
Fig. 18. Propeller spray interference at 310,000 lb on modications N and T.



$\alpha_k = 7\cdot0^\circ$, 25·1 KNOTS

$\alpha_k = 8\cdot0^\circ$, 31·3 KNOTS

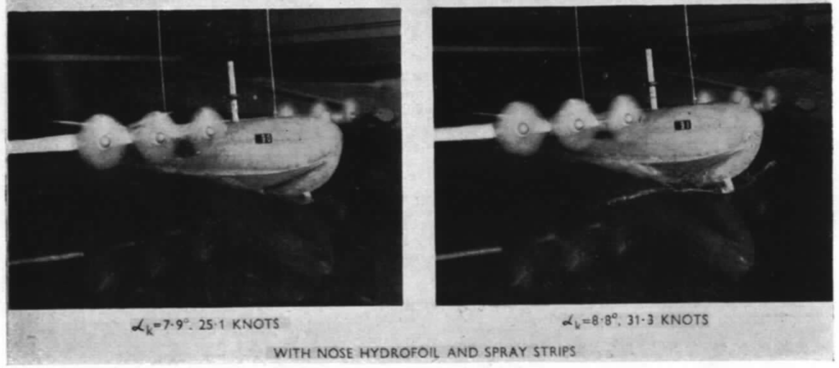
WITH NOSE HYDROFOIL



$\alpha_k = 6\cdot5^\circ$, 25·1 KNOTS

$\alpha_k = 8\cdot6^\circ$, 31·3 KNOTS

WITH SPRAY STRIPS



$\alpha_k = 7\cdot9^\circ$, 25·1 KNOTS

$\alpha_k = 8\cdot8^\circ$, 31·3 KNOTS

WITH NOSE HYDROFOIL AND SPRAY STRIPS

Fig. 19. Effect of nose hydrofoil and spray strips on propeller spray interference at 310,000 lb on modification N.

