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Hydrodynamic Design of Seaplane Floats

By

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ADDENDUM

Subsequent to the publication of this report a better method of afterbody design was evolved consisting in essence of fitting the afterbody to the calculated wake shape to provide adequate ventilation in the planing condition. This method was applied to the R.A.E. floats described in this report and an improved version of the floats produced. A summary of this method of afterbody design with the results obtained on the R.A.E. floats was presented at the 7th International Congress of Applied Mechanics and is reported in the Proceedings.*

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* Proceedings of the 7th International Congress of Applied Mechanics, 1948.

"Some Aspects of the Flow Round Planing Seaplane Hulls or Floats and Improvements in Step and Afterbody Design." - K.M. Tomaszewski and A.G. Smith.

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Hydrodynamic Design of Seaplane Floats

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SUMMARY

A generalised float form together with its attachment to the seaplane is designed on the basis of existing data and tank tests.

It is shown that a good compromise can be achieved between design for water stability, trim, spray, seaworthiness on waves, good aerodynamic form, buoyancy and ease of manufacture.

Much stronger afterbodies can be used for floats than for hulls without loss of porpoising stability and are necessary for good stability and trim at the hump speed.

The final form evolved should prove a useful basis for the design of floats for any particular purpose.

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1 Introduction

The purpose of this report is to examine the geometry of seaplane floats and their position relative to the C.G. for porpoising stability, spray clearance and seaworthiness.

A pair of floats and their attachment to a small seaplane have been designed and tested in the R.A.E. seaplane towing tank, to illustrate the principles involved. The design features are however set out in a non-dimensional form for general use.

Tests with float-seaplanes have shown[1] that design for porpoising stability is more severe for flying-boats, than float-seaplanes. It is necessary to design for much deeper steps, higher and smaller afterbodies for the former. For this reason the shape of the floats was based in the first place on flying-boat hull design and later changes were made by strengthening the afterbody to improve stability and trim in the hump region. The design layout was chosen as a compromise between manufacturing requirements and theoretical design.

The water characteristics of the twin-float-seaplane are determined by six main parameters: (1) static load on the water (beam of the float and total weight of seaplane), (2) geometry of the float in terms of the beam, (3) position of the step of the float relative to the C.G. of seaplane, (4) wing setting relative to the float, (5) aerodynamic characteristics and (6) track of float (distance between the centres of floats). The float design for good porpoising stability and seaworthiness is a series of compromises between these parameters.

In this report the parameters (2) and (3) are investigated for constant values of the parameters (1), (4), (5) and (6). The beam of the float was chosen for a static beam loading coefficient $C_{\Delta_0} = 1.5$ and has been kept constant. At this beam loading the volume of the float was chosen to give reserve buoyancy of 110% on the original form. It was increased to 140% for the final proposed form.

The position of the float relative to the C.G. of the seaplane was first fixed for static stability[2] and then modified to satisfy the results of the trim and stability tests on a powered-dynamic model. For all tests the wing setting relative to the float datum was kept constant[2] at 5.8°. A powered-dynamic model of the Auster V was used, so keeping the aerodynamic characteristics constant for all the modifications. The track of the floats was the same as for the Auster V with "Queen Bee" floats but observation of spray conditions during the tests show that better results may be obtained if the track be increased. This will also improve the lateral stability. The increase is however limited because seaplanes with large tracks are difficult to keep on a straight course when landing on one float. C.A.G.I. recommended that the track of floats be 15 to 20% of the wing span[3].

Stability and seaworthiness tests were made both in calm water and waves.

2 Design of float geometry

In the design of a float for good porpoising stability and seaworthiness it is convenient to consider three different conditions on the water; (1) at rest or at low speed (the displacement region), (2) during transition from displacement to planing flow (the hump region) and (3) planing on the forebody (the planing region). These three different conditions depend on (a) forebody geometry, (b) geometry of step, (c) geometry of afterbody and (d) location of floats relative to the seaplane. From available information on existing designs of floats and hulls for a given static beam loading coefficient (C_{Δ_o}) the geometry of the required float may be solved non-dimensionally in terms of the beam and from static stability considerations the floats may be located relative to the seaplane.

Floats designed in this manner still require testing in a towing tank in order to obtain the best final form for any given operational requirements.

The lines of the first version of the float design are given in Fig. 3.1 and the dimensions in terms of the beam in Table I. The derivation is as below.

2.1 First version forebody shape

The shape of the forebody affects conditions on the water during take-off, landing and taxying. A long forebody with a fine bow gives good spray clearance and high static trim in the displacement region. A low forebody deadrise angle is better for resistance and lower limit porpoising stability, and a high deadrise for impact and spray characteristics. In the planing region a flat bottom (small deadrise) with constant beam and no keel rise is necessary to obtain the maximum normal force with the minimum wetted area.

2.11 Forebody length

There are in existence several empirical rules giving forebody length (ℓ_F) in terms of beam (b) for a given static beam loading coefficient (in our case $C_{\Delta_o} = 1.5$) required to satisfy spray conditions and static stability.

Parkinson gives the formula[4]

$$\ell_F = b.\sqrt{\frac{C_{\Delta_o}}{K}}$$

where K = constant.

Then for K = 0.0525, (very light spray), $\ell_F = 5.35.b$
K = 0.0675, (satisfactory spray), $\ell_F = 4.71.b$
K = 0.0825, (heavy but acceptable for overload), $\ell_F = 4.26.b$
K = 0.0975, (excessive spray), $\ell_F = 3.92.b$

Locke[5] gives the forebody length in terms of beam and static beam loading coefficient to provide flotation at rest and to prevent nosing under when taking-off or alighting as

$$\ell_F = 3.5.b.C_{\Delta_o}^{\frac{1}{3}}.$$

For $C_{\Delta_o} = 1.5, \quad \ell_F = 4.b.$

All the existing rules for the forebody length are very empirical and must be used very carefully.

In the preliminary design of the floats the forebody length was chosen as $\ell_F = 4.7.b.$

2.12 Bow height

If the forebody length is short a high bow reduces the buoyancy and hydrodynamic lift of the forebody at low speeds so increasing the resistance and spray severely.

In rough water a low bow gives rise to very severe spray. If the forebody is lengthened sufficiently and at the same time the bow is raised, the entrance into the water is less abrupt and the spray characteristics are improved. A high bow with large forebody length might be more favourable even in smooth water. For the large forebody length of $\ell_F = 4.7.b$, the height of the bow was chosen as $h_b = 0.75.b$, for good spray conditions on calm and rough water.

2.13 Keel height

In the planing region the best results are obtained with no keel rise. For this reason the keel line is made straight for a distance $\ell_C = 1.7.b$ forward of the step. This assumes that this is the maximum wetted length of the keel during planing. From $\ell_C = 1.7.b$ to the bow the keel line rises as an ellipse with semi-major axis $(\ell_F - \ell_C) = 3.b$ and semi minor axis $h_b = 0.75.b.$ An elliptical shape with a large bow deadrise angle gives reasonable air drag and good buoyancy at rest. The keel line designed in this way is drawn in Fig. 1.1. Heights are given in terms of the beam.

2.14 Forebody deadrise angle

It is necessary to be very careful in choosing the forebody deadrise because the various requirements conflict with one another.

To give efficient lifting characteristics in planing, a flat bottom is the best form for the forebody (deadrise angle zero) but such design gives very large impact forces during landing and bad spray characteristics. The increase of deadrise angle reduces these forces and spray severity but raises the lower limit of stability and causes deterioration in planing characteristics. Increase in the angle of deadrise from the step to the bow gives a slight reduction of the resistance before the hump speed and improves the cleanness of running in waves. At the hump speed the part of the float affected by this change of deadrise angle is completely clear of the water in calm conditions. It appears, therefore, that from the design point of view the forebody deadrise angle may be considered in two parts. The forward half of the float forebody, designed from the point of view of the low-speed rough water characteristics, and the after half, from the point of view of the hump resistance, lower limit porpoising stability, good planing characteristics impact and spray conditions. In designing the forward part of the forebody to reduce spray over the windscreen and into the propellers, care should be taken to select a form which will give easy entry into waves encountered head-on. By raising the bow the force of the impact with the oncoming waves is reduced. It appears that satisfactory bow-spray characteristics may be obtained without compromising the planing characteristics and any change which softens the impact between float and waves tends to reduce the spray. American tests show[6] that increasing the angle of deadrise at the bow has little or no effect on the minimum air drag or angle of minimum drag. To obtain a low lower-limit of porpoising stability, good planing characteristics and reasonable forces due to impact when landing, the deadrise angle at the main step was chosen as $\theta_m = 25^\circ$ and kept constant for $\ell_c = 1.7.b$. To obtain the best spray formation especially on waves the deadrise angle increased smoothly from $\ell_c = 1.7.b$ to the bow. The change of deadrise angle with the forebody length was chosen from the spray analysis[7] and is represented in Fig. 1.2. The increase of deadrise angle at the bow was considerably greater than had normally been used in the past.

2.15 Forebody shape in plan view

For planing the breadth of the part of a float wetted should be constant. The breadth of the float is therefore kept constant ($b_x = b$), from the step forward to $\ell_c = 1.7.b$. From $\ell_c = 1.7.b$ to the bow the plan view is part of a "Standard" streamline form[8] with a maximum diameter corresponding to the beam at $\ell_c = 1.7.b$ (40% of the total length of a streamline). Such a form should give good planing characteristics and low air drag. Fig. 1.1 gives the local beam of the forebody in terms of beam at main step.

2.16 Forebody chine height

The forebody chine line may be obtained for each transverse plane of the float as an intersection of the local deadrise with the chine half breadth, the latter being obtained from the forebody plan view of the float. Fig. 13 shows the method of obtaining the chine line and Fig. 1.1 the height of the chine in terms of the beam along the forebody length.

2.17 Forebody bottom shape

Concave curvature at the forebody bottom improves the spray conditions and reduces impact forces but makes for some complication in manufacturing the floats. Constant curvature of the bottom reduces this complication a little. For this reason the curvature of the forebody bottom was chosen as a constant symmetrical parabola between keel and chine for all transverse sections of the forebody. Fig. 1.4 represents the shape and method of drawing this parabola and Fig. 1.3 gives the location of this curvature relative to keel or chine lines of the float.

2.2 First version afterbody shape

The design of the afterbody is very closely connected with the design of the main step. Some information is given in references 5 and 10 on the effect of dimensions and proportion of the afterbody on the water characteristics of the hull or floats.

2.21 Afterbody length

At low and medium speeds (hump speed) the afterbody serves to provide aft buoyancy and prevent the attitude from becoming too high at the hump speed. At high speeds (when planing) the length of the afterbody should be as short as possible. A long afterbody leads to porpoising on the upper limit of instability. Near the hump speed a strong afterbody lowers the lower limit of instability. The requirements for the length of the afterbody are therefore conflicting - long at low speeds and short at high speeds. Smith and White[11] recommended that the length of afterbody for boat seaplane be 2.5 to 3.0 of beam with a pointed rear step.

Locke[4] gives a formula for the average length of the afterbody,

$$\ell_a = 2.5 \cdot C_{\Delta_o}^{\frac{1}{3}} \cdot b,$$

for

$$C_{\Delta_o} = 1.5, \; \ell_a = 2.9 \cdot b.$$

The R.A.E. tests with float-seaplanes show[1], that floats with afterbodies up to 3.8 times the beam and pointed rear steps have large stable ranges at both hump and planing speeds. For this reason the length of afterbody for the first tests was chosen as $\ell_a = 3.2.b$.

2.22 Afterbody keel angle to forebody keel

The angle of the afterbody keel to the forebody keel at the step has a large effect on trim, water resistance, porpoising stability and skipping of the seaplane. At low speeds, including the hump speed, increase in the afterkeel angle reduces the buoyancy and the hydrodynamic lift of the afterbody. To compensate for this reduction in lift the floats tend to assume a higher trim. At very low speeds this increase in trim is small and the change in resistance is negligible. The maximum effect is at the hump speed at which increase in afterkeel angle causes a large increase in trim and accompanying large increase in free-to-trim resistance. At planing speeds however, it lowers the resistance and improves the stability. A low afterkeel angle gives cleanest running but gives a lower upper limit of stability just above the hump speed. According to American tests[14] the low afterkeel angle prevents skipping especially in rough water. For the first tests the afterkeel angle was chosen as 9° and the keel line made straight. If the results of tests with such a high afterkeel angle show that free-to-trim angles at the hump speed are large the afterkeel angle could be reduced to 7° as proposed by Smith and White[11], for the minimum afterkeel angle (for flying boats) giving satisfactory porpoising stability at planing speeds.

2.23 Afterbody deadrise angle

A larger deadrise angle on the afterbody than on the forebody at the step position improves the ventilation of the afterbody bottom. This causes improvement in the ventilation of the forward half of the afterbody, improvement in the upper limit of porpoising stability in the planing region and alleviates skipping. The aft half of the afterbody controls the upper limit of porpoising stability near the hump speed. A more pointed rear step generally gives an improvement in stability[14]. Increasing the angle of deadrise aft on the afterbody decreases the lift of the afterbody and therefore increases the trim and reistance at the hump. Most of this increased resistance is due to the higher trim. Full scale aft taxying tests with floats having decreasing aft deadrise in the afterbody show dangerous diving tendency even at very low taxying speeds. This tendency to dive is mainly because of the suction on the after part of the afterbody bottom which occurs when the chine is immersed. If the deadrise angle is increased towards the rear step diving can be eliminated.

The selected distribution of deadrise angle is given in Fig. 1.6.

2.24 Afterbody length with rudder

To improve control on the water at low speeds the afterbody length was increased to 3.5.b to accommodate a water rudder.

2.25 Afterbody shape in plan view

The plan view of the afterbody is the after part of the "Streamline" form[8] used on the front of the forebody. Maximum diameter corresponds to that at the step position and the trailing edge of the streamline occurs at 3.2.b from the step. Because of the rudder the end of the streamline form was modified as shown Fig. 1.5.

2.26 Afterbody bottom shape

For the first series of tests the sides of the afterbody bottom were made flat, Fig. 1.3 and Fig. 3.1.

2.27 First version step form and keel height

At speeds below and at the hump a small depth of step is desirable for low resistance. At high speeds the water resistance decreases as the depth of step is increased due to a greater clearance of the afterbody from the water (better ventilation of the afterbody bottom). For constant value of the afterkeel angle the water resistance decreases as the depth of step is increased up to a certain depth beyond which no further reduction is obtained. This value of the step depth depends on the afterbody keel line. For shallow steps when the attitude of the float is such that the afterbody keel is nearly horizontal, the flow from the step suddenly tends to cover the entire afterbody planing surface and the resistance and draft are suddenly increased. This is accompanied by longitudinal instability. Increasing the depth of step removes the tendency toward instability. American tests show[6] that a 75% increase in depth of step (from 2.5% to 4.4% of the beam) caused a very small increase in aerodynamic drag and very marked improvement in stability.

For the first tests the depth of step was chosen as 7.7 percent of beam at main step. The step was faired in elevation to a distance approximately four times the step depth.

The height of the keel line is given in Fig. 1.5. To reduce forces on the rudder when landing on two steps the afterkeel angle of the rudder is raised to 10°.

2.28 Afterbody chine height

The afterbody chine height may be obtained by the same method as for the forebody chine height. Fig. 1.5 shows the height of the chine line in terms of beam along the afterbody length and Fig. 1.3 the method of obtaining this height.

2.3 Float deck design

The shape of the deck was designed for low air drag. The top line of the deck from the bow to $\ell_x = 0.9.b$ is an ellipse and then a straight line parallel to the datum line of the float and ending as a part of a "Standard" streamline form[7]. The radius of the float body was taken as half the breadth of the float. The deck line and the height of the radius centre above datum is given in Fig. 1.5 in terms of the beam at main step.

2.4 Float attachment

The float attachment was designed in a trouser leg form for minimum air drag and maximum strength. This form also has minimum interference with the spray formed by the floats. The leg can be varied in transverse angle as required relative to the float. The upper end of the streamline leg can be attached to any reasonable part on the fuselage or wing.

Data and illustrations are given in Fig. 1.7 in terms of the beam at main step.

3 Description of Model for Testing Floats

To examine trim, stability and spray formation of these floats on calm water and waves the floats were fixed to a 1/5th scale powered-dynamic model of the Auster V. The full scale beam of the float was chosen for a normal take-off weight of the aircraft (1820 lb),

$$b = \sqrt[3]{\frac{\Delta_o}{C_{\Delta_o} \cdot W}}$$

where

$$\Delta_o = \frac{1820}{2} = 910 \text{ lb} = \text{static load on the water}$$

$$C_{\Delta_o} = 1.5 = \text{static beam loading coefficient}$$

$$W = 62.5 \text{ lb/ft}^3 = \text{density of fresh water}$$

$$b = 26 \text{ inches}$$

The general arrangement of seaplane is given in Fig. 2, and the float dimensions in Fig. 3.1.

4 Characteristics of First Version Floats

4.1 Trim and porpoising stability

The results are given in Fig. 4 for take-off at overload ($C_{\Delta_o} = 1.58$) and landing at light load ($C_{\Delta_o} = 1.42$). The model has a poor lower limit of stability, being unstable without disturbance at all speeds above 20 knots when left free to trim with elevator neutral. This instability becomes less severe as the take-off speed is reached.

The attitude, when the model is left free-to-trim with elevator neutral, increases sharply with speed as it approaches the hump (15.9 knots) and then decreases rapidly, giving a large variation of trim with speed.

It is not possible to increase the attitude sufficiently to reach an upper limit of stability despite ample elevator power.

With slipstream, the elevator is very effective even at the hump speed.

4.2 Spray characteristics

Spray characteristics are shown in Fig. 9 for landing at light load (C_{Δ_0} = 1.42) and in Fig. 10 for take-off at overload (C_{Δ_0} = 1.58).

The propeller and windscreen are clear of spray at all take-off and landing speeds.

At low speeds (up to 10.6 knots) the floats are very clean and no part of the seaplane is affected by the spray. In the hump speed range the spray, due to interference between the two floats, wets the undersurface of the central and aft parts of the fuselage. At planing speeds the floats are again very clean and no part of the seaplane is affected by the spray.

5 Modifications and their effect on trim, porpoising stability and spray on calm water

To improve the lower limit of stability and decrease the attitude at the hump speed three modifications were made. First the fairing was removed from the step - Mod. "A". Second the step was moved forward 21% of the beam at main step (step depth at keel reduced to 4.21% of beam at main step) - Model "B". Third the afterbody was strengthened - Mod."C". Table II gives the dimensions of the float in terms of the beam at the main step for modification "C" and Fig. 3.2 represents the float lines.

The effect of the modifications are summarised in Table III and illustrated in Figs. 4 to 6. A comparison of the different floats is made in Table IV. Fig. 7 gives a comparison of attitudes with the stick central and stability limits with and without disturbance during take-off at overload. Fig. 8 compares the different stick positions which make the float unstable and also the rate of change of attitude with elevator angle on the stability limits.

5.1 Modification "A"

The results of porpoising stability tests are given in Fig. 5A for take-off case at overload (C_{Δ_0} = 1.58). Comparison of the first version with modification "A" shows that removing the fairing from the step gives:

(1) A reduction of hump attitude of about $\frac{1}{2}^{\circ}$ ($\eta = 0^{\circ}$),

(2) a lowering of the stability limit of about 2° in the speed range just above the hump,

(3) an improvement of elevator sensitivity on the stability limit,

(4) a more central stick position on the stability limit below 40 knots,

(5) a farther back stick position on the stability limit above 40 knots,

(6) a slight improvement in spray characteristics at the hump speed probably due to a lower attitude,

(7) a reduction of buoyancy 0.3% relative to the first version.

5.2 Modification "B"

The results of porpoising stability tests are given in Fig. 6B for take-off at overload (C_{Δ_o} = 1.58). Comparison of modification "A" with "B" shows that moving the step forward gives:

(1) no change of attitude at hump speed,

(2) a lowering of the stability limit of about $1\frac{1}{2}^{\circ}$ at speeds just above the hump,

(3) a worse elevator sensitivity on the stability limit,

(4) a more central stick position on the stability limit,

(5) a reduction of buoyancy 0.7% relative to the first version.

5.3 Modification "C"

The results of porpoising stability tests are given in Fig. 6 for landing and take-off at overload (C_{Δ_o} = 1.58). Comparison of modifications "B" and "C" shows that strengthening the afterbody gives:

(1) a reduction of hump attitude (η = 0°) of about $1\frac{1}{2}^{\circ}$ (about 2° when compared with first version of floats),

(2) a lowering of the stability limit of about $\frac{1}{2}^{\circ}$ (about 3.7° when compared with first version of floats) just above the hump speed,

(3) a wider stable range of speeds and attitudes without disturbances,

(4) a more constant elevator sensitivity on the stability limit,

(5) a slight improvement in spray characteristics in the hump speed range,

(6) an increase of buoyancy 0.7% relative to the first version.

It is expected that even in rough water conditions (with large disturbances) the floats will be stable during take-off at attitudes above 6° due to the fact that the unstable range with disturbances is very narrow and during accelerated motion the seaplane passes through the unstable region just above the hump so quickly that instability has no time to build up.

6 Seaworthiness with modification "C"

6.1 Take-off in waves

Tests have been made with four different systems of waves[15] and in zero wind conditions. Fig. 11 shows the wave test conditions, Fig. 12 the spray characteristics obtained for waves 1.25 ft height and 25 ft long, Fig. 13 the spray characteristics for waves 2.1 ft height and 84 ft long. Table V summarises the results of the tests in waves and calm water.

These tests show that small waves up to 0.8 ft (wave height: float beam = 0.37) improve the spray characteristics in hump region by reducing the interference between the two floats. With larger waves up to 2.1 ft (wave height: float beam = 0.99) the floats are very clean at low speeds but in the hump speed range the spray due to the blister interference between the two floats hits the undersurface of the fuselage slightly. This occurs when the seaplane runs at very small and very large attitudes due to the effect of the waves. At medium attitudes the floats are very clean. At speeds just before take-off the model starts to bounce at higher attitudes.

6.2 Aft taxying

Full scale experience shows that float seaplanes can be lost because of a very dangerous tendency to dive when taxying in an aft direction. Aft taxying tests were made in R.A.E. Seaplane Tank with R.A.E. floats - modification "C". The model was free to pitch and rise abouts its C.G. at overload. Tests were made at speeds up to 15.9 knots (full scale) without disturbances and with small and large disturbances. The results of tests are tabulated in Table VI. These tests show that in aft taxying on calm water (no disturbances) there is no tendency to dive. Up to a speed of about 8 knots the seaplane runs similarly to normal forward taxying and no part of the aircraft is affected by the spray. At speeds higher than 10.6 knots the seaplane runs bow down and at a speed of 13.2 knots and above it runs with the rear step clear of the water but spray hits the propeller. When small disturbances were applied the seaplane behaved in the same way as without disturbances up to a speed of 8 knots. At a speed of 10.6 knots and above there is a slight tendency to dive (bow up) which starts to be dangerous at a speed of 15.9 knots. Large disturbances causing complete submerging of the aft part of the float do not affect stability up to a speed of 6.6 knots, but at a speed of 8 knots there is a slight tendency to dive (bow up) and at a speed of 13.2 knots and above the seaplane dives (bow up).

These tests show that up to a speed of 6.6 knots the aft taxying condition is very safe even when large disturbances are applied. It is expected that in practice the aft taxying performance will be much better because the model was pulled through its C.G. position.

7 Modifications and their effect on buoyancy

M.A.E.E. tests of the Auster with "Queen Bee" floats showed that the floats were just satisfactory for buoyancy and stability in calm conditions but at overload and in disturbed sea conditions the buoyancy was on the low side.

Table IV gives a comparison of the buoyances of the "Queen Bee" and the various R.A.E. floats. Fig. 15 shows the variation of reserve of buoyancy with static beam loading coefficient for the first version, modification "C", "Queen Bee" and proposed floats. It can be seen that at overload the "Queen Bee" floats have only 83% reserve buoyancy, whereas that of the R.A.E. floats tested is 100% to 104% and that of the proposed floats 129%. For the same static beam loading coefficient the total buoyancy of the R.A.E. floats tested is 1 to 3 percent smaller than that of the "Queen Bee" floats. The total buoyancy of the proposed floats is 10 percent greater than that of the "Queen Bee" floats.

Fig. 16 gives the variation of draft with attitude and static beam loading coefficient for the first version and the proposed R.A.E. floats. This figure shows that for the same values of C_{Δ_0} and attitude the draft is smaller for the proposed floats than for the first version floats. The difference in draft between these two floats is greater at higher attitudes and higher static beam loading coefficients. For $C_{\Delta_0} = 1.5$ the difference in draft would be as follows:

Attitude degrees	Percentage Reduction
-3°	3%
6°	8%

Fig. 17 gives the variation of the distance of the line of buoyancy from the F.P. for constant static beam loading coefficient ($C_{\Delta_0} = 1.5$) for the first version and proposed R.A.E. floats. Comparison of the two floats shows that for the same position of C.G. the static floating angle will be smaller for the proposed floats. For constant height of C.G. above the float datum the difference in floating angle increases when the C.G. is nearer the step.

8 Conclusions

The interesting features of the float design considered in this report are (1) the greater freedom of design permissible compared with hull design which results from the possible use of strong afterbodies and shallow steps, (2) the good stability, trim and seaworthiness achievable at a high beam loading.

No upper limit of porpoising stability is present, and the floats are very well behaved in waves up to a height equal to the beam. In addition the floats can be towed in an aft direction without diving, even when subjected to a tail down disturbance.

The lower limit of stability is very high at the hump speed on the floats tested with weak afterbodies, so that poor stability resulted for the first version which was based on boat seaplane hull design. This stability was considerably improved by use of a strong afterbody without the introduction of an upper limit at high speeds, a solution not possible with boat seaplane hulls.

The requirements for good spray conditions are shown to be a fine entry combined with a high bow, ample reserve buoyancy forward and an overall reserve buoyancy of at least 100 percent. To avoid interference between the floats the track (distance between them) should be at least 3.2 times the beam at the main step.

It is considered that further improvement of the float form "C" may be obtained by lowering the afterbody so that the step depth is reduced from 7.7 to 5 percent of the beam, as shown in Fig. 14. This is based on the following reasons:

(1) at speeds below and at the hump speed a smaller depth of step reduces the resistance.

(2) In the hump speed range the float with stronger afterbody has a lower free-to-trim attitude and lower limit of stability.

(3) The tests of the Auster V on the "Queen Bee" floats with a depth of step of 2.38 percent of the beam show that floats with such small depth have quite a reasonable lower limit of stability and no upper limit despite ample elevator power.

(4) A stronger afterbody and forebody will reduce the tendency to nose up and down in waves and by causing the floats to run at medium attitudes at the hump speed will reduce the spray.

(5) Floats with a stronger afterbody will not reach such high attitudes when planing on waves and will have less tendency to bounce.

In conclusion it is considered that the dynamic design features discussed in this report, together with the static design features described in reference 2, will enable a designer to achieve a good float design for any desired operational condition. Any such float form should be tank tested if possible.

LIST OF SYMBOLS

Angles:

α_k°	= attitude relative to the forebody keel at the step
η°	= elevator angle
α°_a	= afterkeel angle
ϕ	= heel to heel angle
β°	= overall deadrise angle
θ_k°	= deadrise angle at keel
θ_c°	= deadrise angle at chine
θ_m°	= mean deadrise angle

Length:

b	= beam at main step
b_x	= local beam
ℓ_x	= distance aft from F.P. along datum line of the float
ℓ_c	= maximum wetted length of the keel of the forebody during planing (assumed)
ℓ_F	= the forebody length
ℓ_a	= the afterbody length
ℓ_{aR}	= the afterbody length with rudder
h_k	= keel height above float datum
h_c	= chine height above float datum
h_b	= bow height above float datum
h_R	= height of radius centre above float datum
R	= radius of the float body
h_D	= deck height above float datum
$S_{C.G.}$	= distance of C.G. from step along float datum
$h_{C.G.}$	= height of C.G. above float datum
L	= track (distance between the centres of floats)
a	= wave height (crest to trough)
λ	= wave length
ℓ_{Δ}	= distance of buoyancy from F.P.

Speed:

V	= forward speed of aircraft
V_h	= hump speed
V_t	= take-off speed
V_b	= landing speed
V_{tax}	= taxying speed

Density:

W	= 62.5 lb/ft^3 density of fresh water

Forces:

W_o	= overload weight
W_n	= normal weight
W_L	= light weight
Δ_o	= static load on the water

Acceleration:

g	= 32.19 ft/sec^2 acceleration due to gravity

Coefficients:

C_v	$= \dfrac{V}{\sqrt{g.b.}}$ = velocity coefficient (Froude Number)
C_{Δ_o}	$= \dfrac{\Delta_o}{\sqrt{w.b.^3}}$ = static beam loading coefficient
$\dfrac{d\alpha}{d\eta}$	= elevator sensitivity

General:

C.G.	= centre of gravity
F.P.	= forward position of float on float datum.

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TABLE I

FLOAT DIMENSIONS IN TERMS OF BEAM

(First Version)

FOREBODY															
Station	F.P.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$(\ell_x:b)\cdot 100\%$	0	7.5	15	30	60	90	120	150	180	210	240	270	300	449	470
$\theta_m{}^\circ$	55°	55°	55°	55°	53.5°	51°	47°	42°	37°	32.5°	29°	26°	25°	25	25°
$(h_k:b)\cdot 100\%$	75	58.5	51.5	42.3	30	21.5	15	10	6.2	3.5	1.5	0.4	-	0	0
$(h_c:b)\cdot 100\%$	75	74.6	74.2	73.5	70.8	65.4	56.9	48.5	40.4	33.8	28.3	25.0	23.8	23.8	23.8
$(b_x:b)\cdot 100\%$	0	22.0	31.2	43.4	60	71.2	80.0	86.6	91.6	95.4	97.6	99.6	100	100	100
$(h_R:b)\cdot 100\%$	75	69.4	67.9	64.2	59.2	54.0	49.8	46.7	44.2	42.3	41.2	40.2	40.0	40.0	40.0
$(R:b)\cdot 100\%$	0	11.0	15.6	21.7	30.0	35.6	40.0	43.3	45.8	47.7	48.8	49.8	50.0	50.0	50.0
$(a:b)\cdot 100\%$	0	9.8	13.8	19.0	25.2	28.2	29.2	29.0	28.8	28.5	27.9	27.9	27.9	27.9	27.9

TABLE I (Contd)

FLOAT DIMENSIONS IN TERMS OF BEAM
(First Version)

AFTERBODY												
Station	14	15	16	17	18	19	20	21	22	23	24	25
$(\ell_x:b) \cdot 100\%$	470	502	534	566	598	630	662	694	726	758	790	820
$\theta_m{}^\circ$	26°	26°	26.75°	28°	30°	32°	34°	36°	37.25°	37.75°	38°	38°
$(h_k:b) \cdot 100\%$	7.7	12.7	17.7	22.7	27.7	32.7	37.7	42.7	47.7	52.7	57.7	65.8
$(h_c:b) \cdot 100\%$	32.1	36.7	41.7	47.1	52.5	56.7	60.4	62.3	62.9	61.7	60.8	65.8
$(b_x:b) \cdot 100\%$	100	98.4	95.8	92.3	86.1	77.7	67.3	54.2	40.0	23.4	8.0	0
$(H_R:b) \cdot 100\%$	40.0	40.2	42.1	43.8	46.9	51.2	56.2	62.7	69.6	76.9	82.5	83.7
$(R:b) \cdot 100\%$	50.0	49.2	47.9	46.2	43.1	38.8	33.7	27.1	20.0	11.7	4.0	0
$(a:b) \cdot 100\%$					Straight Line							

b = beam at main step
b_x = local beam
ℓ_x = distance aft from F.P. along datum line
h_k = keel height above datum line
h_c = chine height above datum line
h_R = height of centre above datum line
R = radius of body
a = distance from centre of planing bottom curve

TABLE II

FLOAT DIMENSIONS IN TERMS OF BEAM
(Modification "C")

FOREBODY														
Station	F.P.	1	2	3	4	5	6	7	8	9	10	11	12	13
$(\ell_x:b)\cdot 100\%$	0	7.5	15	30	60	90	120	150	180	210	240	270	300	449
$\theta_m{}^\circ$	55°	55°	55°	55°	53.5°	51°	47°	42°	37°	32.5°	29°	26°	25°	25°
$(h_k:b)\cdot 100\%$	75	58.5	51.5	42.3	30	21.5	15	10	6.2	2.5	1.5	0.4	0	0
$(h_c:b)\cdot 100\%$	75	74.6	74.2	73.5	70.8	65.4	56.9	48.5	40.4	33.8	28.3	25.0	23.8	23.8
$(b_x:b)\cdot 100\%$	0	22.0	31.2	43.4	60	71.2	80.0	86.6	91.6	95.4	97.6	99.6	100	100
$(h_R:b)\cdot 100\%$	75	69.4	67.9	64.2	59.2	54.0	49.8	46.7	44.2	42.3	41.2	40.2	40.0	40.0
$(R:b)\cdot 100\%$	0	11.0	15.6	21.7	30.0	35.6	40.0	43.3	45.8	47.7	48.8	49.8	50.0	50.0
$(a:b)\cdot 100\%$	0	9.8	13.8	19.0	25.2	28.2	29.2	29.0	28.8	28.5	27.9	27.9	27.9	27.9

AFTERBODY													
Station	13A	14	15	16	17	18	19	20	21	22	23	24	25
$(\ell_x:b)\cdot 100\%$	449	470	502	534	566	598	630	662	694	726	758	790	820
$\theta_m{}^\circ$	26°	26°	26°	26°	26°	26.5°	26.25°	27°	28°	29.5°	33.5°	45°	-
$(h_k:b)\cdot 100\%$	7.7	10.4	14.3	18.3	22.3	26.2	30.2	34.2	38.1	42.1	46.0	50.0	55.8
$(h_c:b)\cdot 100\%$	32.1	34.6	36.2	41.5	45.0	48.1	50.4	52.7	54.4	55.4	55.8	55.8	55.8
$(b_x:b)\cdot 100\%$	100	100	98.4	95.8	92.4	88.4	80.8	73.1	61.6	47.7	30.8	2.4	0
$(h_R:b)\cdot 100\%$	40.0	40.0	40.8	42.1	43.8	46.9	51.2	56.2	62.7	69.6	76.9	82.5	83.6
$(R:b)\cdot 100\%$	50.0	50.0	49.2	47.9	46.2	43.1	38.8	33.7	27.1	20.0	11.7	4.00	0
$(a:b)\cdot 100\%$	27.9	27.9	27.5	26.7	25.8	24.4	22.7	20.6	17.3	13.7	9.00	4.20	0

TABLE III

LIST OF MODIFICATIONS

Modification	Nature of Modification	Effect of Modification
"A"	Step fairing removed (Step depth at keel ÷ beam = 7.69%)	(1) Reduction of hump attitude ($\eta=0^{\circ}$) about $\frac{1}{2}^{\circ}$. (2) Just above the hump speed the lower stability limit is lowered about 2° and elevator sensitivity on stability limit improved. (3) Below 40 knots for instability position of stick more central, above this speed more aft.
"B"	(1) step moved forward 21% of beam (2) step depth at keel reduced (step depth at keel÷ beam = 4.21%)	(1) Hump attitude the same as modification "A" ($\eta=0^{\circ}$) (2) Just above the hump speed the stability limit is lowered $1\frac{1}{2}^{\circ}$ relative to modif. "A" but elevator sensitivity on stability limit worse than modific. "A". (3) On stability limit position of stick more central than modification "A".
"C"	(1) Step depth as modification "A" (2) Position of step as modification "B" (3) After keel angle to forebody keel reduced from 9° to 7°. (4) Afterbody bottom curve as forebody curve	(1) Reduction of hump attitude ($\eta=0^{\circ}$) about $1\frac{1}{2}^{\circ}$ relative to modif. "B". (2) Just above the hump speed the stability limit is lowered $\frac{1}{2}^{\circ}$ relative to modific. "B" (3.7° relative to first version) (3) wider range of stable speeds without disturbances. (4) More constant elevator sensitivity on stability limit.

TABLE IV

COMPARISON OF FLOAT TESTED AND SOME DETAILS OF RELATIVE WATER PERFORMANCE

	Queen Bee Floats	R.A.E. Floats				
		First Version	Modification "A"	Modification "B"	Modification "C"	Proposed
Beam (ft)	2.035	2.17	2.17	2.17	2.17	2.17
Length of forebody ÷ beam	4.28	4.70	4.70	4.49	4.49	4.70
Length of afterbody ÷ beam	3.85	3.50	3.50	3.71	3.71	3.71
Total length of float ÷ beam	8.13	8.20	8.20	8.20	8.20	8.41
Height of float ÷ beam	0.85	0.90	0.90	0.90	0.90	0.90
Step depth at keel ÷ beam |%|	2.38	With fairing	7.69	4.21	7.69	5.00
C.G. Position: Distance forward of step, parallel to keel datum ÷ beam	0.40	0.61	0.61	0.40	0.40	0.40
C.G. Position: Height above keel datum ÷ beam	2.62	2.38	2.38	2.38	2.38	2.38
Track of floats ÷ beam	3.11	2.98	2.98	2.98	2.98	3.20
Maximum cross sectional area ÷ beam x height of float	0.71	0.74	0.74	0.74	0.74	0.74
Forebody deadrise at step	25°	25°	25°	25°	25°	25°
After keel angle to forebody keel	5.75°	9°	9°	9°	7°	7°
Keel angle to fuselage datum	-4.5°	-3°	-3°	-3°	-3°	-3
Angle of mean chord to fuselage datum	2.8°	2.8°	2.8°	2.8°	2.8°	2.8°
C_{Δ_o} at Light weight (1720 lb)	1.59	1.42	1.42	1.42	1.42	1.42
C_{Δ_o} at Overload weight (1920 lb)	1.78	1.58	1.58	1.58	1.58	1.58
Reserve of Buoyancy at Light Weight (1720 lb)	106%	124%	123%	122%	126%	154%
Reserve of Buoyancy at Overload weight (1920 lb)	83%	102%	101%	100%	104%	129%
Reserve of Buoyancy at $C_{\Delta_o} = 1.5$	118%	112%	111%	110%	114%	140%
Volume of float ÷ (beam)^3	3.26	3.18	3.17	3.16	3.20	3.60
Forebody volume ÷ afterbody volume	-	2.74	-	2.24	2.17	1.83
Volume of float ÷ max. cross sectional area x total length	0.666	0.584	-	0.58	0.586	0.642

TABLE IV (Contd.) COMPARISON OF FLOAT TESTED AND SOME DETAILS OF RELATIVE WATER PERFORMANCE

	Queen Bee Floats	R.A.E. Floats			
		First Version	Modification "A"	Modification "B"	Modification "C"
	Take - off at overload - Flaps 20°				
Maximum attitude (relative to keel datum) on stability limit with 7° distur.	7.7°	12.7°	10.8°	9.5°	9°
Corresponding (Speed (knots)	26.25	20.5	21.0	21.0	21.0
Corresponding (Incidence of mean chord	15°	18.5°	16.6°	15.3°	14.8°
Maximum attitude (relative to keel datum) on stability limit without distur.	7.7°	12.5°	10.0°	9.3°	6.2°
Corresponding (Speed (Knots)	26.25	21.0	21.0	21.0	26.25
Corresponding (Incidence of mean chord	15°	18.3°	15.8°	15.1°	12.0°
Maximum attitude (Relative to keel datum) for elevator position $\eta = 0^\circ$	9.25°	12.4°	11.8°	11.8°	10.4°
Corresponding (Speed (knots)	20.00	16.0	16.5	17.0	18.0
Corresponding (Incidence of mean chord)	16.55	18.2°	17.6°	17.6°	16.2°
	Landing at overload - Flaps 20°				
Maximum attitude (relative to keel datum) on stability limit with 7° distur.	-	-	-	-	5.25°
Corresponding (Speed (knots)	-	-	-	-	32.0°
Corresponding (Incidence of mean chord	-	-	-	-	11.05°
Maximum attitude (relative to keel datum) for elevator position $\eta = 0^\circ$	-	-	-	-	9.75°
Corresponding (Speed (knots)	-	-	-	-	25.0
Corresponding (Incidence of mean chord	-	-	-	-	15.55°
	Landing at light load - Flaps 20°				
Maximum attitude (relative to keel datum) on stability limit without distur.	6.8°	11.25°	-	-	-
Corresponding (Speed (knots)	26.2	21.0	-	-	-
Corresponding (Incidence of mean chord	14.5°	17.05°	-	-	-
Maximum attitude (relative to keel datum) for elevator position $\eta = 0^\circ$	8.0°	14.1°	-	-	-
Corresponding (Speed (knots)	19.0	16.0	-	-	-
Corresponding (Incidence of mean chord	15.3°	19.9°	-	-	-

TABLE V

SEAWORTHINESS IN WAVES, C_{Δ_0} = 1.58

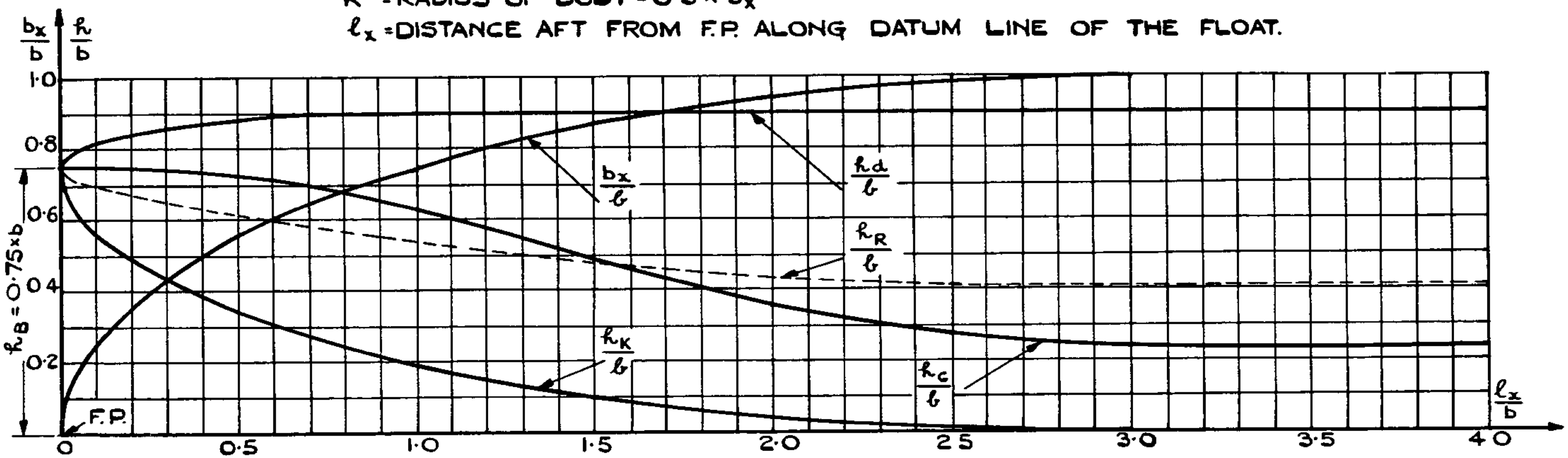
Wave	Speed knots									
	0	5.3	10.6	13.2	15.9	18.5	21.2	26.5	31.8	37.1	42.4
No Wave	Very Clean	Very Clean	Clean	Clean	Spray due to blister interference between the two floats slightly hits undersurface of central and aft part of fuselage			Clean	Very Clean	Very Clean	Very Clean
I	As Above	As Above	Improvement in spray conditions due to reduction of the interference between the two floats.						As Above	As Above	As Above
II	As Above	As Above	As Above						As Above	As Above	As Above
III (Fig. 12)	As Above	As Above	Clean	Clean	Spray due to blister interference between the two floats slightly hits undersurface of fuselage			Clean	Clean	Clean	Bouncing
		Photo. 1-5	Photo. 6-10	Photo. 11-15	Photo 16-20	Photo. 21-26	Photo. 27-32	Photo 33-38			Photo. 39.44
IV (Fig. 13)	As above	As Above	As Above	As Above	As Above			Slightly Wetted aft under-surface of fuselage	As Above	Bouncing	As Above
	Photo. 45-54	Photo. 55-60	Photo. 61-66	Photo. 67-72	Photo. 73-78	Photo. 79-84	Photo. 85-90	Photo. 91-96	Photo. 97-102	Photo. 103-108	Photo. 109-114

TABLE VI

AFT TAXYING PERFORMANCE ($C_{\Delta_o} = 1.58$)

Speed Knots	Nature of taxying without disturbances	Effect of small disturbances (bow up and down)	Effect of large disturbances
2.7	Attitude of taxying similar to normal taxying	Very steady. No tendency to change attitude.	Very steady. No tendency to change attitude.
5.3	As above	As above	As above
6.6	As above	As above	As above
8.0	As above	As above	Slight tendency to dive(bow up)
10.6	Running with bow slightly down.	Slight tendency to dive (bow up).	Tendency to dive (bow up).
13.2	Running with bow down. Rear step clear of water. Spray hits propeller.	As above	Diving (bow up).
15.9	As above	Dangerous tendency to dive (bow up).	Diving (bow up)

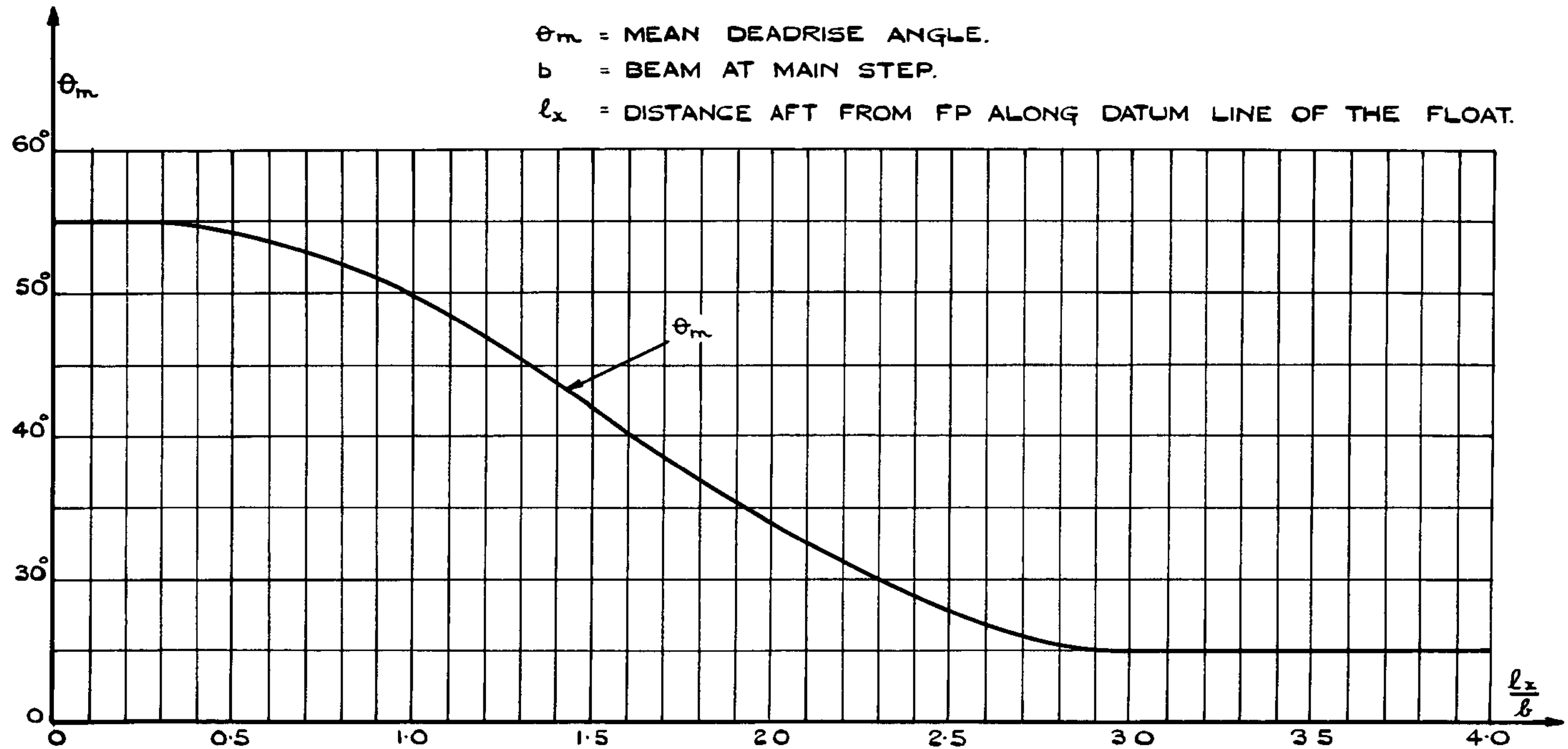
b = BEAM AT MAIN STEP.
b_x = LOCAL BEAM.
h_K = KEEL HEIGHT ABOVE FLOAT DATUM.
h_C = CHINE HEIGHT ABOVE FLOAT DATUM.
h_R = HEIGHT OF RADIUS CENTRE ABOVE FLOAT DATUM.
h_D = HEIGHT OF DECK ABOVE FLOAT DATUM.
h_B = BOW HEIGHT ABOVE FLOAT DATUM = $0{\cdot}75 \times b$
R = RADIUS OF BODY = $0{\cdot}5 \times b_x$
ℓ_x = DISTANCE AFT FROM F.P. ALONG DATUM LINE OF THE FLOAT.