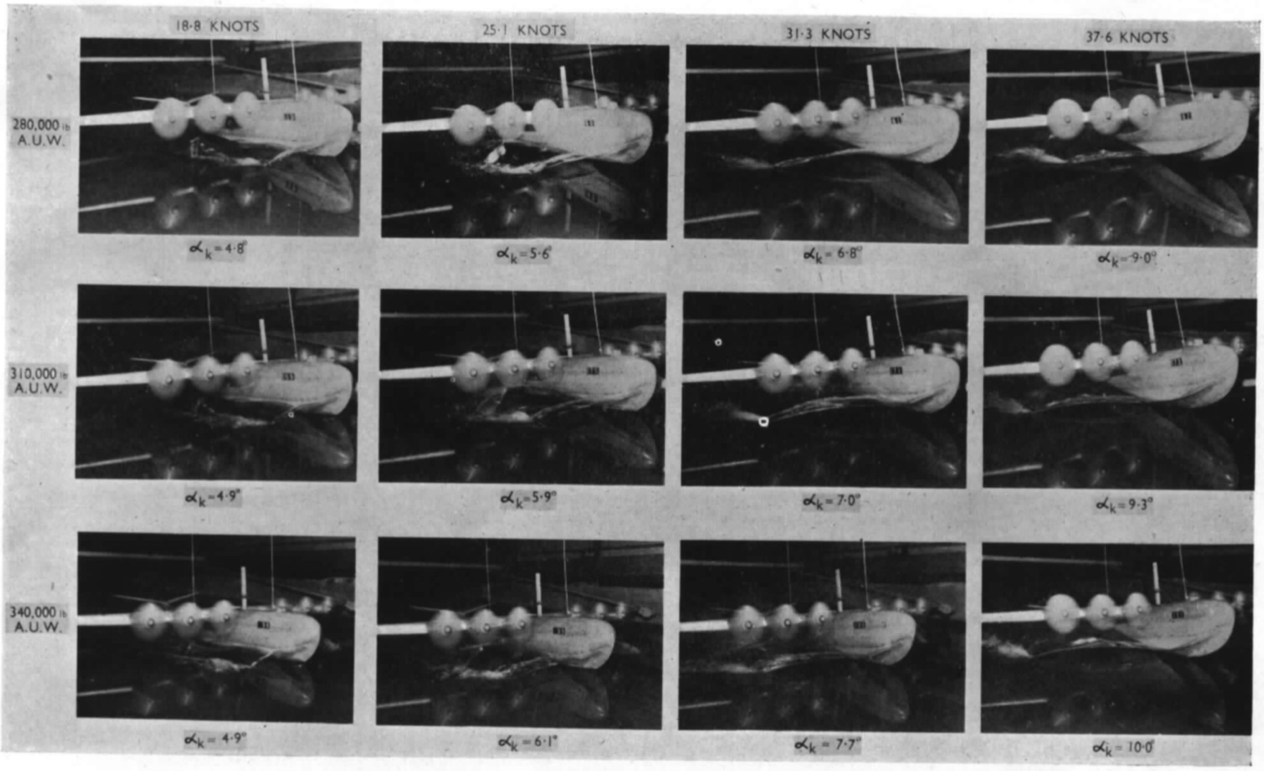


FIG. 20. Effect of all-up weight on propeller spray interference, modification N.

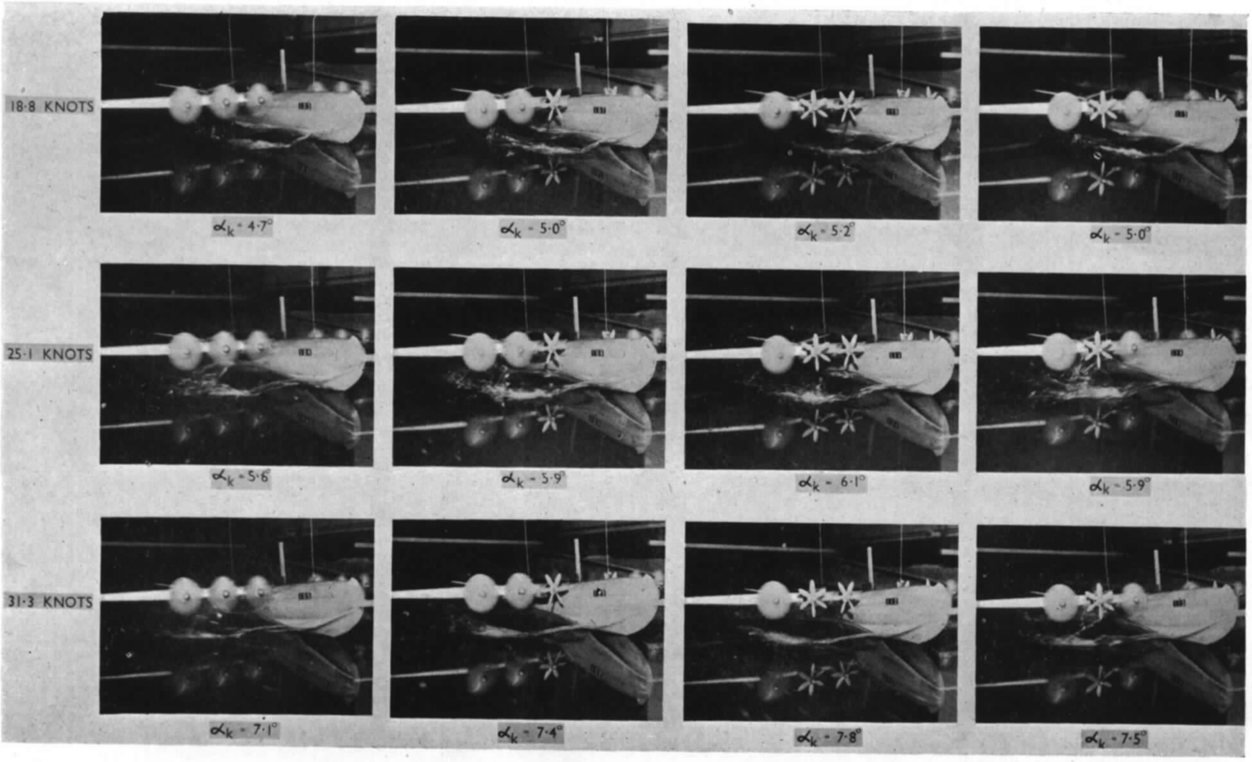


FIG. 21. Propeller spray interference at 310,000 lb with different engines cut on modification T.