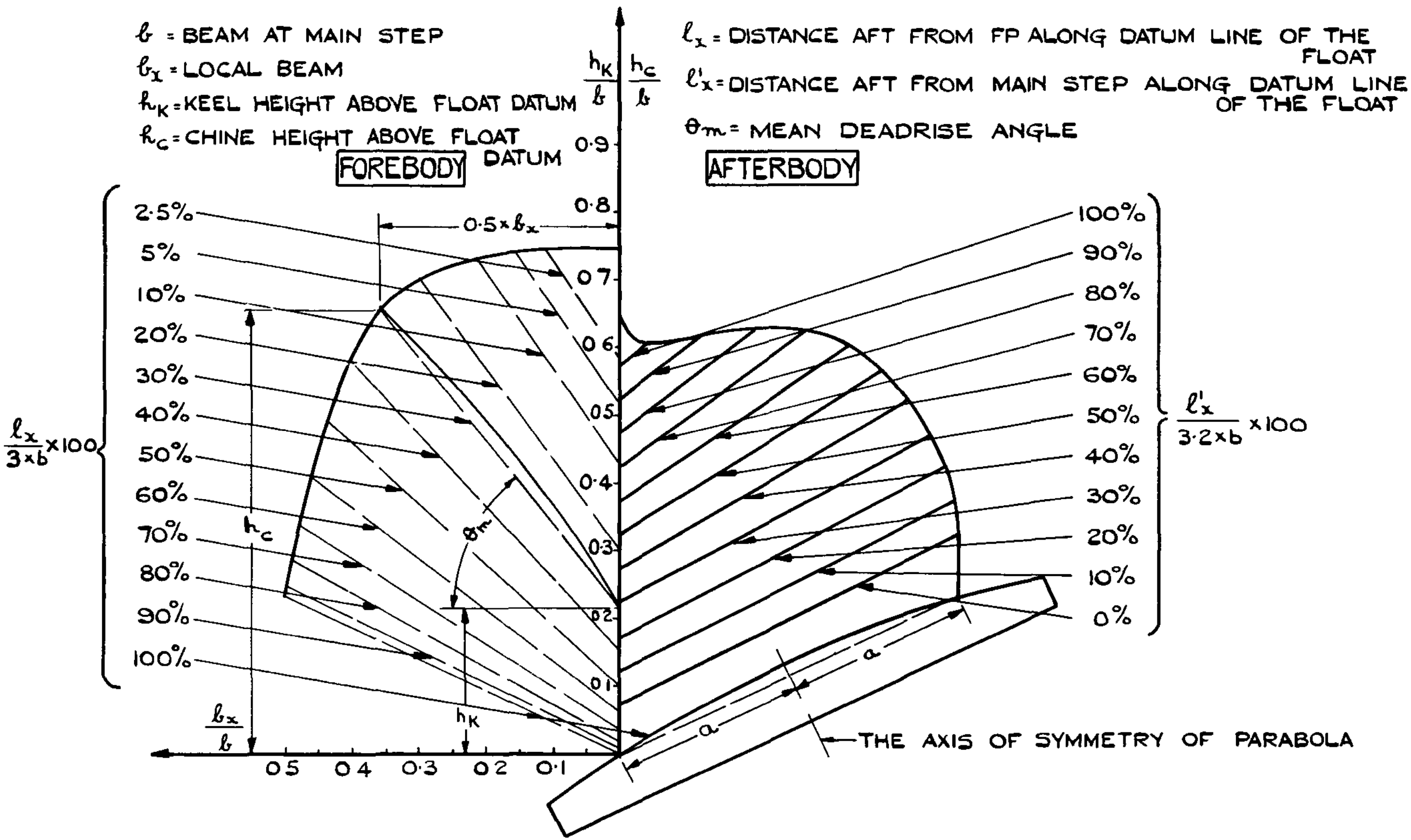
THE GEOMETRY OF THE FOREBODY EXPRESSED NON-DIMENSIONALLY.

FIG.1.
SHEET 1

FIG. 1.
SHEET 2.



FOREBODY DEADRISE DISTRIBUTION.

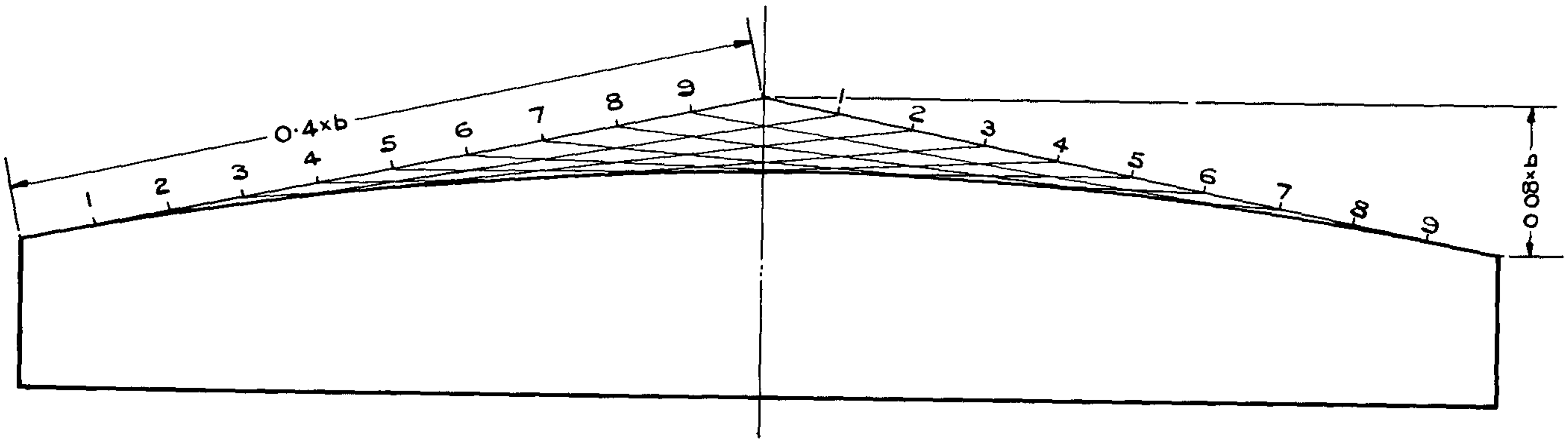


DETERMINATION OF THE BOTTOM OF THE FLOAT.

FIG. 1.
SHEET 3

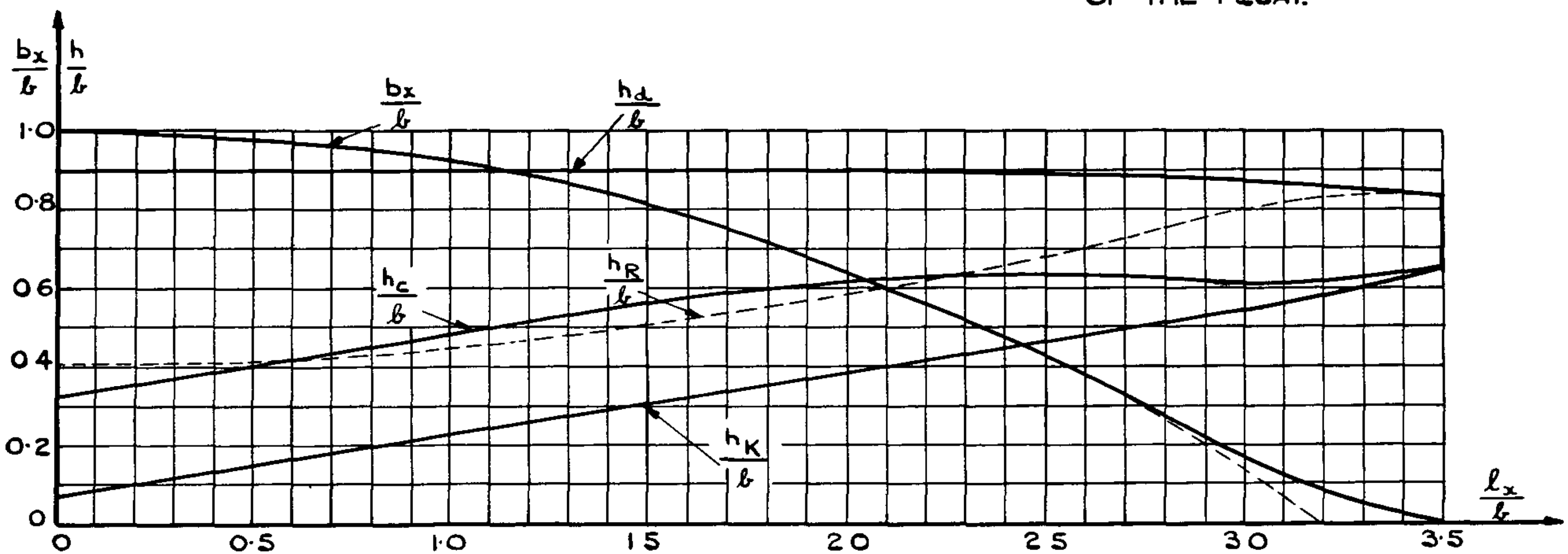
FIG. 1.
SHEET 4

b = BEAM AT MAIN STEP



THE FOREBODY BOTTOM CURVE.

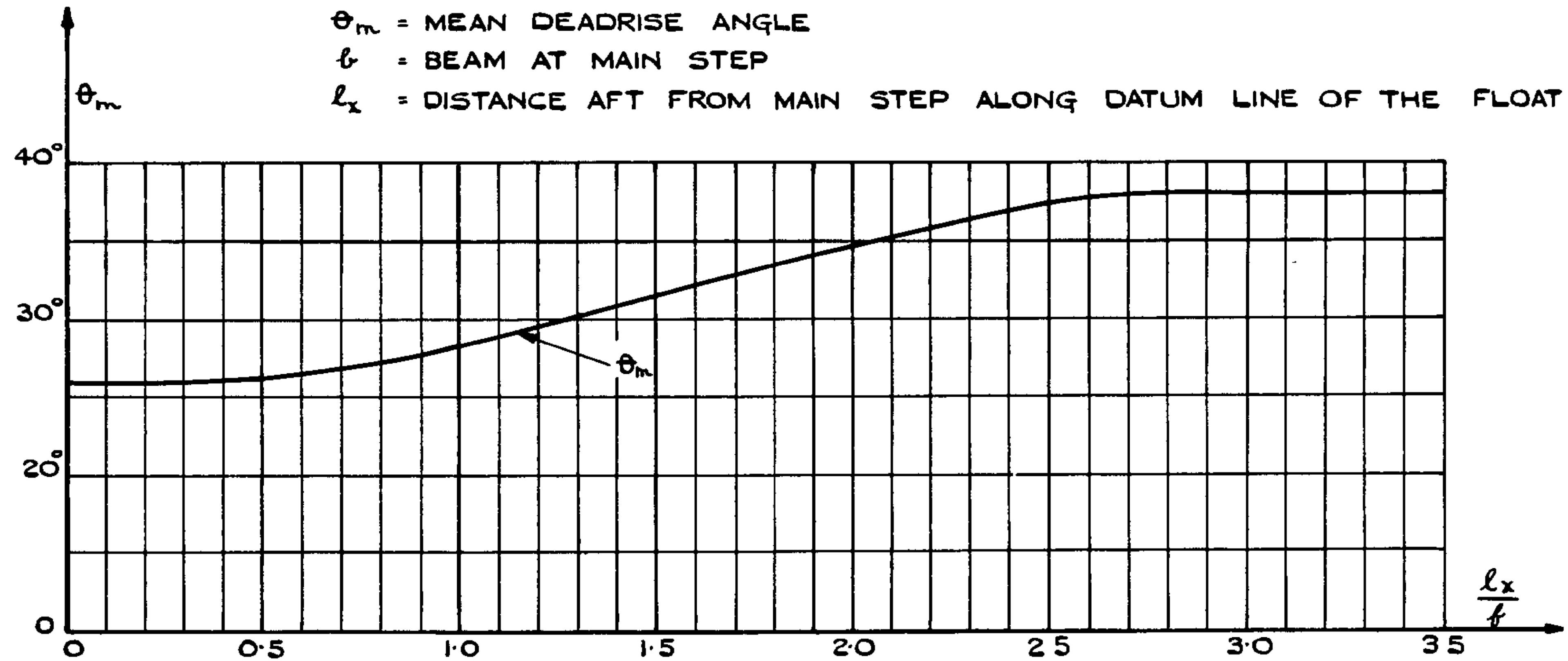
b = BEAM AT MAIN STEP.
b_x = LOCAL BEAM
h_K = KEEL HEIGHT ABOVE FLOAT DATUM
h_c = CHINE HEIGHT ABOVE FLOAT DATUM.
h_R = HEIGHT OF RADIUS CENTRE ABOVE FLOAT DATUM.
h_D = HEIGHT OF DECK ABOVE FLOAT DATUM
R = RADIUS OF BODY = $0.5 \times b_x$.
ℓ_x = DISTANCE AFT FROM MAIN STEP ALONG DATUM LINE OF THE FLOAT.



THE GEOMETRY OF THE AFTERBODY EXPRESSED NON-DIMENSIONALLY.

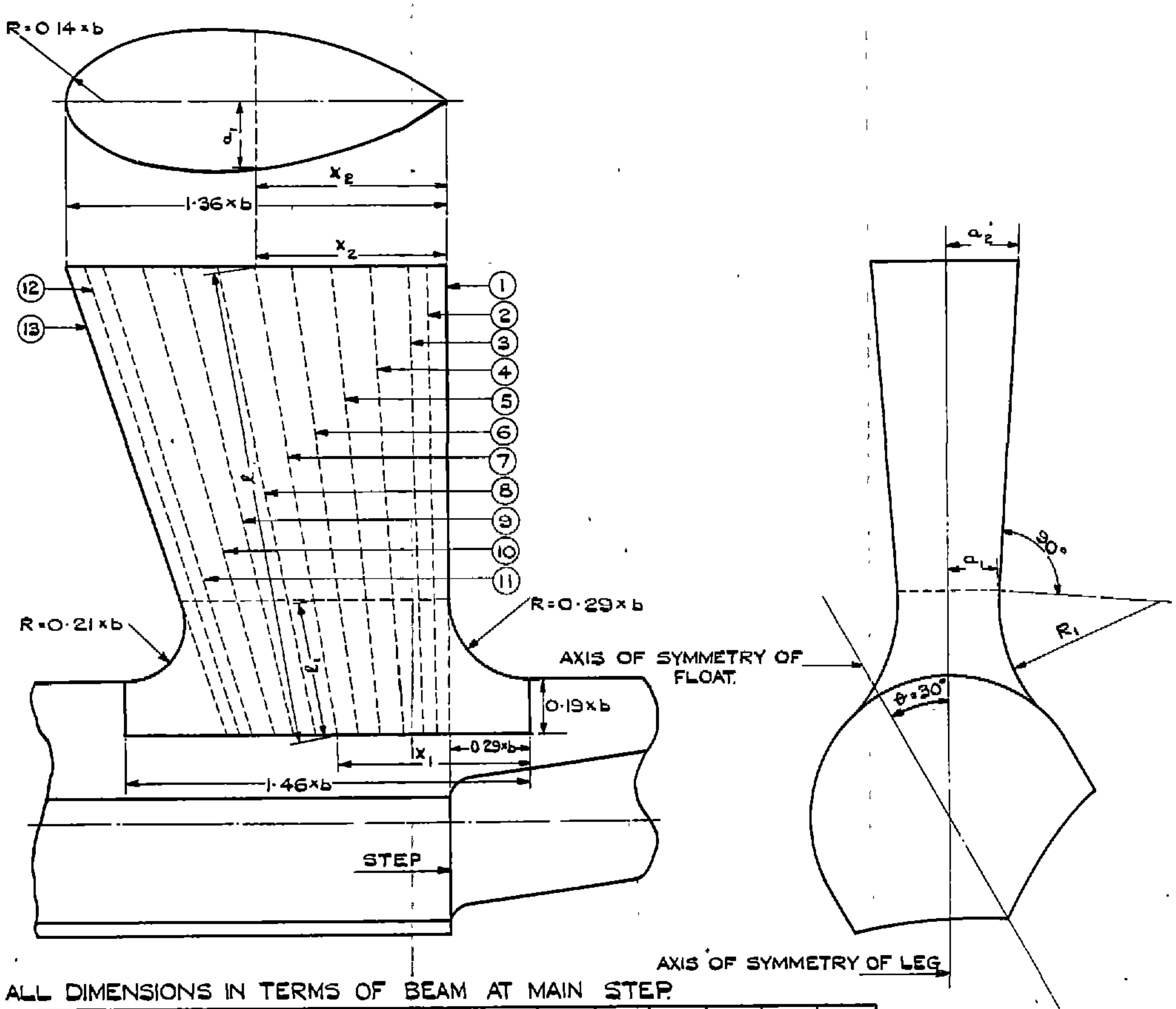
FIG. 1.
SHEET 5

FIG. 1.
SHEET 6.



AFTERBODY DEADRISE DISTRIBUTION.

FIG. 1.
SHEET 7.

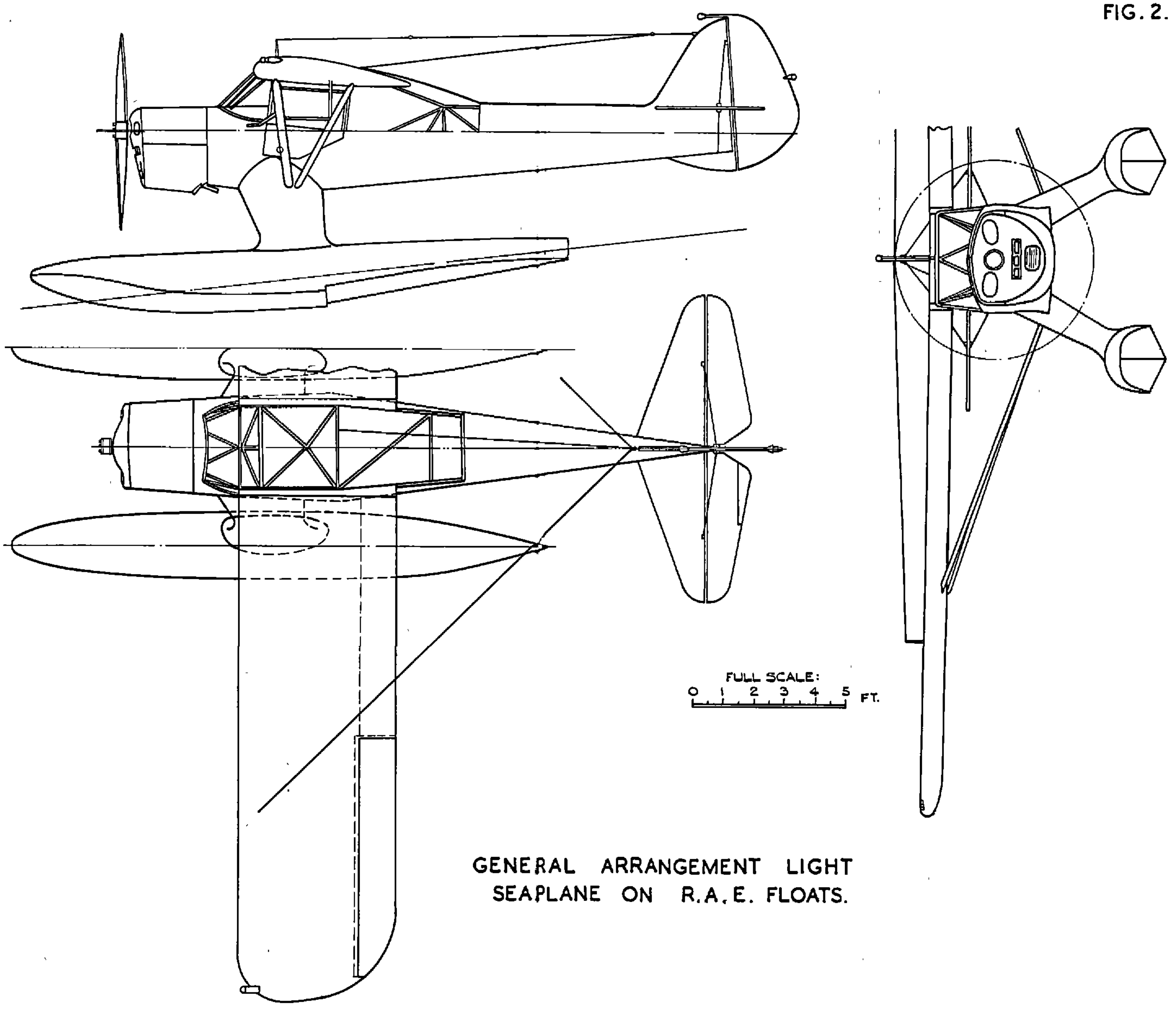


ALL DIMENSIONS IN TERMS OF BEAM AT MAIN STEP.

STATION	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
$x_1 : b$	0·29	0·33	0·37	0·45	0·52	0·60	0·68	0·76	0·84	0·92	1·00	1·04	1·08
$x_2 : b$	0·00	0·07	0·14	0·27	0·41	0·55	0·68	0·82	0·95	1·09	1·23	1·30	1·36
$\ell : b$	1·67	1·67	1·68	1·68	1·69	1·70	1·71	1·72	1·73	1·74	1·75	1·79	–
$\ell_1 : b$	0·48	0·48	0·48	0·48	0·49	0·49	0·49	0·49	0·50	0·50	0·51	0·51	–
$R_1 : b$	–	0·39	0·42	0·47	0·51	0·53	0·56	0·57	0·57	0·55	0·53	0·52	–
$a_1 : b$	–	0·03	0·06	0·11	0·14	0·16	0·18	0·18	0·17	0·15	0·12	0·09	–
$a_2 : b$	–	0·05	0·09	0·15	0·20	0·23	0·25	0·26	0·25	0·22	0·17	0·12	–

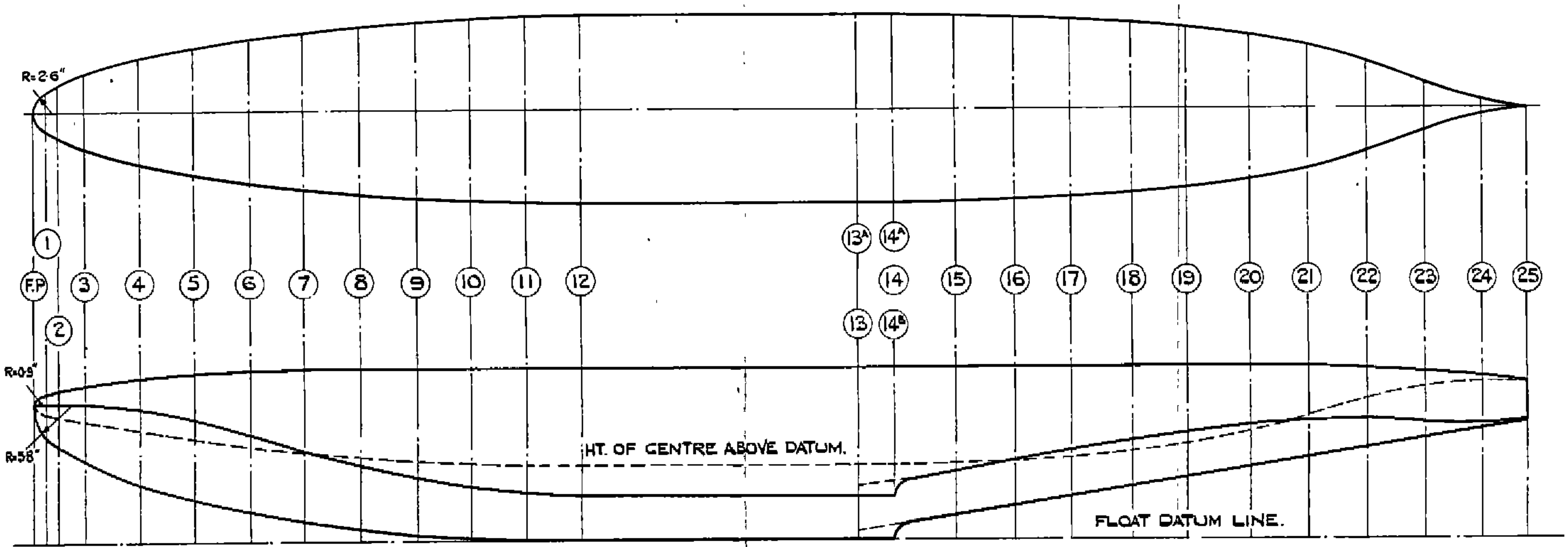
GENERAL ARRANGEMENT OF FLOAT ATTACHMENT.

FIG. 2.



GENERAL ARRANGEMENT LIGHT SEAPLANE ON R.A.E. FLOATS.

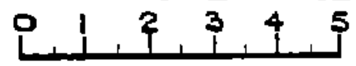
FIG. 3.
SHEET 1.

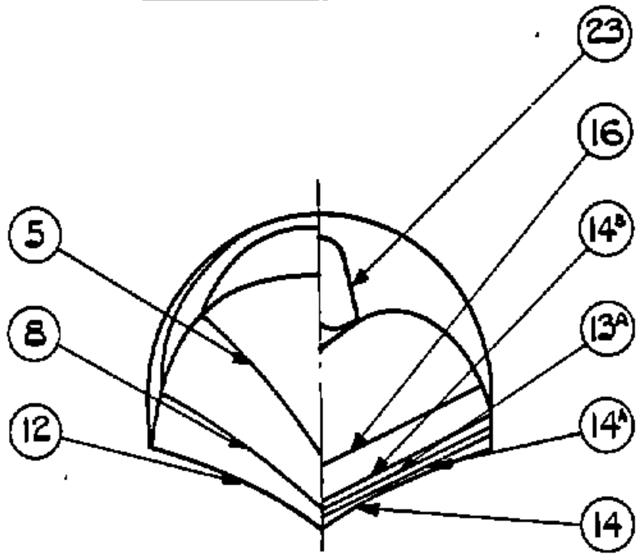


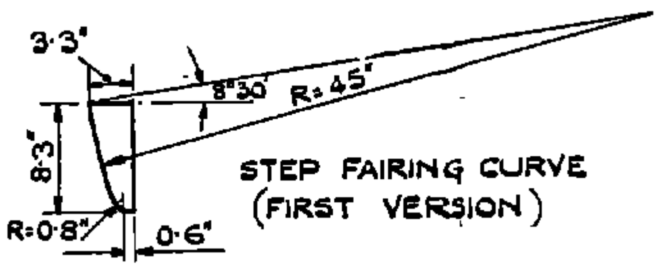
ALL DIMENSIONS IN INCHES

TYPE OF FLOAT		FOREBODY. THE SAME FOR ALL TYPES OF FLOATS														FIRST VERS. AND MOD."A"	AFTERBODY. MOD."B"	FIRST VERSION	MOD. "A" AND "B"	THE SAME FOR ALL TYPES OF FLOATS										
STATION F.P.	Nº	F.P.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	13A	14A	14B	15	16	17	18	19	20	21	22	23	24	25
DISTANCE AFT OF F.P.	ℓ_x	THE SAME AS MODIFICATION "C".															THE SAME AS MODIFICATION "C"													
KEEL Ht.	h_K															THE SAME AS STATION 13.	1·10	0·60	2·00	3·30	4·60	5·90	7·20	8·50	9·80	12·10	12·40	13·70	15 00	17·10
CHINE Ht.	h_c																7·40	6·95	8·35	9·55	10·85	12·25	13·65	14·75	15·70	16·20	16·35	16·01	15 80	17·10
CHINE HALF BREADTH	$\frac{\ell_x}{2}$																						11·20	10·10	8·75	7·05	5·20	3·05	1·05	
Ht. OF CENTRE ABOVE DATUM	h_R																THE SAME AS MODIFICATION "C".													
RADIUS OF BODY	R																													
	a																FLAT BOTTOM													

1:5 MODEL SCALE







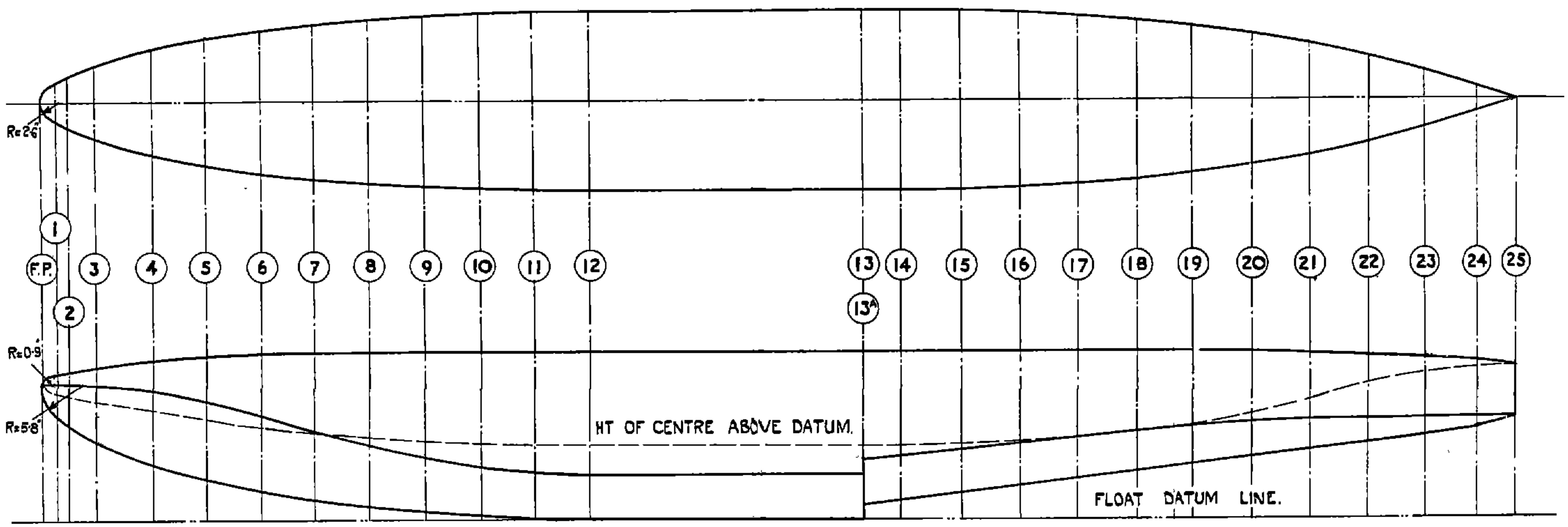
STEP FAIRING CURVE
(FIRST VERSION)

R.A.E. FLOAT LINES
FIRST VERSION AND MODIFICATIONS "A" AND "B".

SCALE - 1/15.

DIMENSIONS GIVEN IN INCHES; FULL SCALE.

FIG. 3.
SHEET 2.

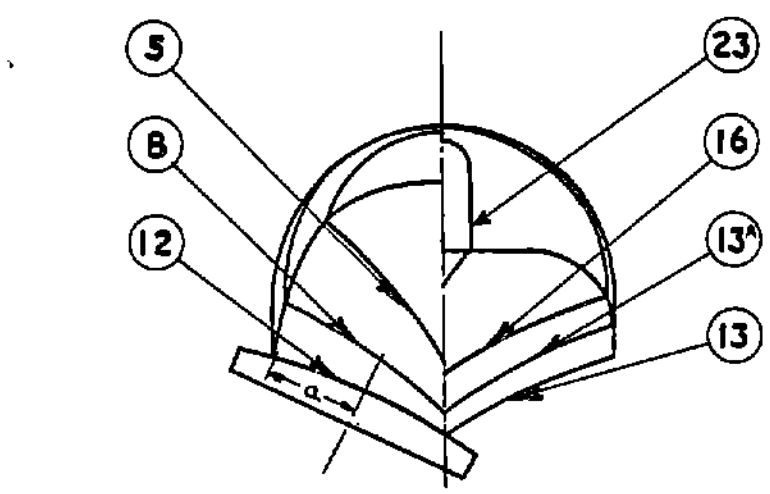


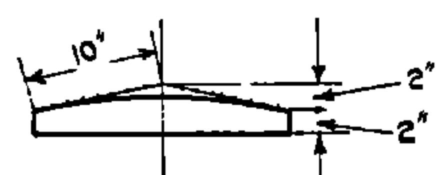
ALL DIMENSIONS IN INCHES.

STATION F.P.	Nº	FOREBODY. F.P.	1	2	3	4	5	6	7	8	9	10	11	12	13
DISTANCE AFT OF F.P.	ℓ_x	0·00	1·95	3·90	7·80	15·60	23·40	31·20	39·00	46·80	54·60	62·40	70·20	78·00	116·50
KEEL Ht	h_K	19·50	15·20	13·40	11·00	7·80	5·60	3·90	2·60	1·60	0·90	0·40	0·10	0·00	0·00
CHINE Ht	h_c	19·50	19·40	19·30	19·10	18·40	17·00	14·80	12·60	10·50	8·80	7·35	6·50	6·20	6·20
CHINE HALF BREADTH	$\frac{b_x}{2}$	0·00	1·85	4·05	5·65	7·80	9·25	10·40	11·25	11·90	12·40	12·70	12·95	13·00	13·00
Ht OF CENTRE ABOVE DATUM	h_R	19·50	18·05	17·45	16·70	15·40	14·25	13·10	12·25	11·60	11·10	10·80	10·55	10·50	10·50
RAD. OF BODY	R	0·00	1·85	4·05	5·65	7·80	9·25	10·40	11·25	11·90	12·40	12·70	12·95	13·00	13·00
	a	0·00	1·55	3·60	4·95	6·55	7·35	7·60	7·55	7·50	7·40	7·25	7·25	7·25	7·25

STATION F.P.	Nº	AFTERBODY. 13A	14	15	16	17	18	19	20	21	22	23	24	25
DISTANCE AFT OF F.P.	ℓ_x	116·50	122·00	130·30	138·60	146·90	155·20	163·50	171·80	180·10	188·40	196·20	205·00	213·00
KEEL Ht	h_K	2·00	2·70	3·73	4·76	5·79	6·82	7·85	8·88	9·91	10·94	11·97	13·00	14·50
CHINE Ht	h_c	8·35	9·00	9·90	10·80	11·70	12·50	13·10	13·70	14·15	14·40	14·50	14·50	14·50
CHINE HALF BREADTH	$\frac{b_x}{2}$	13·00	13·00	12·80	12·45	12·00	11·50	10·50	9·50	8·00	6·20	4·00	1·60	0·00
Ht OF CENTRE ABOVE DATUM	h_R	10·50	10·50	10·70	11·05	11·50	12·30	13·40	14·70	16·35	18·10	20·00	21·45	21·75
RAD. OF BODY	R	13·00	13·00	12·80	12·45	12·00	11·20	10·10	8·75	7·05	5·20	3·05	1·05	0·00
	a	7·25	7·25	7·15	6·95	6·70	6·35	5·90	5·35	4·50	3·55	2·35	1·10	0·00

1:5 MODEL SCALE:
0 1 2 3 4 5 INCHES.





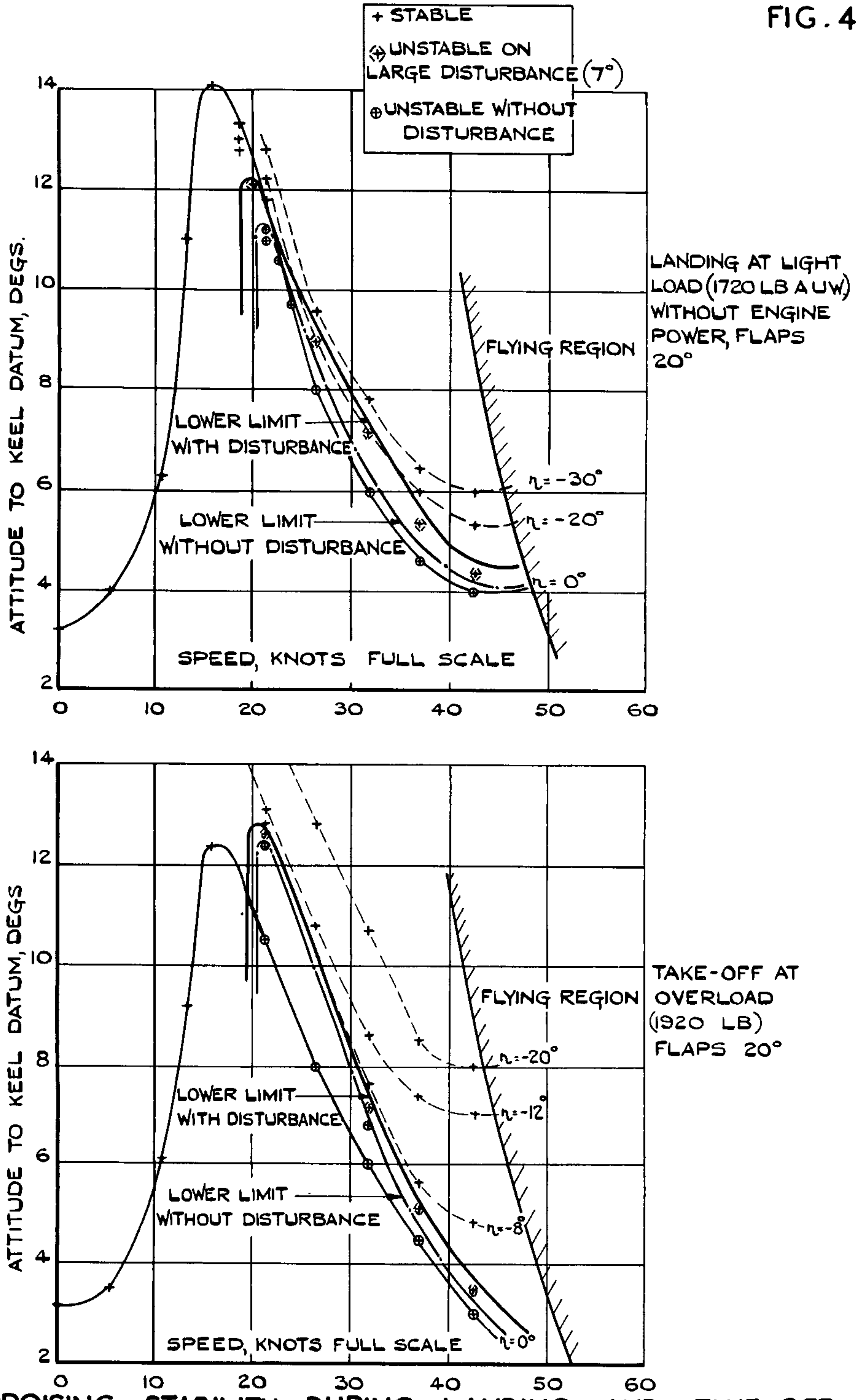
BOTTOM CURVE.

R.A.E. FLOAT LINES – MODIFICATION "C."

SCALE :- 1/15

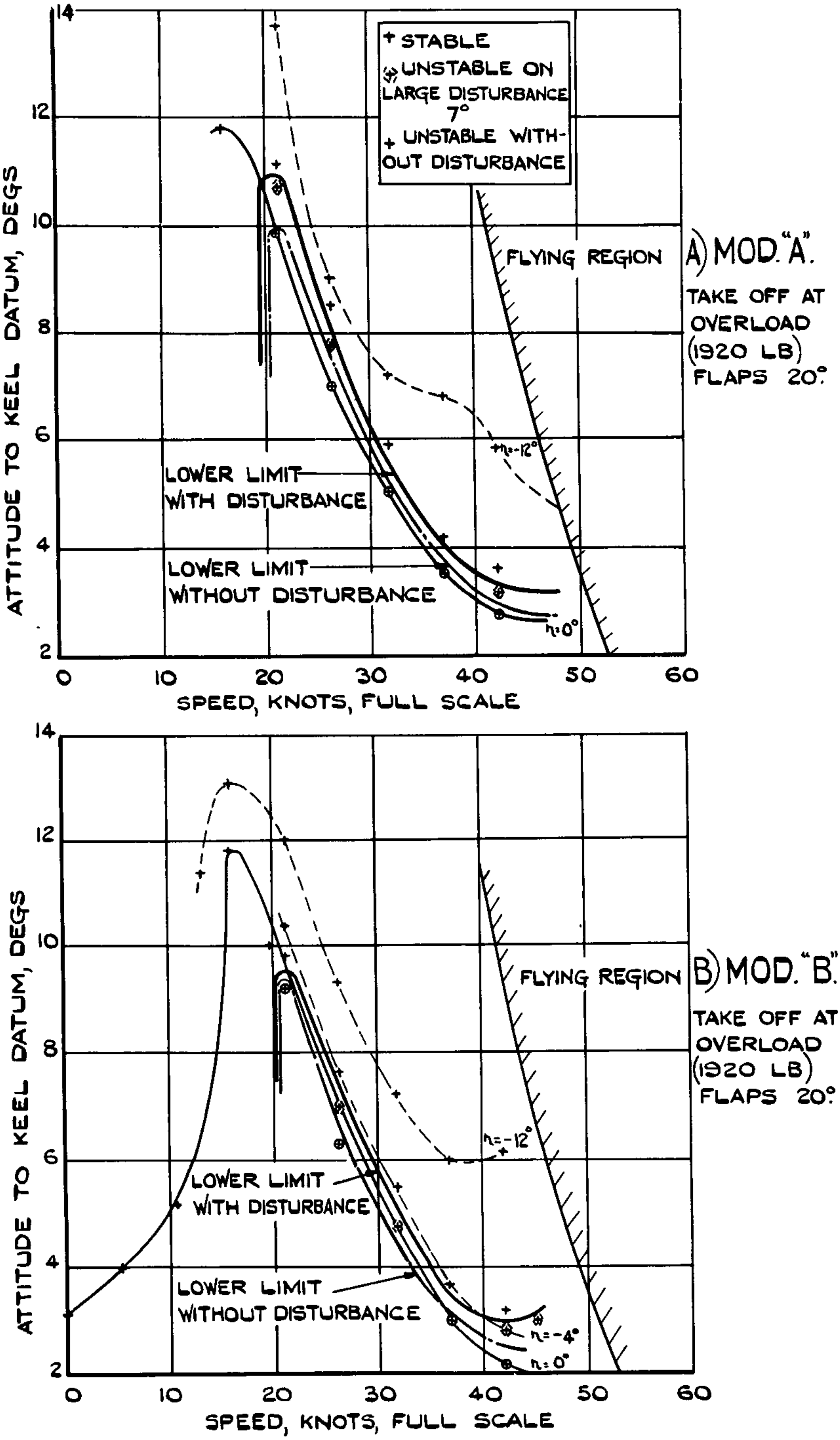
DIMENSIONS GIVEN IN INCHES FULL SCALE.

FIG. 4

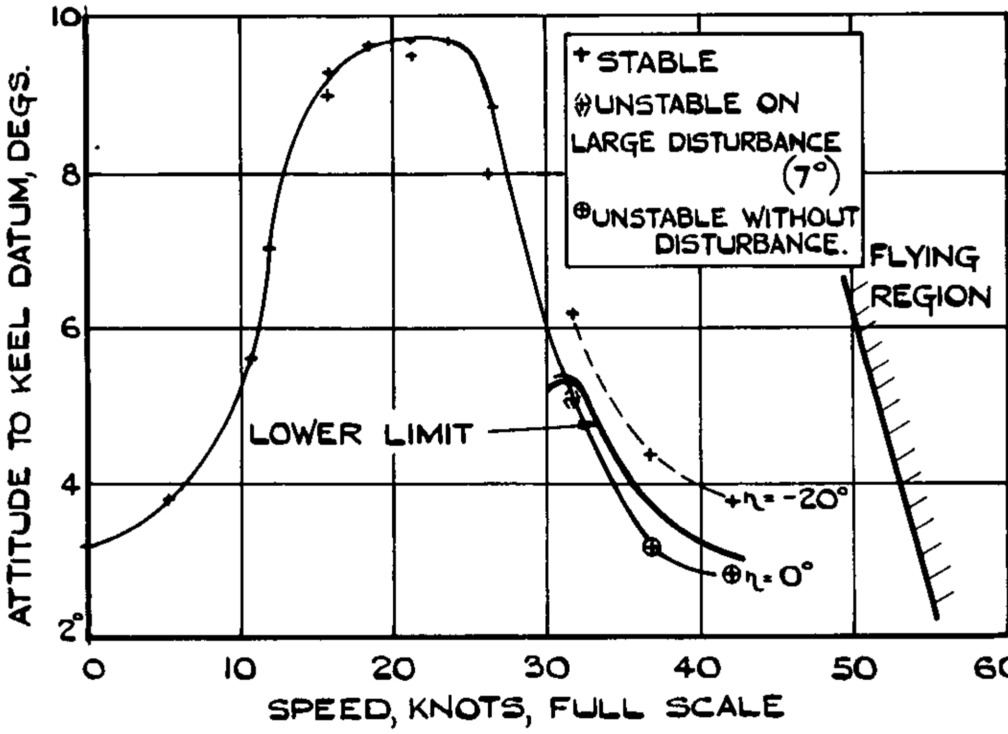


PORPOISING STABILITY DURING LANDING AND TAKE-OFF.
R.A.E. FLOATS - FIRST VERSION.

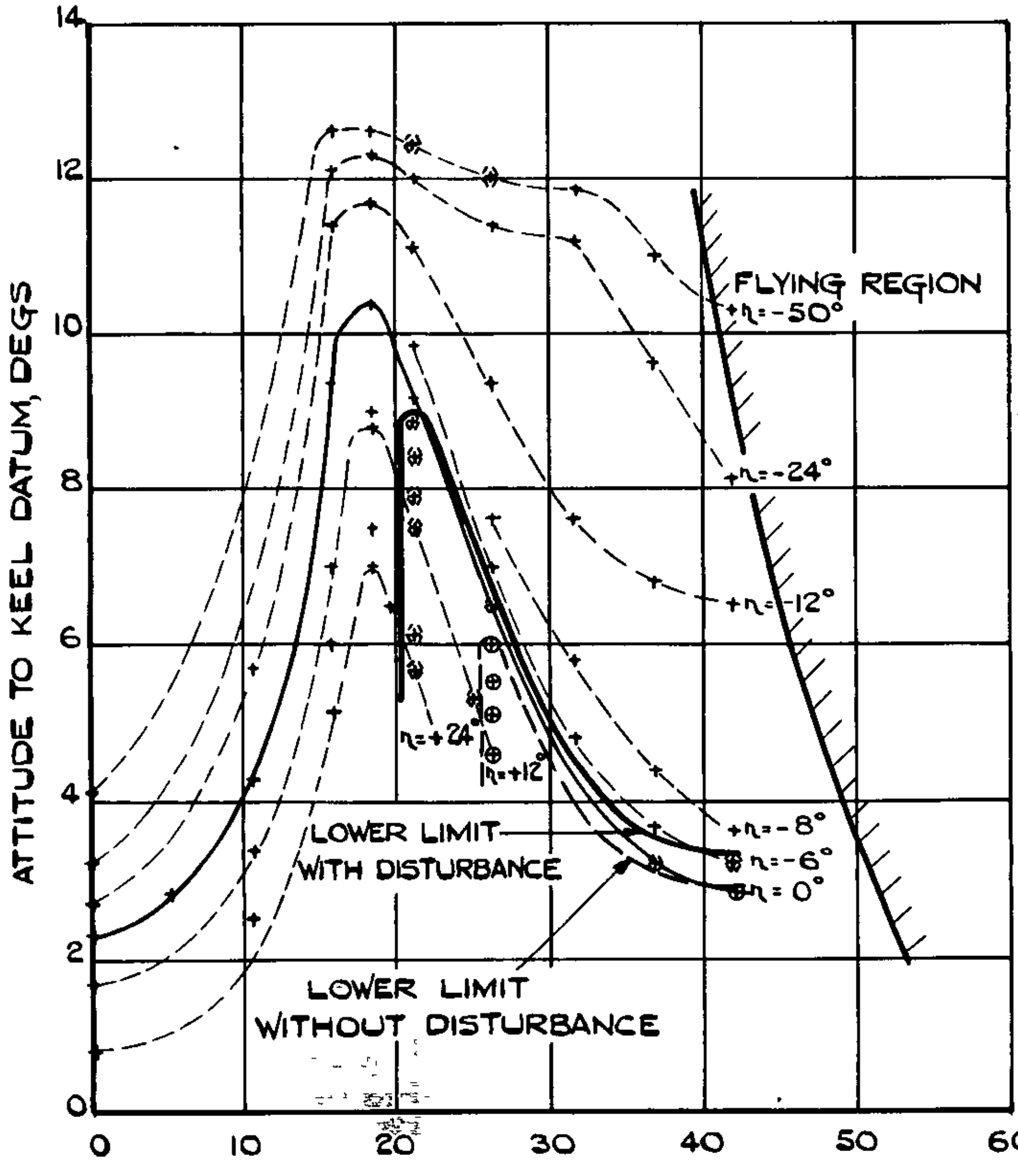
FIG. 5.



PORPOISING STABILITY DURING TAKE-OFF.
R.A.E. FLOATS - MOD. "A" AND "B".



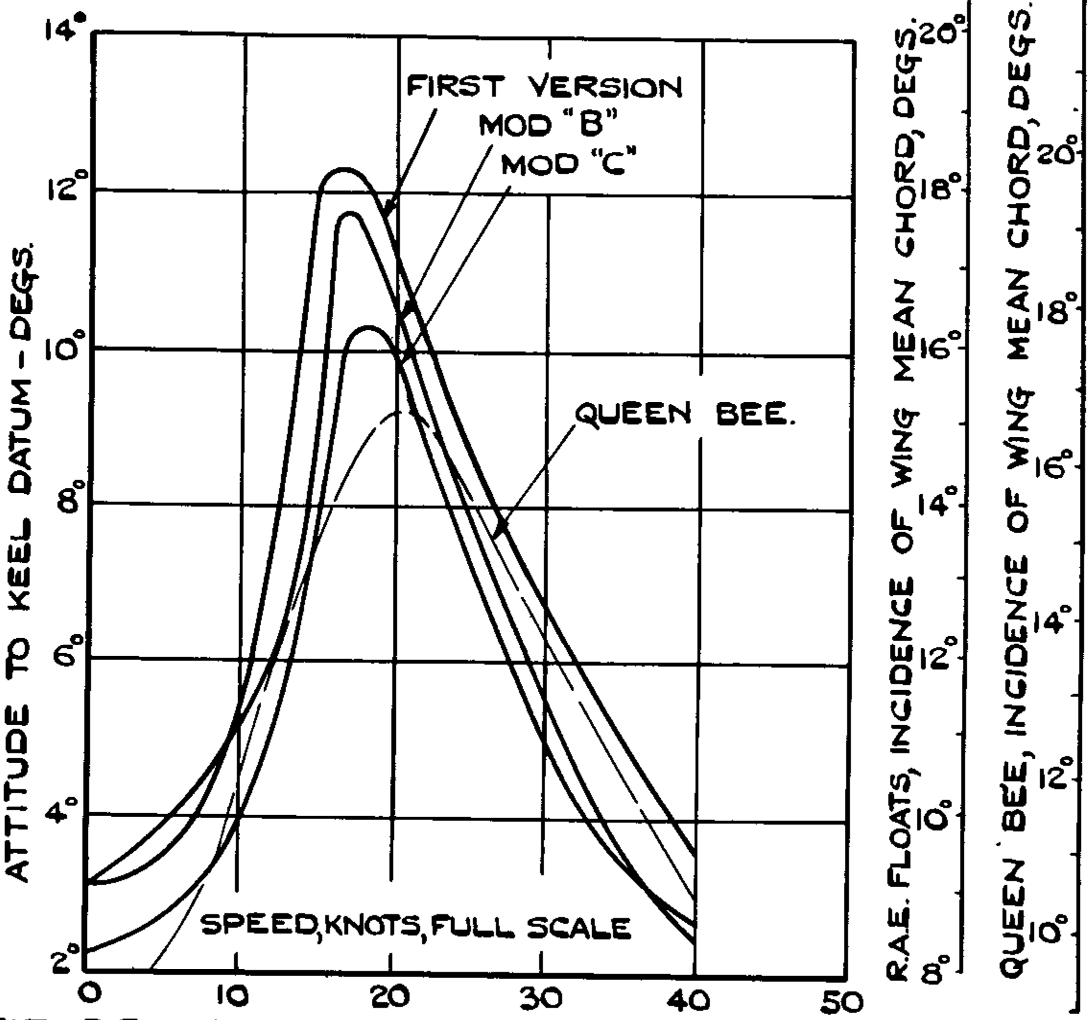
A) LANDING AT OVERLOAD (1920 LB.) WITHOUT ENGINE POWER, FLAPS 20°.