J4275 Wt.13/806 K9 1/53 D&Co. 34-263

PRINTED IN GREAT BRITAIN

R. & M. No. 2641
(11,462)
A.R.C. Technical Report

Publications of the Aeronautical Research Council

ANNUAL TECHNICAL REPORTS OF THE AERONAUTICAL RESEARCH COUNCIL (BOUND VOLUMES)

1936 Vol. I. Aerodynamics General, Performance, Airscrews, Flutter and Spinning. 40*s.* (40*s.* 9*d.*)
Vol. II. Stability and Control, Structures, Seaplanes, Engines, etc. 50*s.* (50*s.* 10*d.*)
1937 Vol. I. Aerodynamics General, Performance, Airscrews, Flutter and Spinning. 40*s.* (40*s.* 10*d.*)
Vol. II. Stability and Control, Structures, Seaplanes, Engines, etc. 60*s.* (61*s.*)
1938 Vol. I. Aerodynamics General, Performance, Airscrews. 50*s.* (51*s.*)
Vol. II. Stability and Control, Flutter, Structures, Seaplanes, Wind Tunnels, Materials. 30*s.* (30*s.* 9*d.*)
1939 Vol. I. Aerodynamics General, Performance, Airscrews, Engines. 50*s.* (50*s.* 11*d.*)
Vol. II. Stability and Control, Flutter and Vibration, Instruments, Structures, Seaplanes, etc. 63*s.* (64*s.* 2*d.*)
1940 Aero and Hydrodynamics, Aerofoils, Airscrews, Engines, Flutter, Icing, Stability and Control, Structures, and a miscellaneous section. 50*s.* (51*s.*)
1941 Aero and Hydrodynamics, Aerofoils, Airscrews, Engines, Flutter, Stability and Control, Structures. 63*s.* (64*s.* 2*d.*)
1942 Vol. I. Aero and Hydrodynamics, Aerofoils, Airscrews, Engines. 75*s.* (76*s.* 3*d.*)
Vol. II. Noise, Parachutes, Stability and Control, Structures, Vibration, Wind Tunnels. 47*s.* 6*d.* (48*s.* 5*d.*)
1943 Vol. I. (*In the press.*)
Vol. II. (*In the press.*)

ANNUAL REPORTS OF THE AERONAUTICAL RESEARCH COUNCIL—

1933–34	1*s.* 6*d.* (1*s.* 8*d.*)	1937	2*s.* (2*s.* 2*d.*)
1934–35	1*s.* 6*d.* (1*s.* 8*d.*)	1938	1*s.* 6*d.* (1*s.* 8*d.*)
April 1, 1935 to Dec. 31, 1936.	4*s.* (4*s.* 4*d.*)	1939–48	3*s.* (3*s.* 2*d.*)

INDEX TO ALL REPORTS AND MEMORANDA PUBLISHED IN THE ANNUAL TECHNICAL REPORTS, AND SEPARATELY—

April, 1950 – – – – – R. & M. No. 2600. 2*s.* 6*d.* (2*s.* 7½*d.*)

AUTHOR INDEX TO ALL REPORTS AND MEMORANDA OF THE AERONAUTICAL RESEARCH COUNCIL—

1909–1949 – – – – – R. & M. No. 2570. 15*s.* (15*s.* 3*d.*)

INDEXES TO THE TECHNICAL REPORTS OF THE AERONAUTICAL RESEARCH COUNCIL—

December 1, 1936 — June 30, 1939.	R. & M. No. 1850.	1*s.* 3*d.* (1*s.* 4½*d.*)
July 1, 1939 — June 30, 1945.	R. & M. No. 1950.	1*s.* (1*s.* 1½*d.*)
July 1, 1945 — June 30, 1946.	R. & M. No. 2050.	1*s.* (1*s.* 1½*d.*)
July 1, 1946 — December 31, 1946.	R. & M. No. 2150.	1*s.* 3*d.* (1*s.* 4½*d.*)
January 1, 1947 — June 30, 1947.	R. & M. No. 2250.	1*s.* 3*d.* (1*s.* 4½*d.*)
July, 1951 – – – – –	R. & M. No. 2350.	1*s.* 9*d.* (1*s.* 10½*d.*)

Prices in brackets include postage.

Obtainable from

HER MAJESTY'S STATIONERY OFFICE

York House, Kingsway, London W.C.2 ; 423 Oxford Street, London W.1 (Post Orders : P.O. Box No. 569, London S.E.1) ; 13A Castle Street, Edinburgh 2 ; 39 King Street, Manchester 2 ; 2 Edmund Street, Birmingham 3 ; 1 St. Andrew's Crescent, Cardiff ; Tower Lane, Bristol 1 ; 80 Chichester Street, Belfast OR THROUGH ANY BOOKSELLER

S.O. Code No. 23-2641