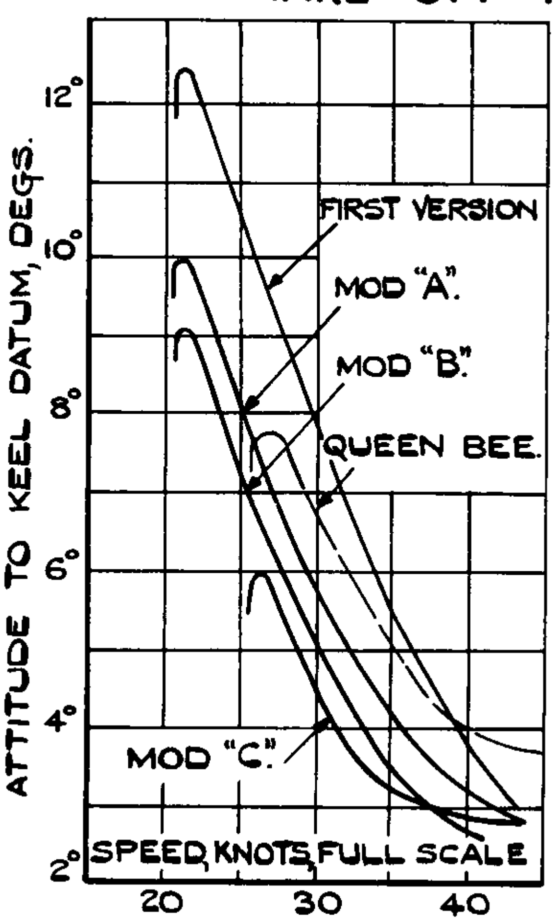
B) TAKE OFF AT OVERLOAD (1920 LB.) FLAPS 20°

PORPOISING STABILITY DURING LANDING AND TAKE OFF.
R.A.E. FLOATS - MOD. "C".

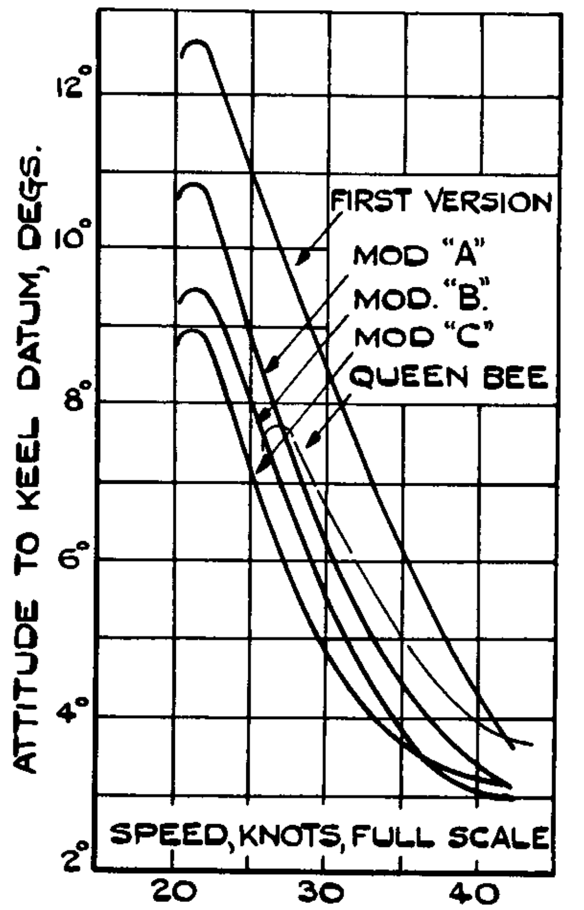
FIG. 7.



A) ATTITUDES WITH THE STICK CENTRAL DURING TAKE OFF AT OVERLOAD.

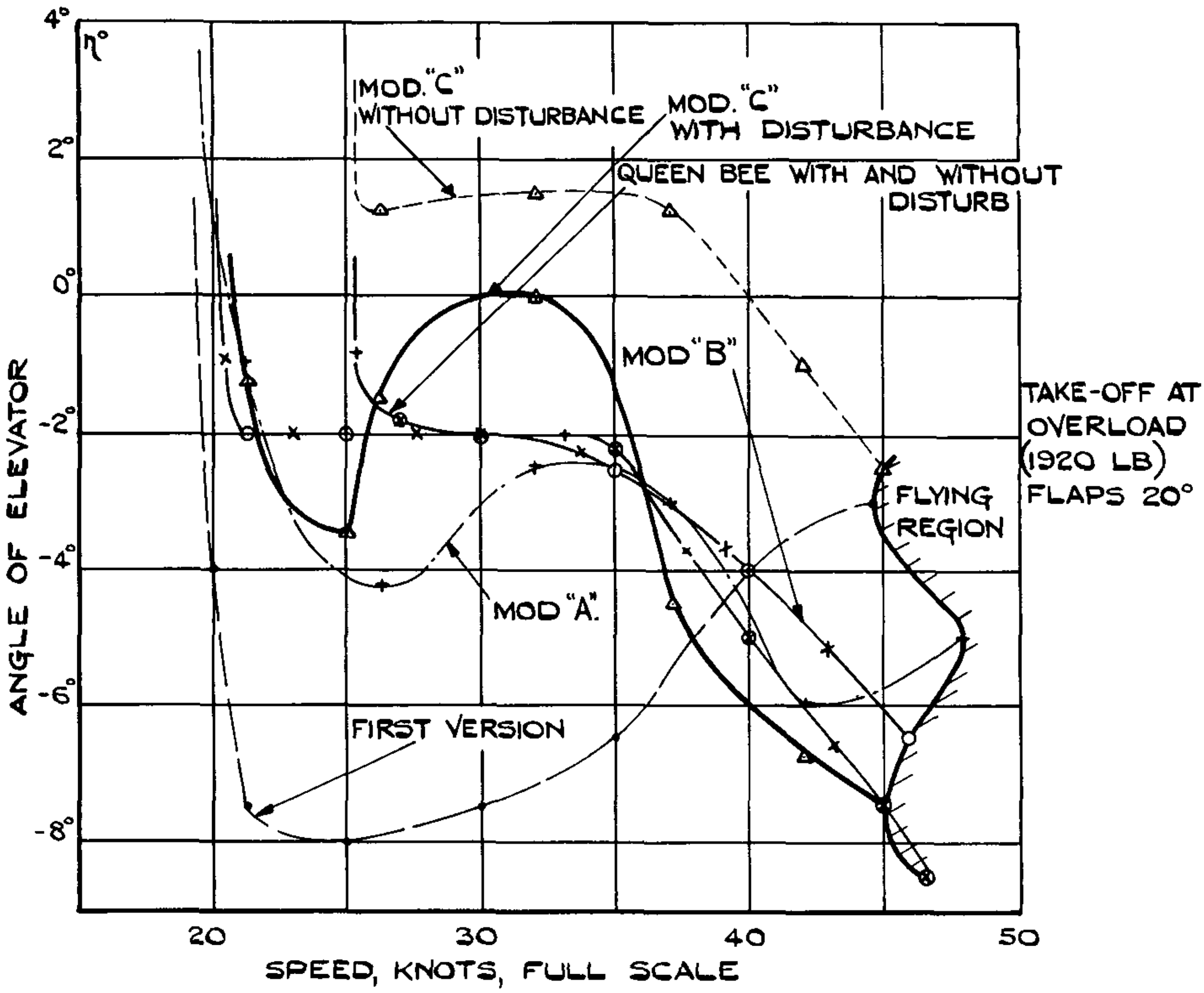


B) STABILITY LIMITS DURING TAKE-OFF AT OVERLOAD WITHOUT DISTURBANCE.

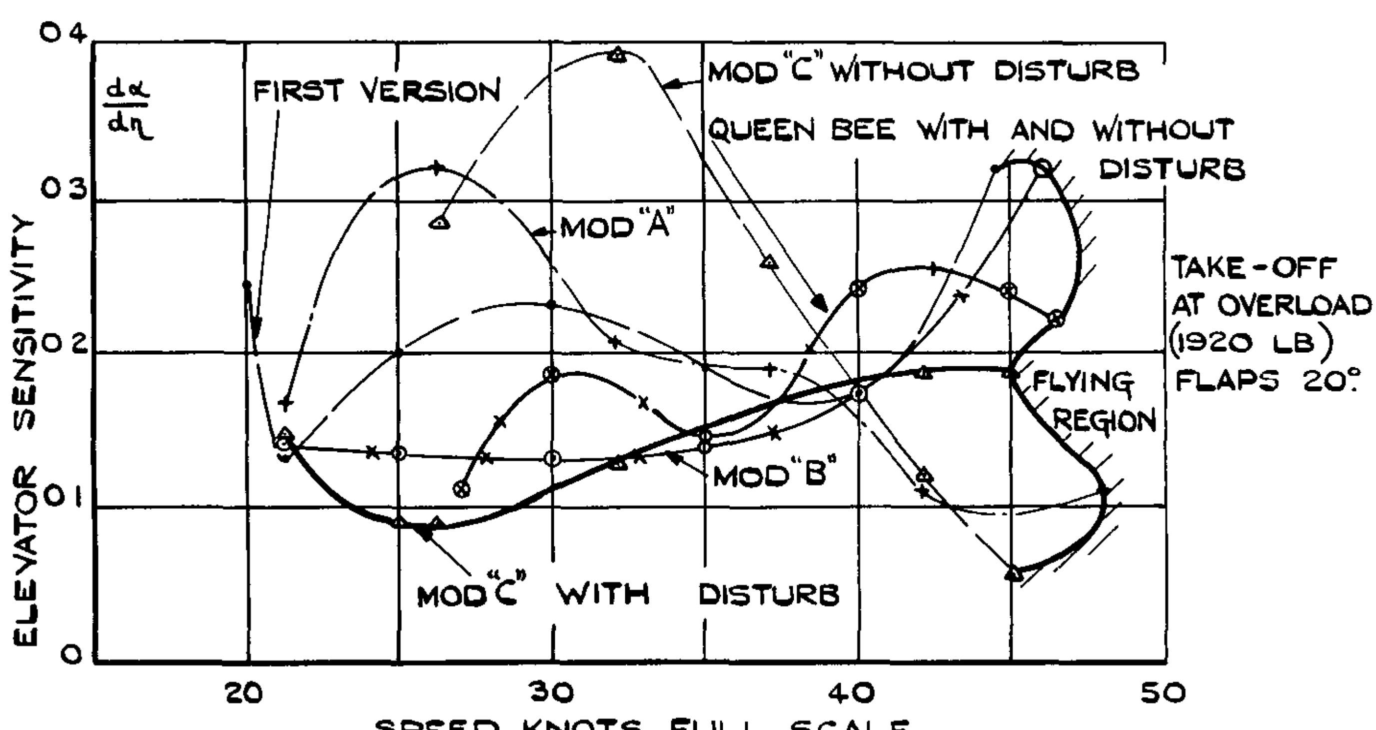


C) STABILITY LIMITS DURING TAKE-OFF AT OVERLOAD WITH 7° DISTURBANCE.

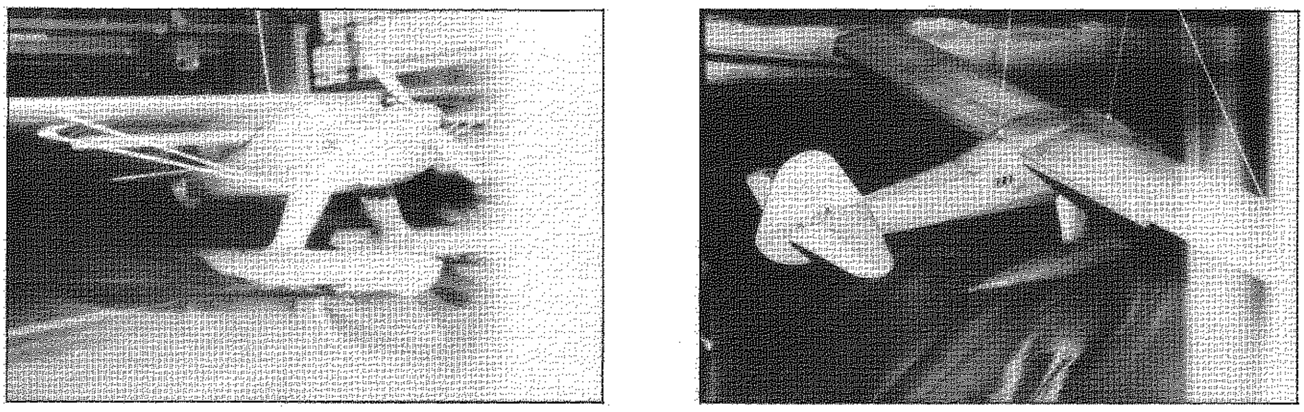
FIG 8.



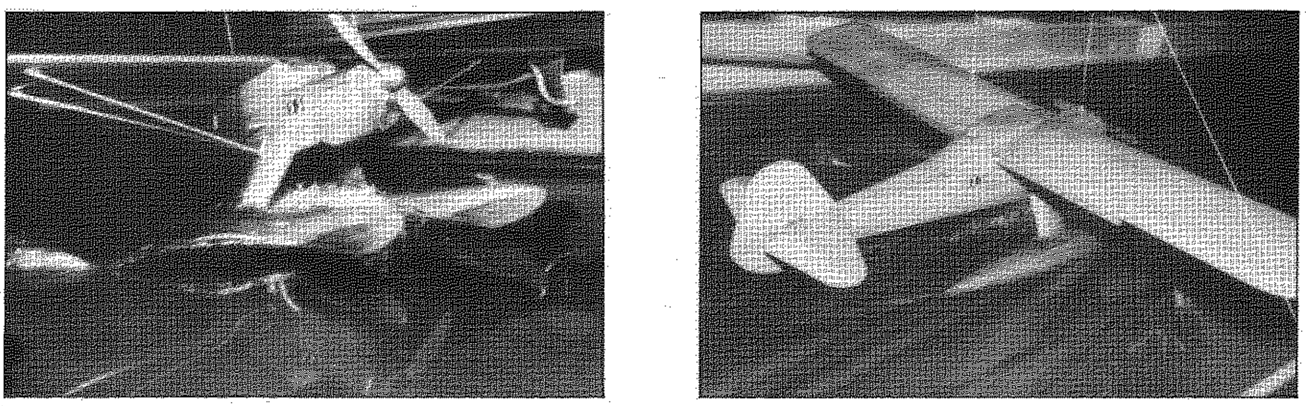
A) COMPARISON OF ANGLES OF ELEVATOR AT STABILITY LIMITS WITH DISTURBANCE.



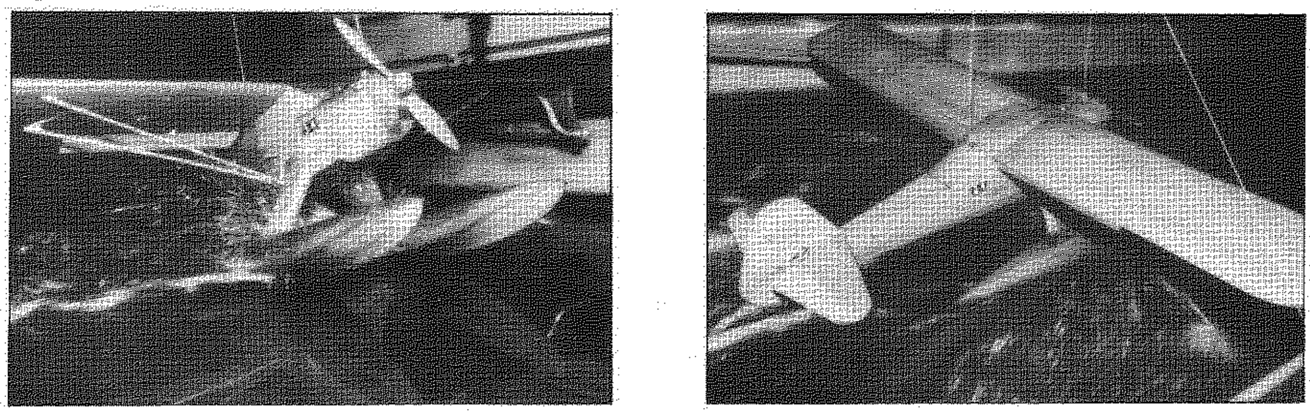
B) COMPARISON OF ELEVATOR SENSITIVITY AT STABILITY LIMITS WITH DISTURBANCE.



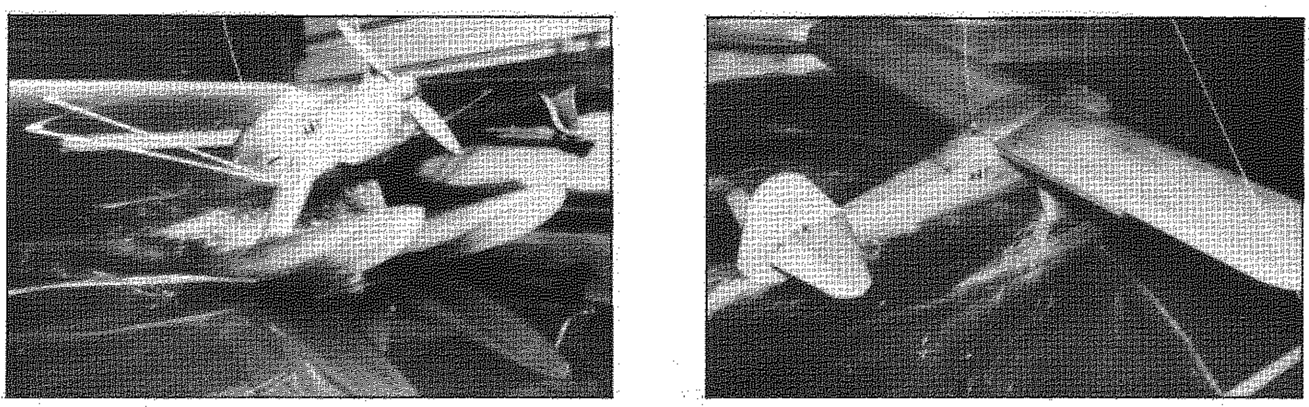
∝ KEEL 4°
5·3 KNOTS



∝ KEEL 6·3°
10·6 KNOTS

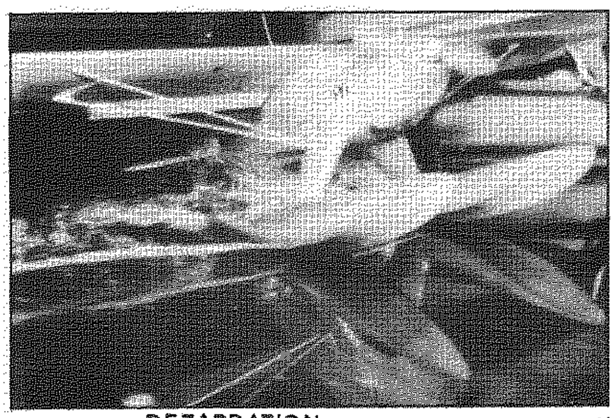


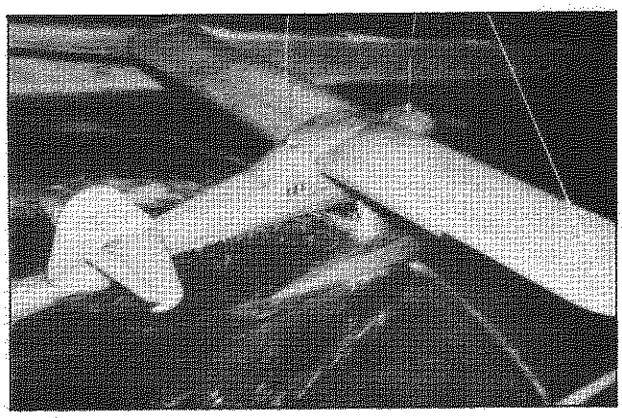
∝ KEEL 14·1°
15·9 KNOTS (HUMP SPEED)



∝ KEEL 11·8°
21·2 KNOTS

ELEVATOR ANGLE - ZERO IN ALL CASES
SPRAY CHARACTERISTICS ON CALM WATER
DURING LANDING AT LIGHT LOAD 1720 lb A.U.W.
R.A.E. FLOATS - FIRST VERSION

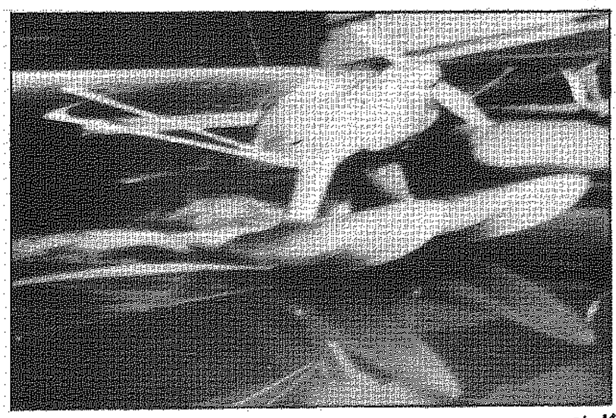


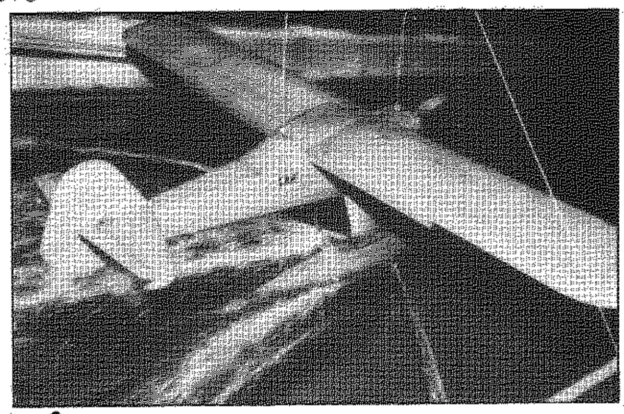


RETARDATION
0·15g

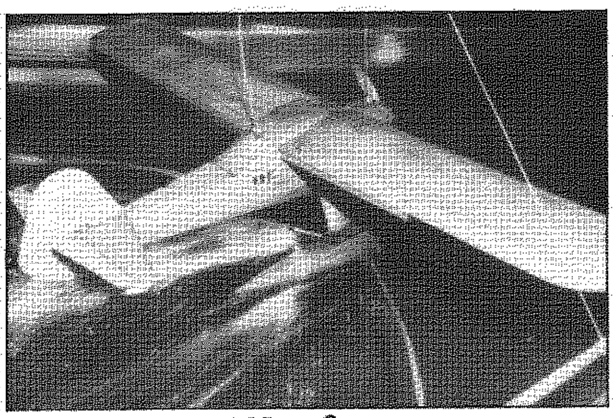
α KEEL 12·8°
η = -30°
21·2 KNOTS

CONSTANT SPEED

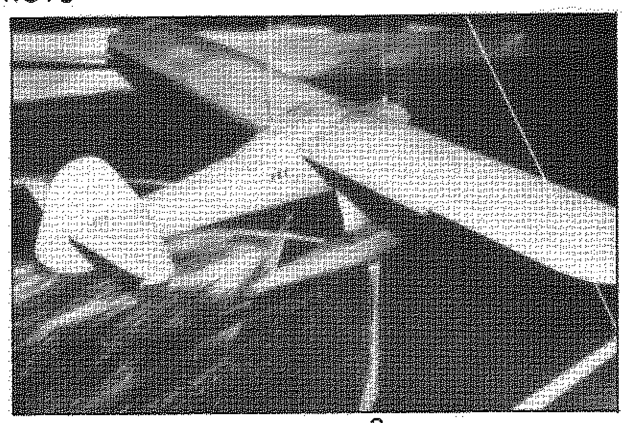




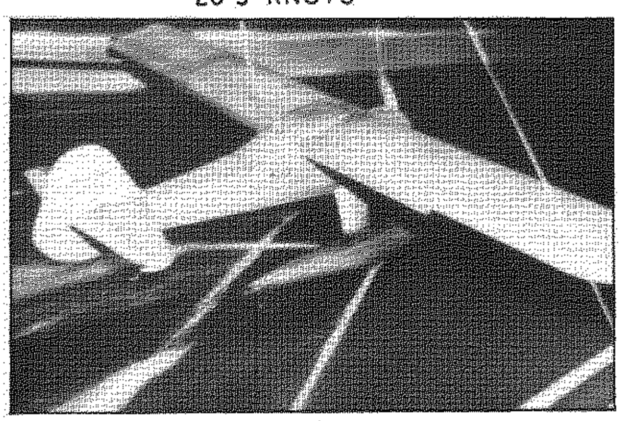
α KEEL 9·6°
η = -30°
26·5 KNOTS



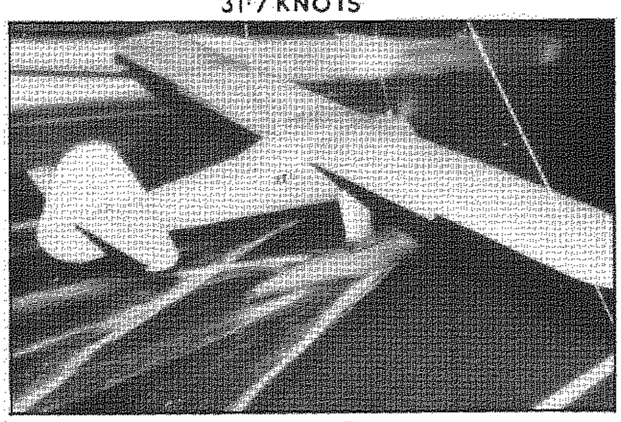
α KEEL 9°
η = -20°
26·5 KNOTS



α KEEL 7·2°
η = -20°
31·7 KNOTS

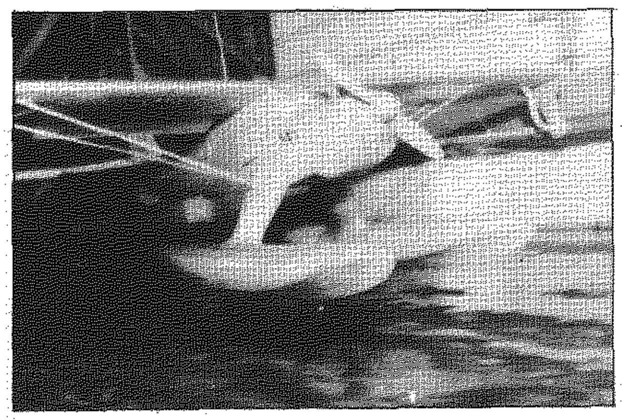


α KEEL 6°
η = -20°
37·1 KNOTS

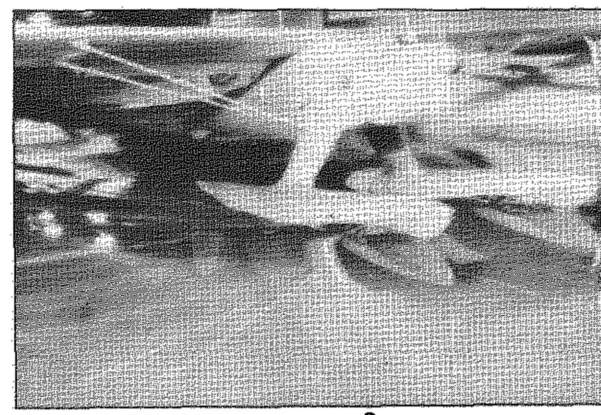


α KEEL 5·3°
η = -20°
42·3 KNOTS

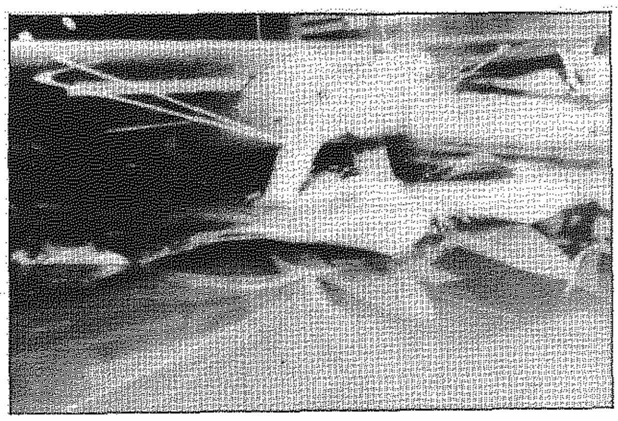
SPRAY CHARACTERISTICS ON CALM WATER
DURING LANDING AT LIGHT LOAD 1720 lb A.U.W.
R.A.E. FLOATS - FIRST VERSION

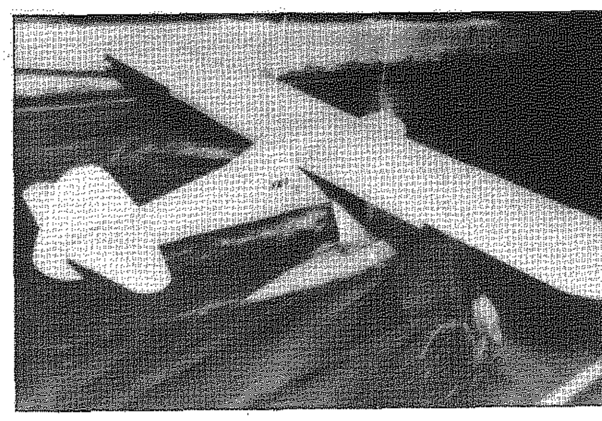


VIEW OF MODEL

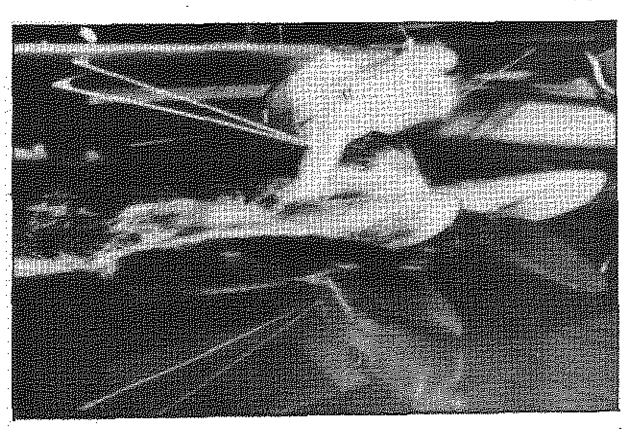


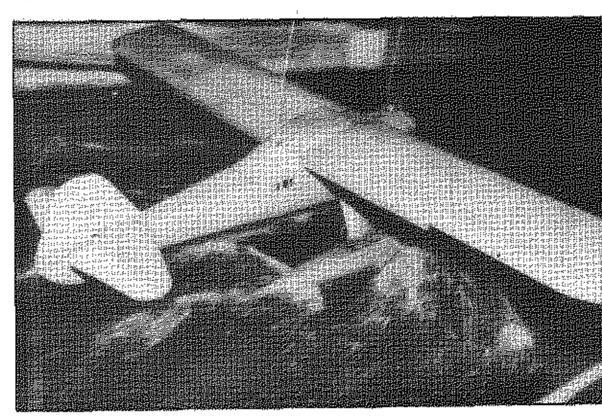
α KEEL 5·5°
η = 0°
5·3 KNOTS



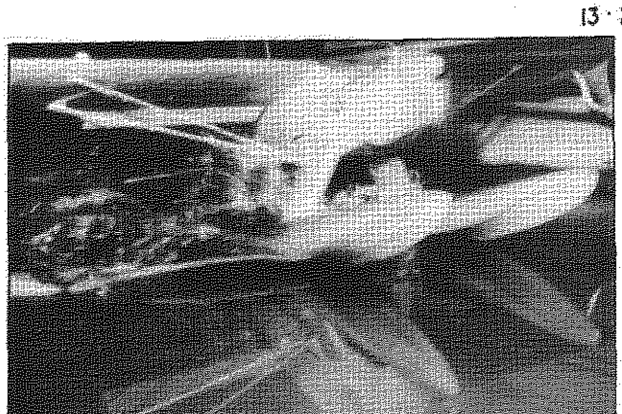


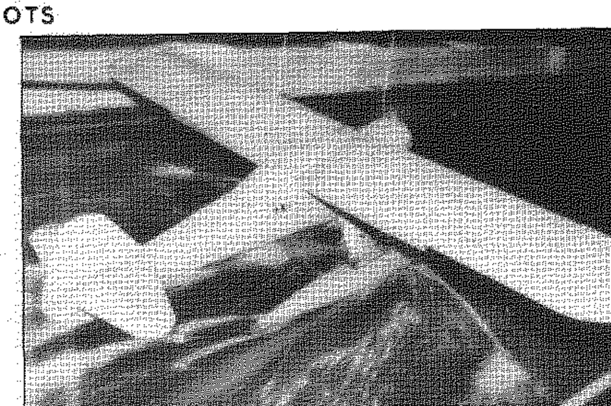
α KEEL 6·1°
η = 0°
10·6 KNOTS





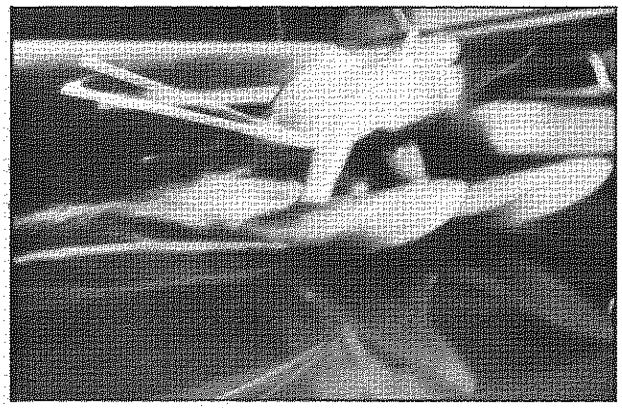
α KEEL 9·2°
η = 0°
13·2 KNOTS

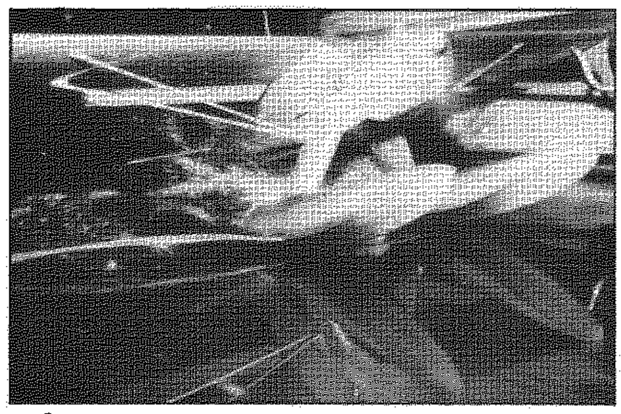




α KEEL 12·4°
η = 0°
15·9 KNOTS (HUMP SPEED)

SPRAY CHARACTERISTICS ON CALM WATER
DURING TAKE-OFF AT OVERLOAD 1920 lb
R.A.E. FLOATS - FIRST VERSION

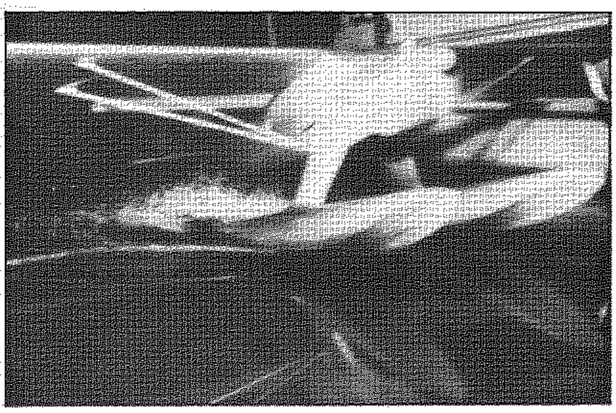


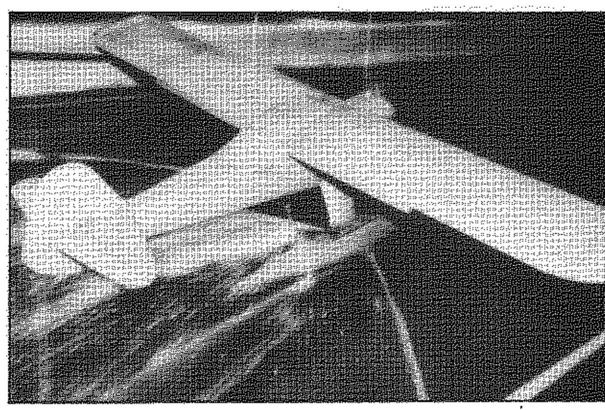


ACCELERATION 0·15 g

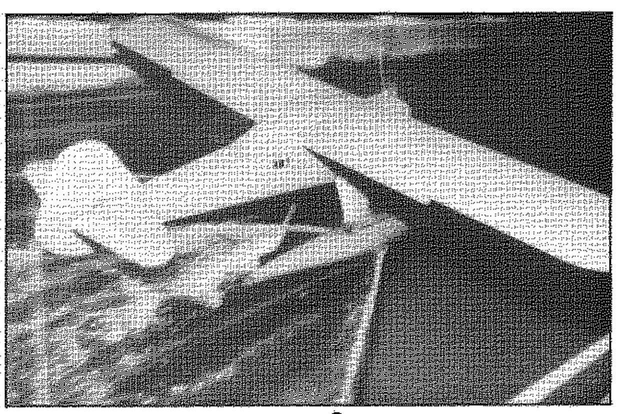
α KEEL 13·2°
$\eta = -12°$
21·2 KNOTS

CONSTANT SPEED

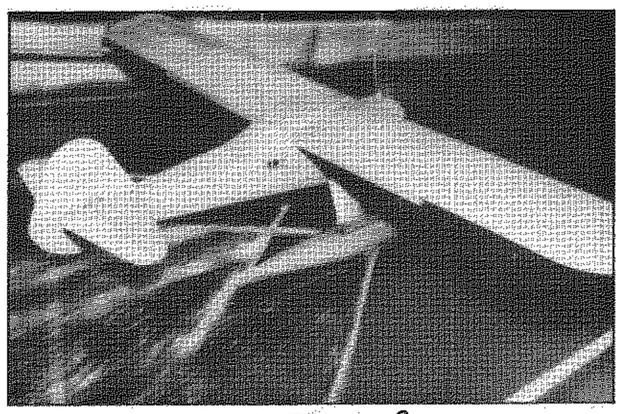




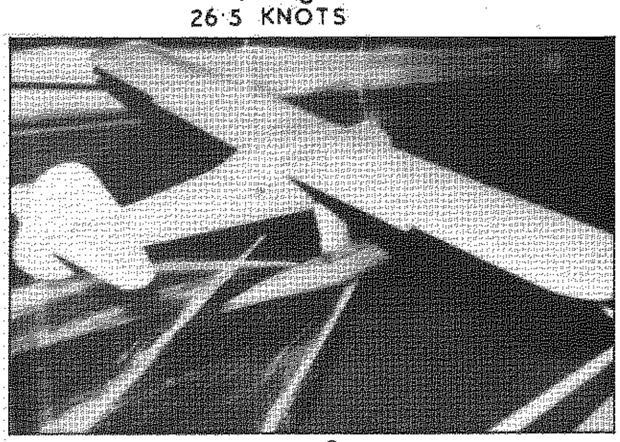
α KEEL 10·8°
$\eta = -12°$
26·5 KNOTS



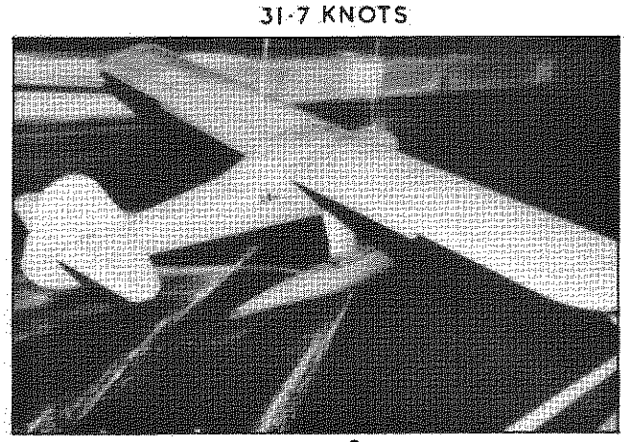
α KEEL 10°
$\eta = -8°$
26·5 KNOTS



α KEEL 7·2°
$\eta = -4°$
31·7 KNOTS



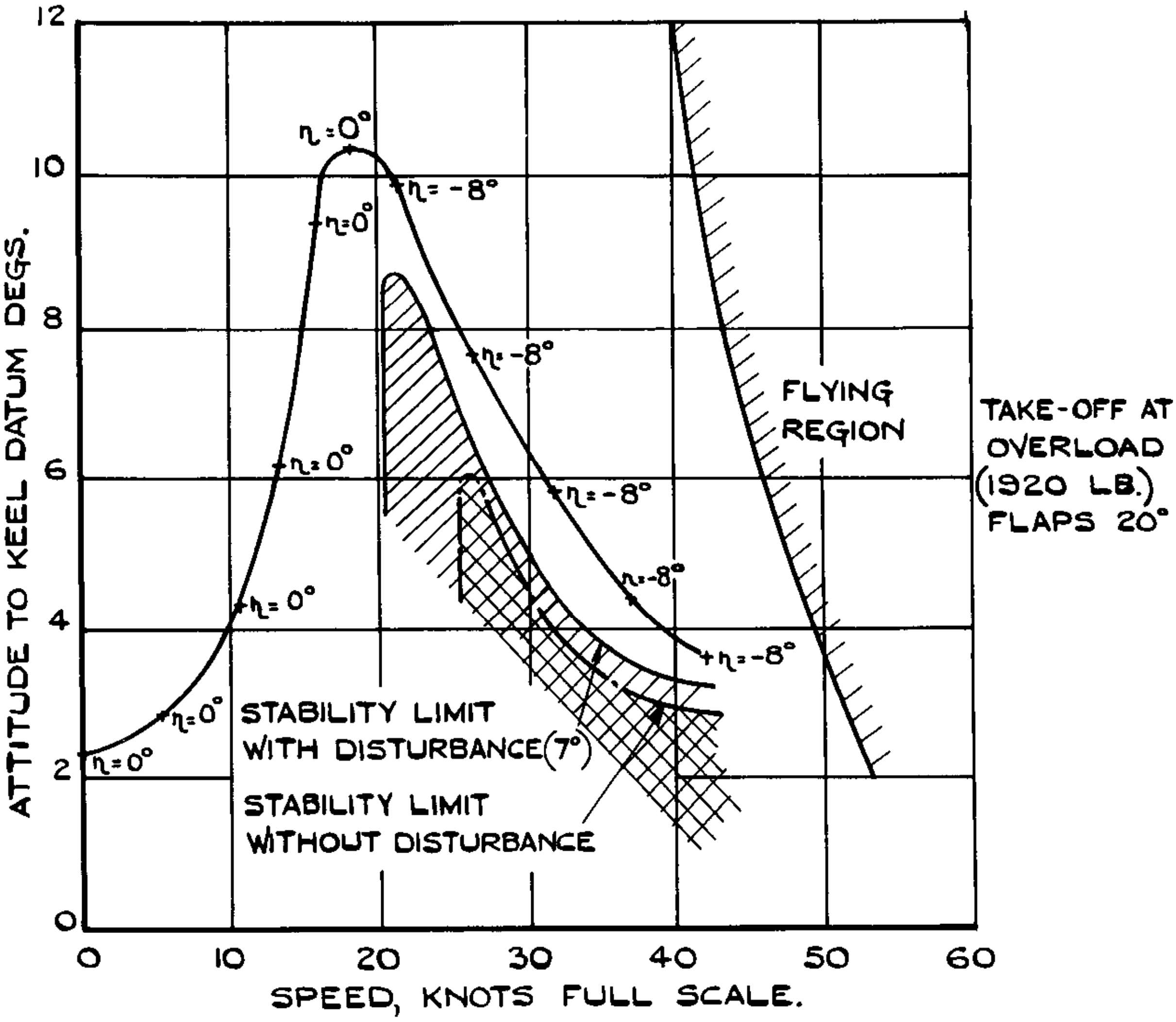
α KEEL 5·6°
$\eta = -8°$
37·1 KNOTS



α KEEL 7°
$\eta = -12°$
42·3 KNOTS

SPRAY CHARACTERISTICS ON CALM WATER
DURING TAKE-OFF AT OVERLOAD 1920 lb
R.A.E. FLOATS - FIRST VERSION

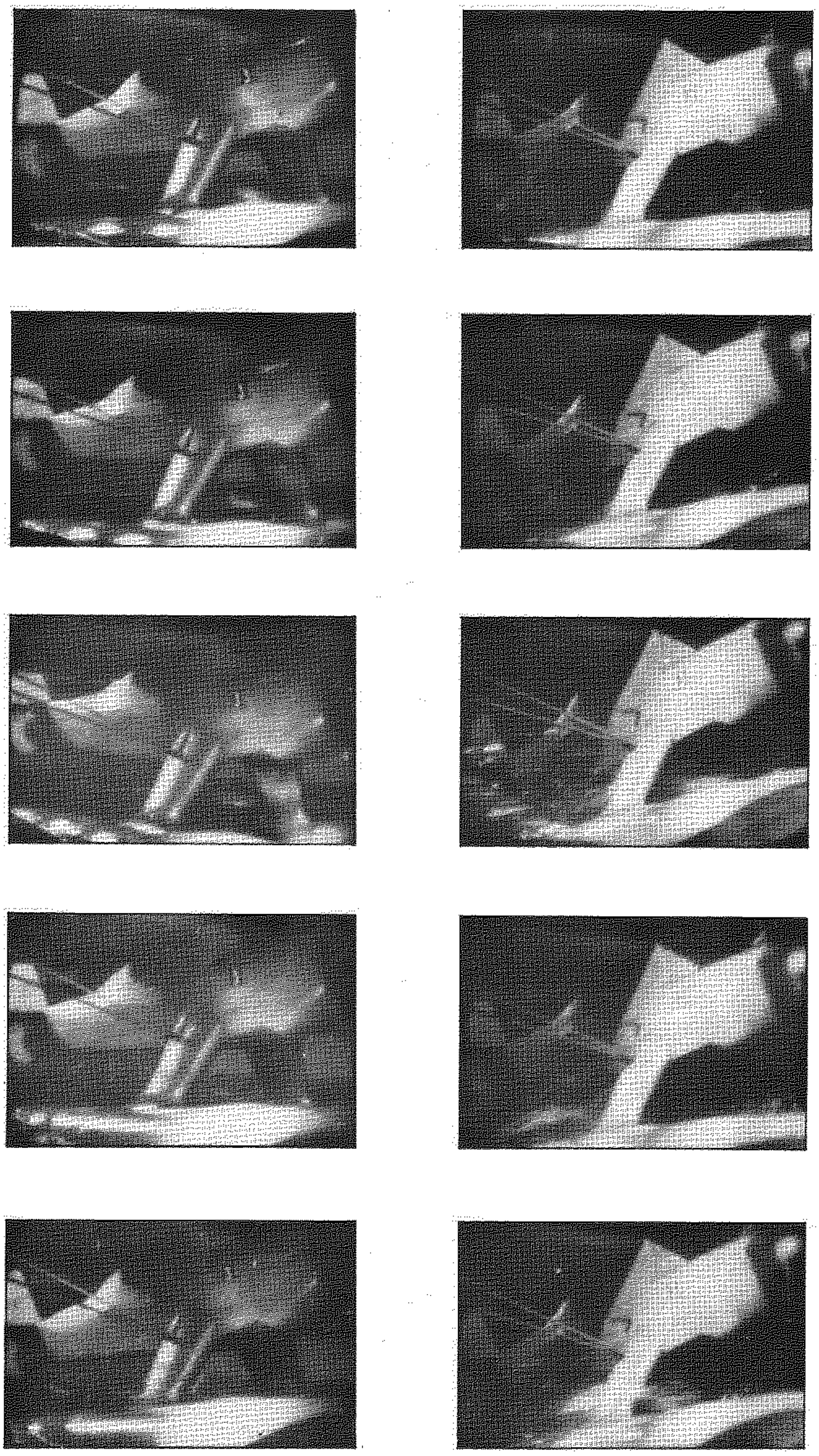
FIG. 11.



WAVE	I	II	III	IV
WAVE HEIGHT	0 5 ft	0 8 ft.	1·25 ft	2·1 ft
WAVE LENGTH	10 ft	16 ft	25 ft	84 ft
WAVE HEIGHT / WAVE LENGTH	1:20	1:20	1·20	1:40
WAVE HEIGHT / FLOAT BEAM	0·23	0 37	0·58	0·99
WAVE LENGTH / FLOAT LENGTH	0·56	0 90	1 41	4·73

WAVE TEST CONDITIONS
(ZERO WIND)

FIG. 12. (1)



1, 2, 3, 4, 5 — 6, 7, 8, 9, 10

SPEED = 5·3 KNOTS
α KEEL = 2·8°; η = 0°

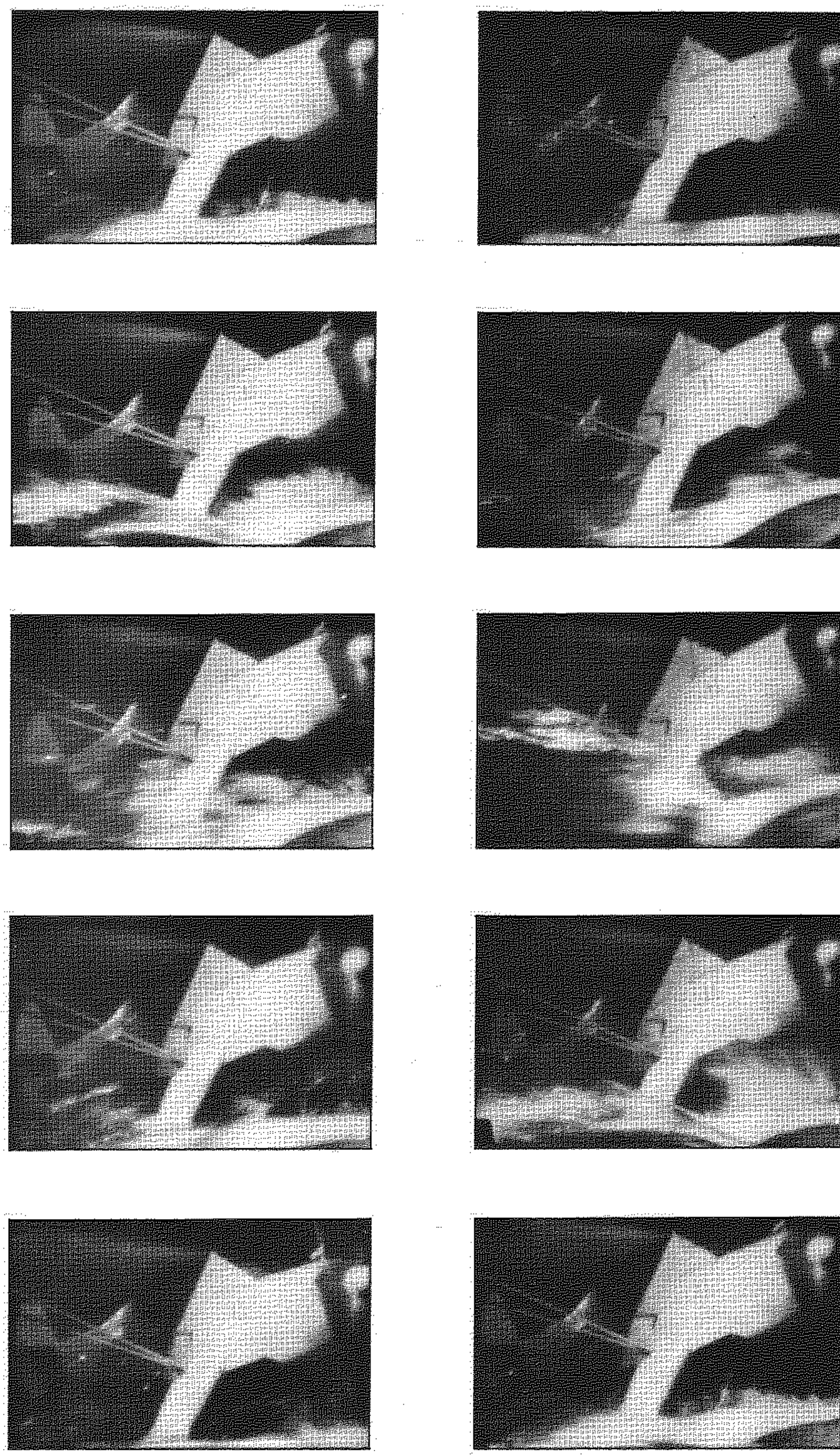
SPEED = 10·6 KNOTS
α KEEL = 4·3°; η = 0°

SPRAY CHARACTERISTICS IN WAVES,

HEIGHT = 1·25 ft., LENGTH = 25 ft.,

ZERO WIND CONDITIONS.

R.A.E. FLOATS - MODIFICATION "C".



11 16

12 17

13 18

14 19

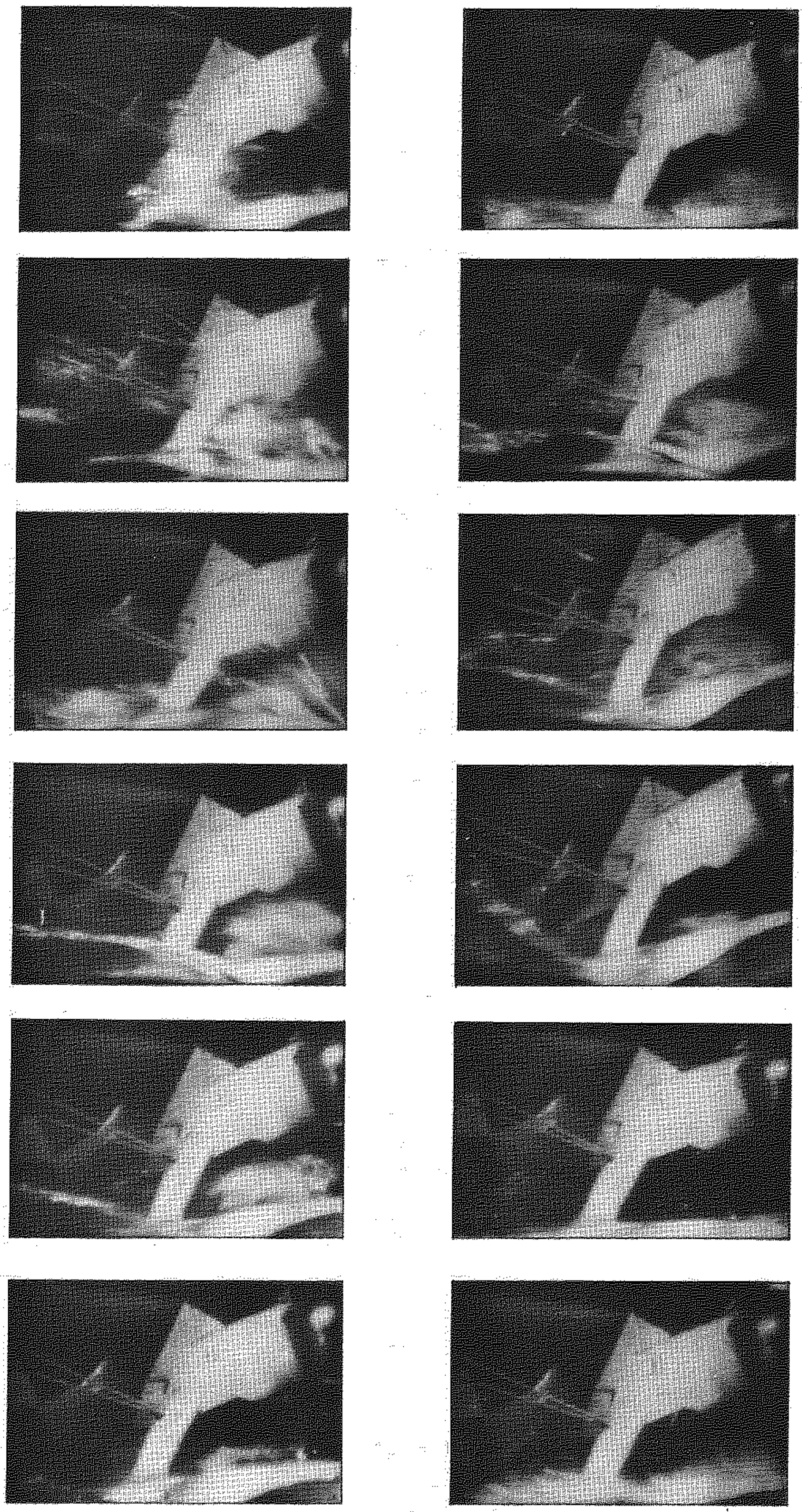
15 20

SPEED = 13·2 KNOTS
α KEEL = 6·2°; η = 0°

SPEED = 15·9 KNOTS
α KEEL = 9·4°; η = 0°

SPRAY CHARACTERISTICS IN WAVES,
HEIGHT = 1·25 ft., LENGTH = 25 ft.,
ZERO WIND CONDITIONS.
R.A.E. FLOATS - MODIFICATION "C".

FIG. 12. (3)



21 22 23 24 25 26

27 28 29 30 31 32

SPEED = 18·5 KNOTS (HUMP)
α KEEL = 10·4°; η = 0°

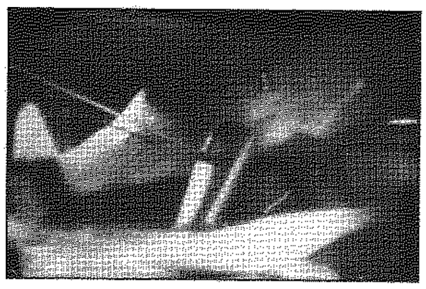
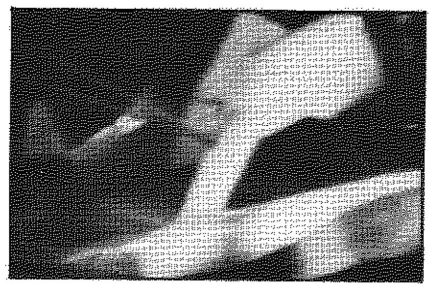
SPEED = 21·2 KNOTS
α KEEL = 9·9°; η = -8°

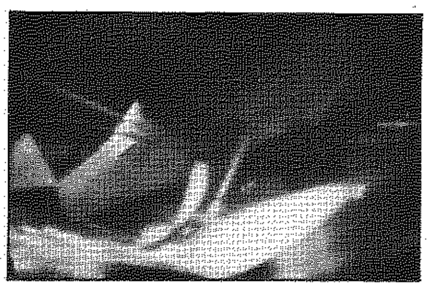
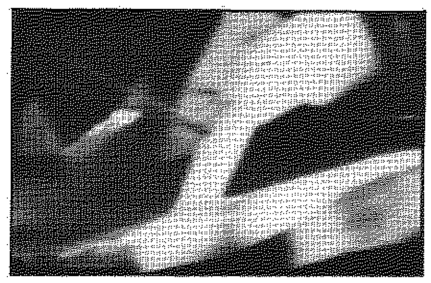
SPRAY CHARACTERISTICS IN WAVES,

HEIGHT = 1·25 ft., LENGTH = 25 ft.,

ZERO WIND CONDITIONS.

R.A.E. FLOATS - MODIFICATION "C".

33


39

34


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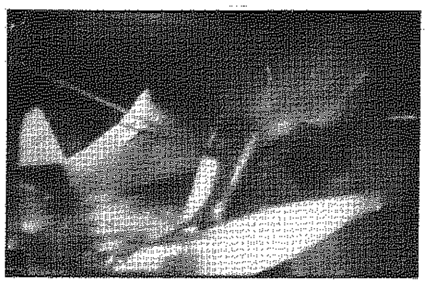
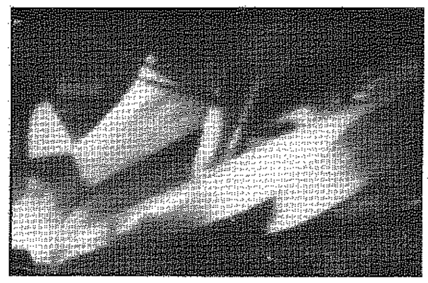
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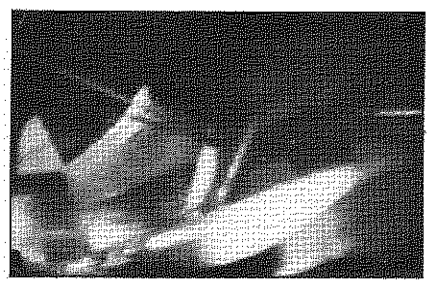
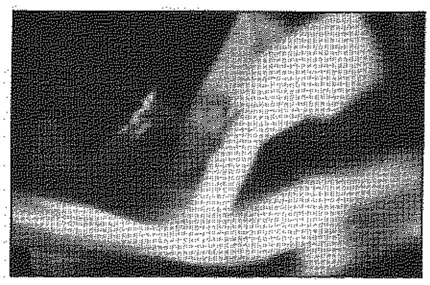
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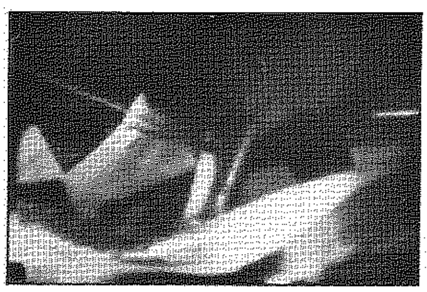
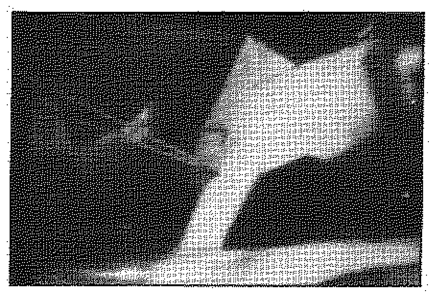
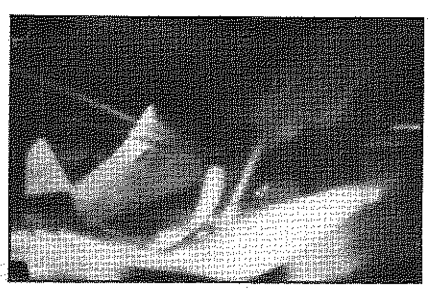
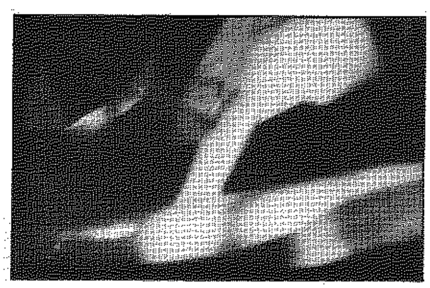


43

38


44

SPEED = 26·5 KNOTS
α KEEL = 7·6°; $\eta = -8°$

SPEED = 42·4 KNOTS
α KEEL = 3·6°; $\eta = -8°$

SPRAY CHARACTERISTICS IN WAVES,

HEIGHT = 1·25 ft., LENGTH = 25 ft.,

ZERO WIND CONDITIONS.

R.A.E. FLOATS - MODIFICATION "C".

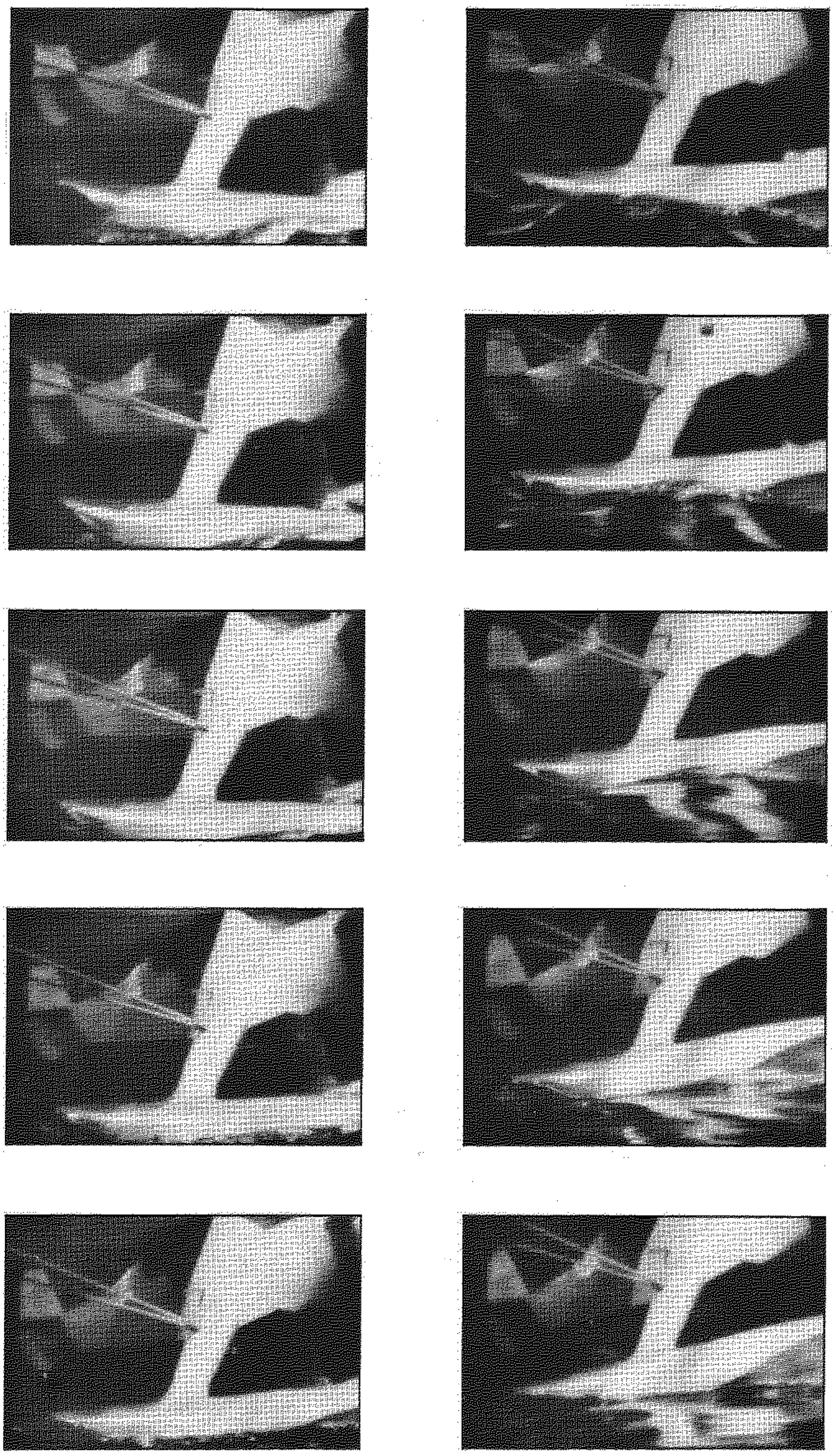
45 50

46 51

47 52

48 53

49 54



NO SPEED (ENGINE ON) α KEEL = $2{\cdot}3^{\circ}$; $\eta = 0^{\circ}$

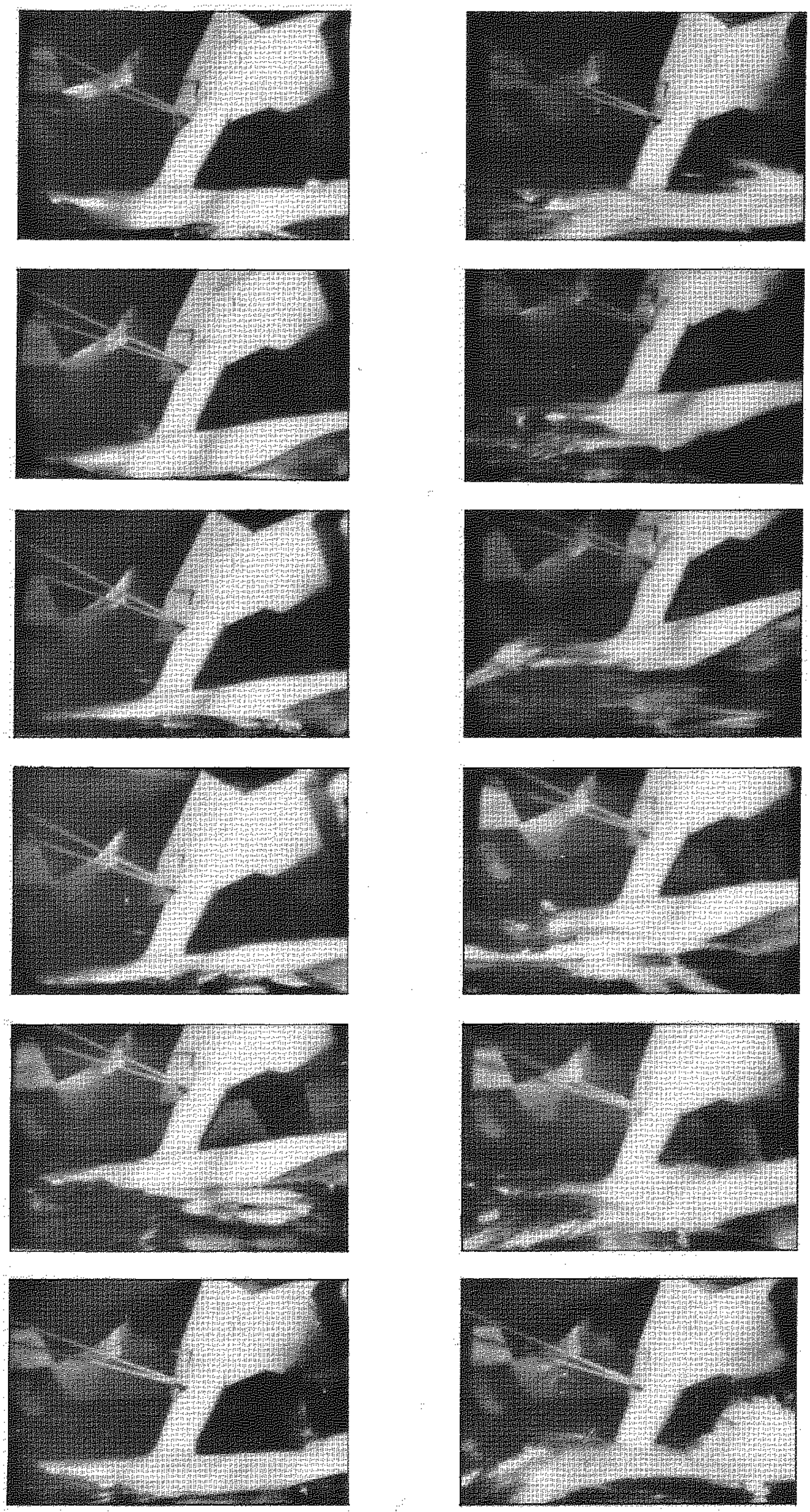
SPRAY CHARACTERISTICS IN WAVES,

HEIGHT = 2·1 ft., LENGTH = 84 ft.,

ZERO WIND CONDITIONS.

R.A.E. FLOATS - MODIFICATION "C".

FIG. 13. (2)



55 56 57 58 59 60

61 62 63 64 65 66

SPEED = 5·3 KNOTS
α KEEL = 2·8°; η = 0°

SPEED = 10·6 KNOTS
α KEEL = 4·3°; η = 0°

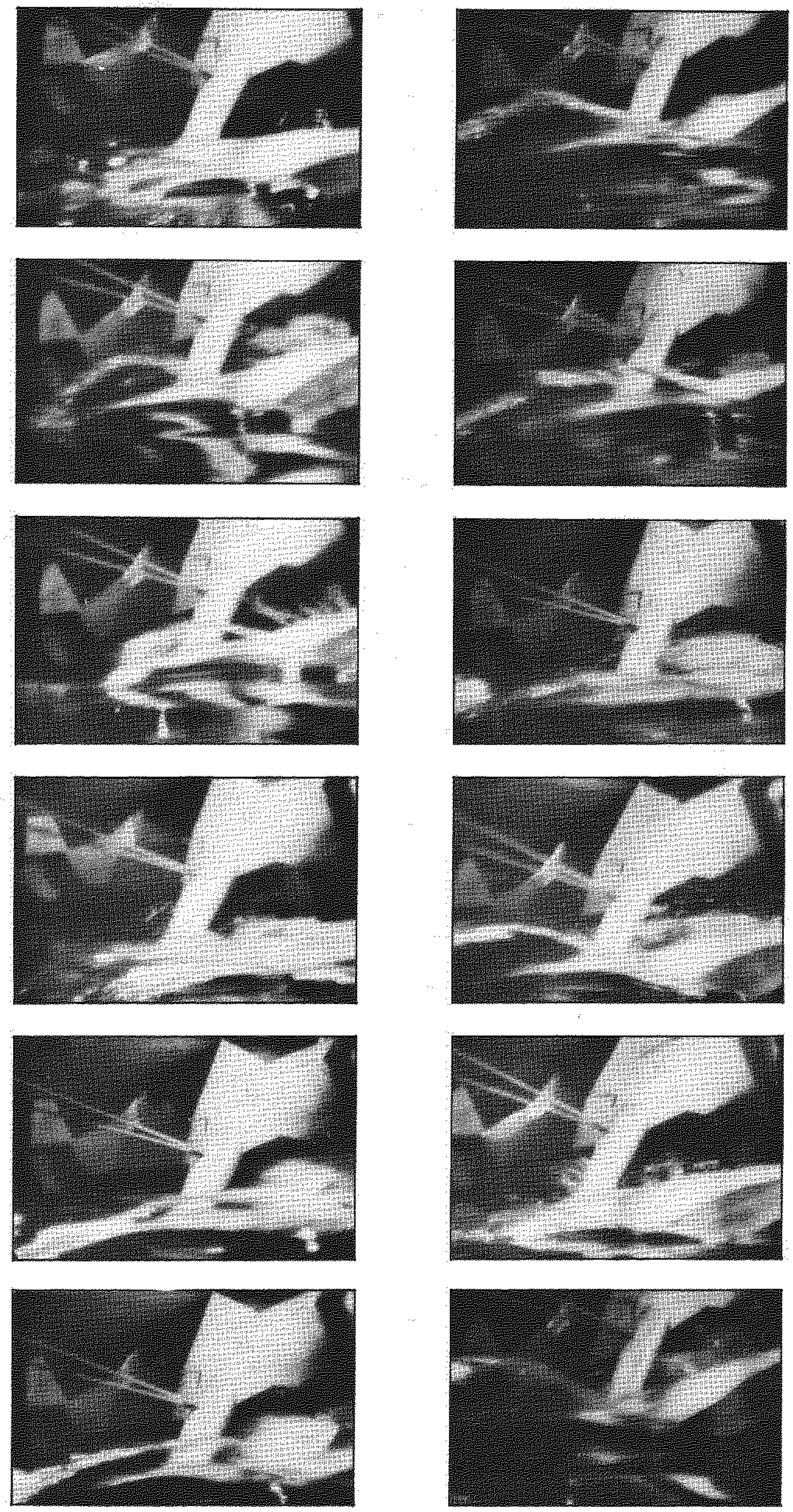
SPRAY CHARACTERISTICS IN WAVES,

HEIGHT = 2·1 ft., LENGTH = 84 ft.,

ZERO WIND CONDITIONS.

R.A.E. FLOATS - MODIFICATION "C."

67 73
68 74
69 75
70 76
71 77
72 78



SPEED = 13·2 KNOTS
α KEEL = 6·2; η = 0°

SPEED = 15·9 KNOTS
α KEEL = 9·4°; η = 0°

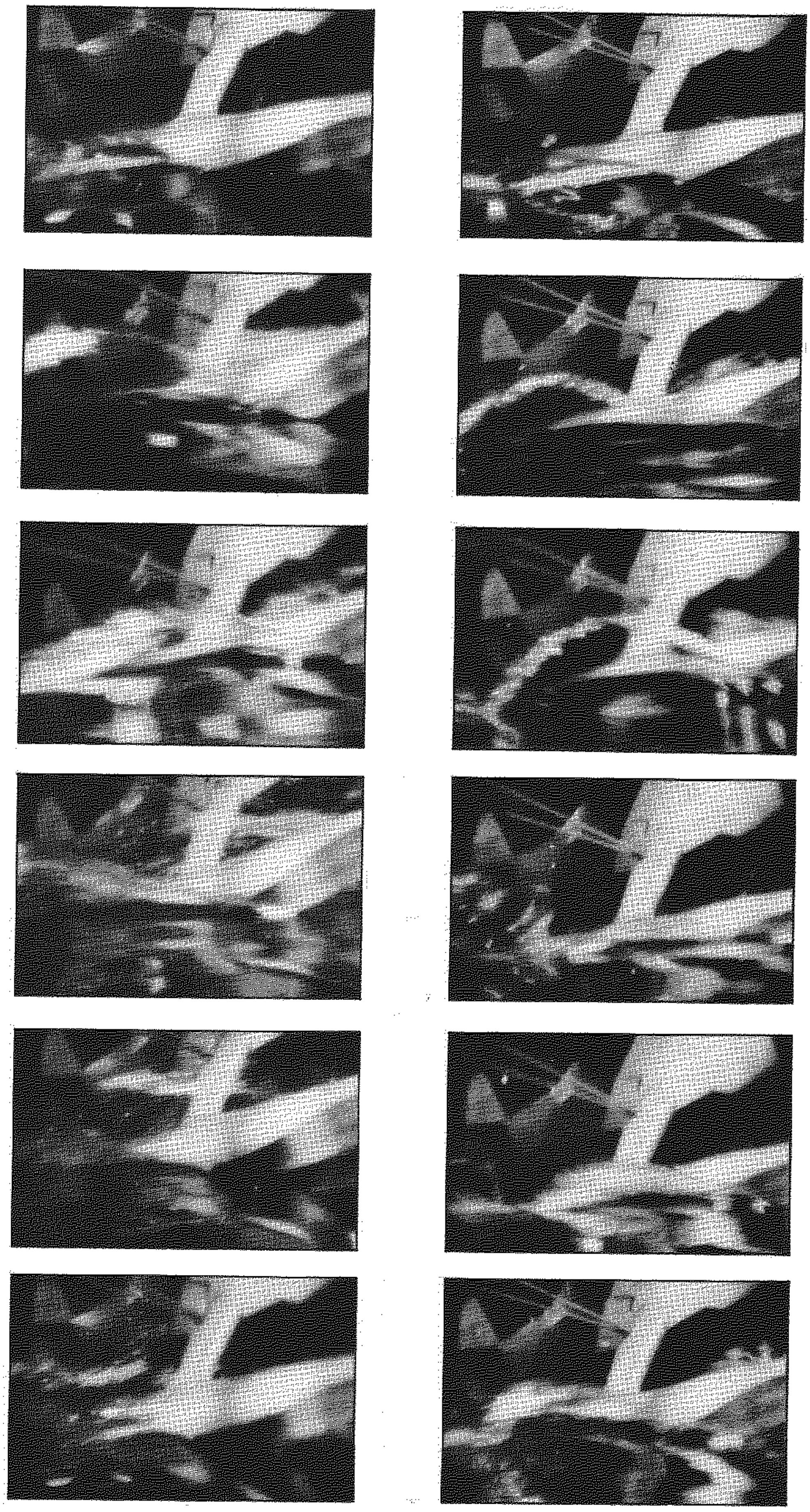
SPRAY CHARACTERISTICS IN WAVES,

HEIGHT = 2·1 ft., LENGTH = 84 ft.,

ZERO WIND CONDITIONS.

R.A.E. FLOATS - MODIFICATION "C."

FIG. 13. (4)



79 80 81 82 83 84

85 86 87 88 89 90

SPEED=18·5 KNOTS (HUMP)
α KEEL=10·4°; η = 0°

SPEED = 21·2 KNOTS
α KEEL=9·9°; η=-8°

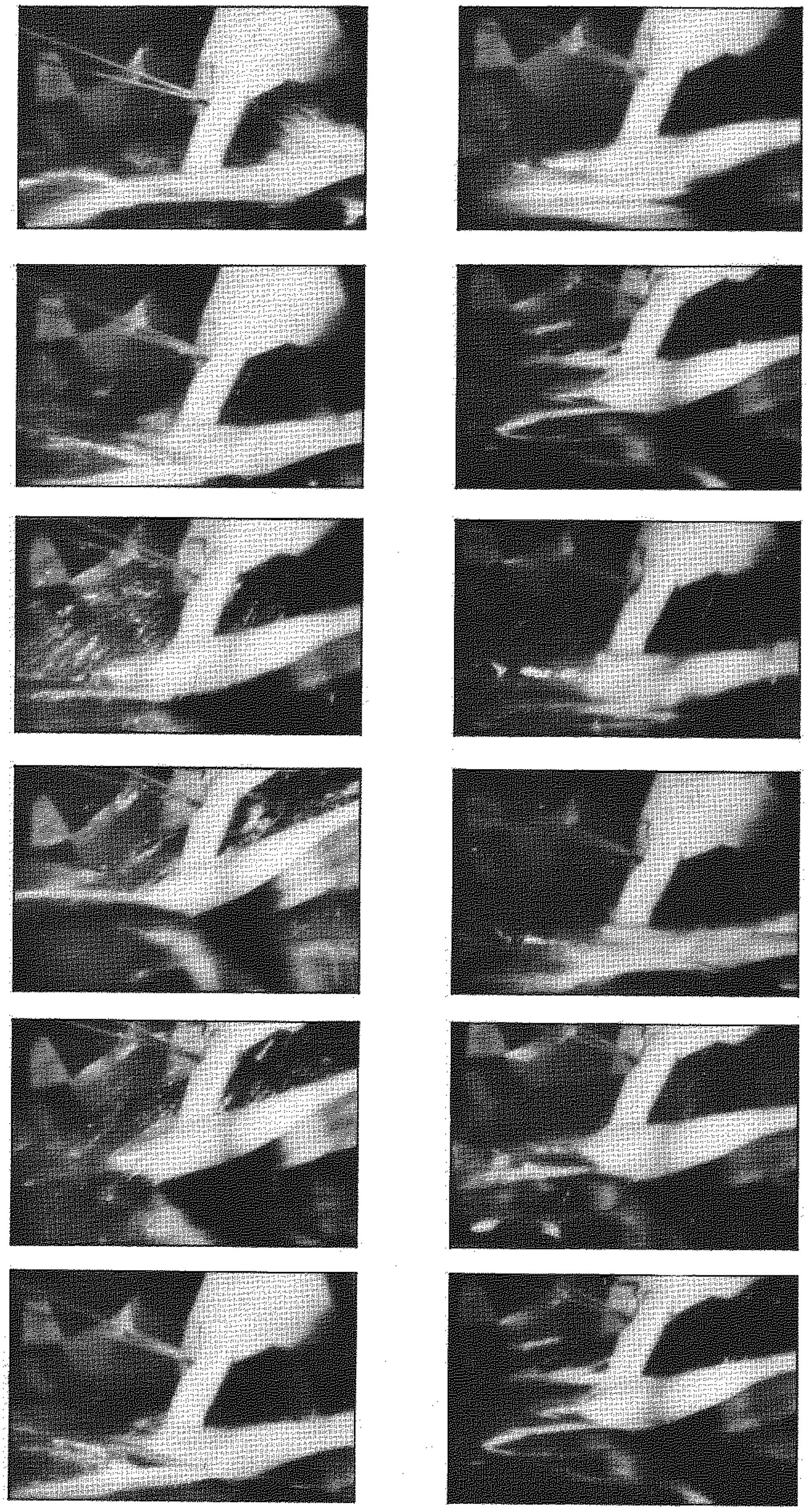
SPRAY CHARACTERISTICS IN WAVES,

HEIGHT = 2·1 ft., LENGTH = 84 ft.,

ZERO WIND CONDITIONS.

R.A.E. FLOATS - MODIFICATION "C."

FIG. 13. (5)



91 92 93 94 95 96

97 98 99 100 101 102

SPEED = 26·5 KNOTS
α KEEL = 7·6°; η = -8°

SPEED = 31·8 KNOTS
α KEEL = 5·8°; η = -8°

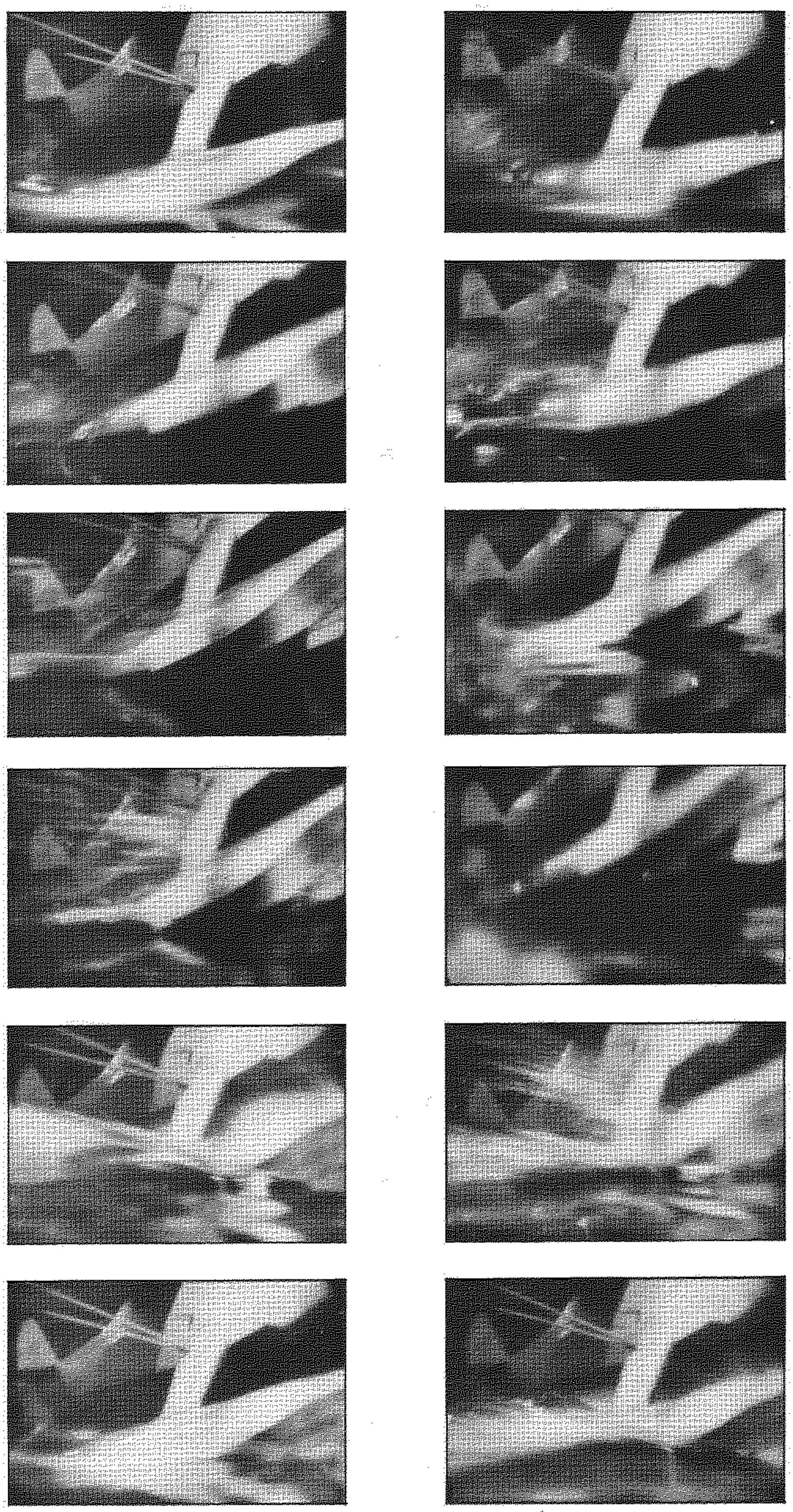
SPRAY CHARACTERISTICS IN WAVES,

HEIGHT = 2·1 ft., LENGTH = 84 ft.,

ZERO WIND CONDITIONS.

R.A.E. FLOATS - MODIFICATION "C".

FIG. 13. (6)



103 109

104 110

105 111

106 112

107 113

108 114

SPEED = 37·1 KNOTS
α KEEL = 4·4°; η = -8°

SPEED = 42·4 KNOTS
α KEEL = 3·6°; η = -8°

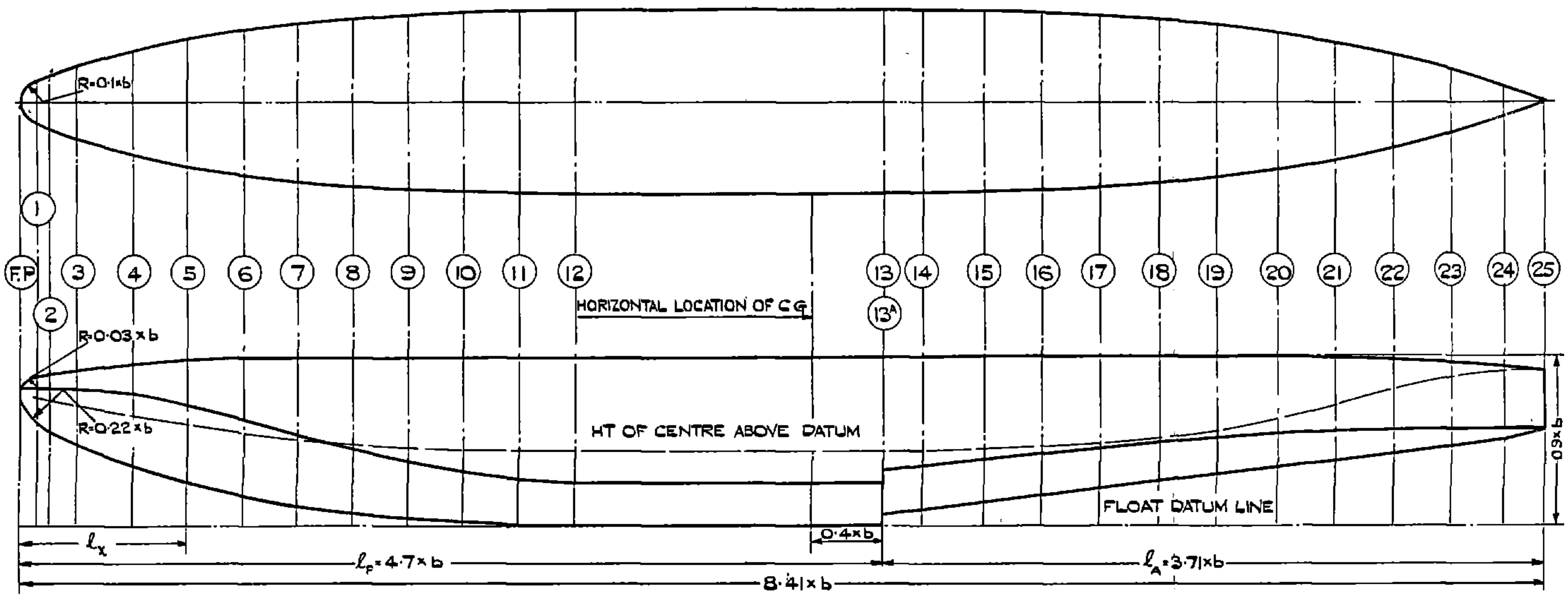
SPRAY CHARACTERISTICS IN WAVES,

HEIGHT = 2·1 ft., LENGTH = 84 ft.,

ZERO WIND CONDITIONS.

R.A.E. FLOATS - MODIFICATION "C".

FIG. 14.

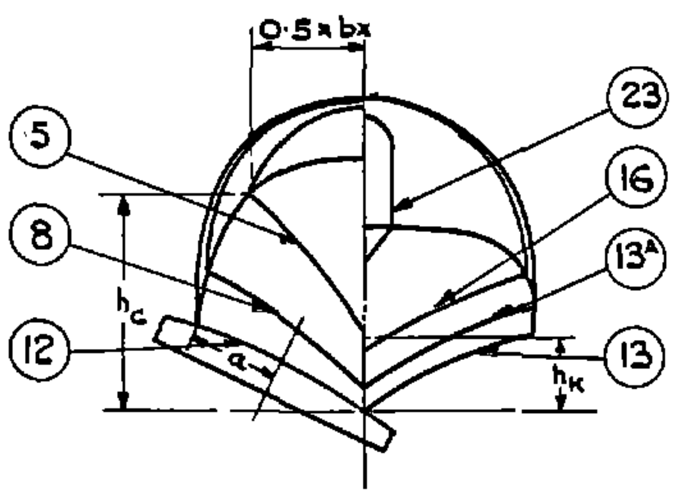


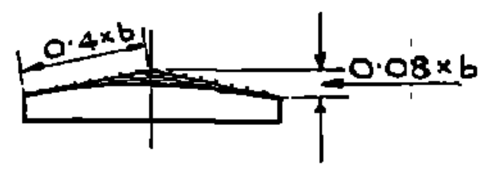
ALL DIMENSIONS IN TERMS OF BEAM AT MAIN STEP.

		FOREBODY.													
STATION F.P.	Nº	F.P.	1	2	3	4	5	6	7	8	9	10	11	12	13
DISTANCE AFT OF FP	$\ell_x : b$	0·000	0·75	0·15	0·30	0·60	0·90	1·20	1·50	1·80	2·10	2·40	2·70	3·00	4·70
KEEL HT.	$h_K : b$	0·75	0·585	0·515	0·423	0 30	0·215	0·15	0·10	0·062	0·035	0·015	0 04	0·00	0·00
CHINE HT.	$h_C : b$	0·75	0·746	0·742	0·735	0·708	0·654	0·569	0·485	0·404	0·338	0·283	0·25	0·238	0·238
LOCAL BEAM.	$b_x : b$	0·00	0·220	0·312	0·434	0·600	0·712	0·800	0·866	0·916	0·954	0·976	0·996	1·00	1·00
HT OF CENTRE ABOVE DATUM	$h_R : b$	0·75	0·694	0·679	0·642	0·592	0·540	0·498	0·467	0·442	0·423	0·412	0·402	0·400	0·400
RADIUS OF BODY.	$R : b$	0·00	0·110	0·156	0·217	0·300	0·356	0·400	0 433	0·458	0·477	0·488	0·498	0·500	0·500
	$a : b$	0·00	0·098	0·138	0·190	0·252	0·282	0·292	0·290	0·288	0·285	0·279	0·279	0·279	0·279

		AFTERBODY													
STATION F.P.	Nº	13A	14	15	16	17	18	19	20	21	22	23	24	25
DISTANCE AFT OF FP	$\ell_x : b$	4·70	4·91	5·23	5·55	5·87	6·19	6·51	6·83	7·15	7·47	7·79	8·11	8·41
KEEL HT.	$h_K : b$	0·050	0·077	0·116	0·156	0·196	0·235	0·275	0·315	0·354	0·394	0·433	0·473	0·531
CHINE HT.	$h_C : b$	0·304	0·319	0·335	0·388	0·423	0·454	0·477	0·500	0·517	0·527	0·531	0·531	0·531
LOCAL BEAM.	$b_x : b$	1·00	1·00	0·984	0·958	0·924	0·884	0·808	0·731	0·616	0·477	0·308	0·124	0·00
HT OF CENTRE ABOVE DATUM	$h_R : b$	0·400	0·400	0·408	0·421	0·438	0·469	0·512	0·562	0·627	0·696	0·769	0·825	0·837
RADIUS OF BODY.	$R : b$	0·500	0·500	0 492	0·479	0·462	0·431	0·388	0·337	0 271	0·200	0·117	0·040	0·00
	$a : b$	0·279	0·279	0·275	0·267	0·258	0·244	0·227	0·206	0·173	0·137	0·090	0·042	0·00

b = BEAM AT MAIN STEP





TRACK = 3·2·b

PROPOSED LINES OF R.A.E. FLOATS.

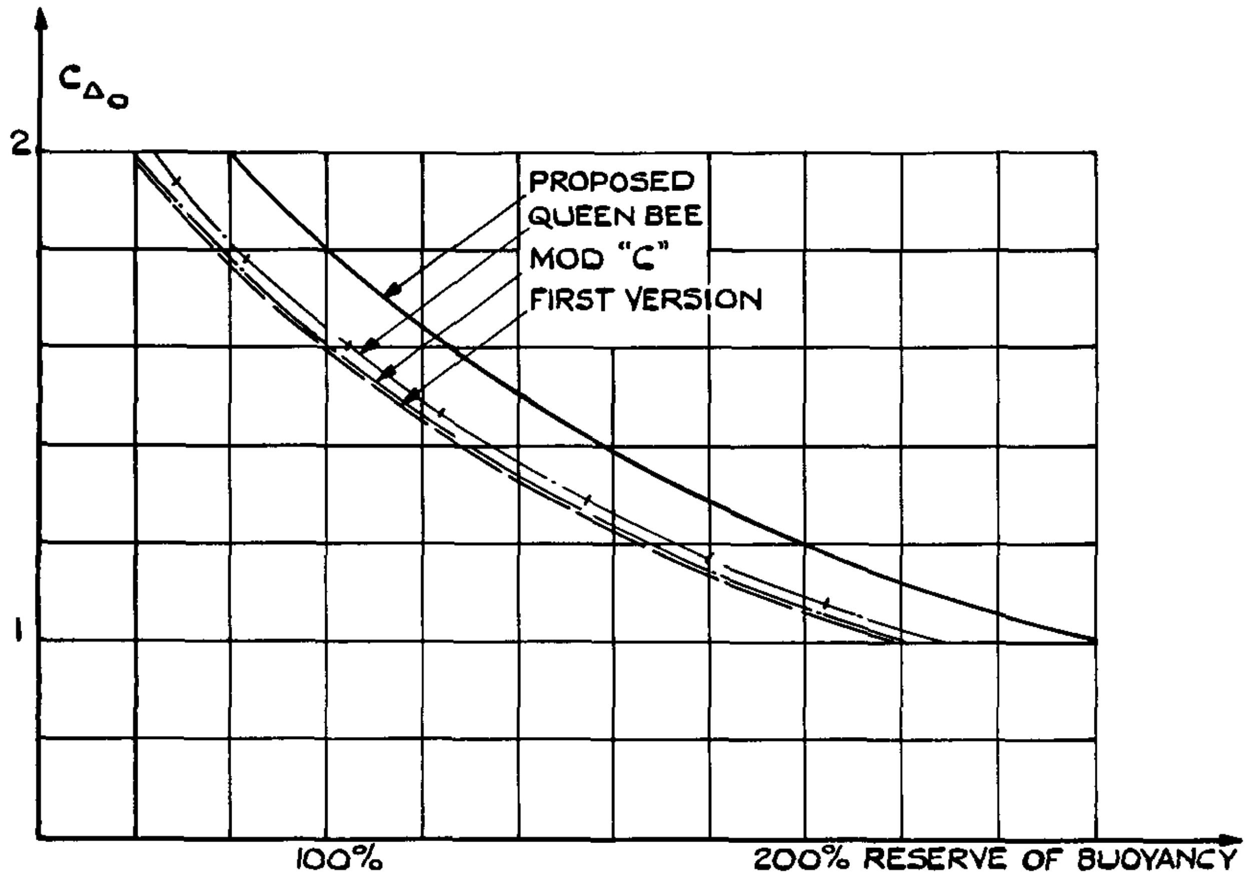


FIG. 15. VARIATION OF RESERVE OF BUOYANCY WITH STATIC BEAM LOADING COEFFICIENT.

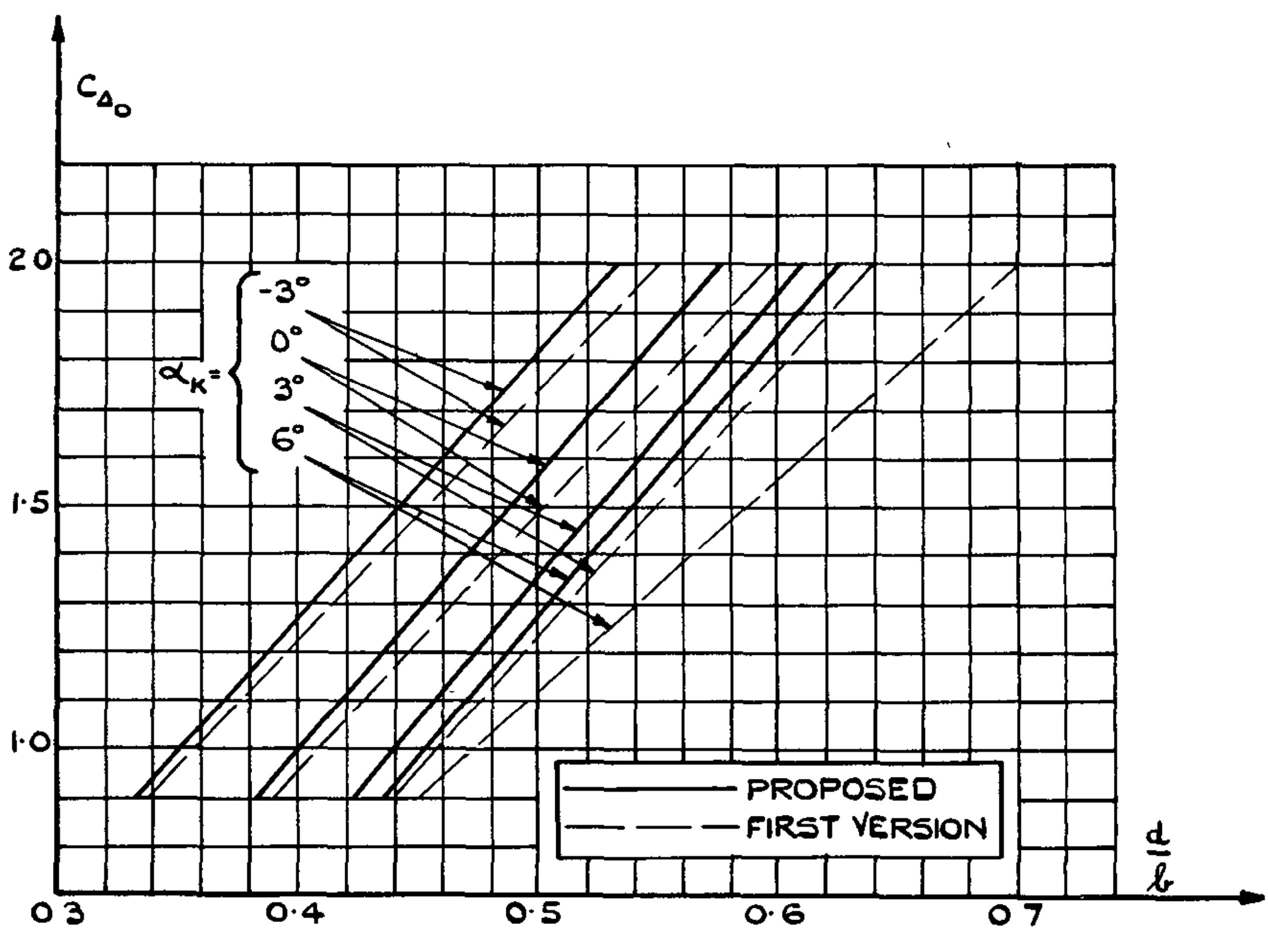
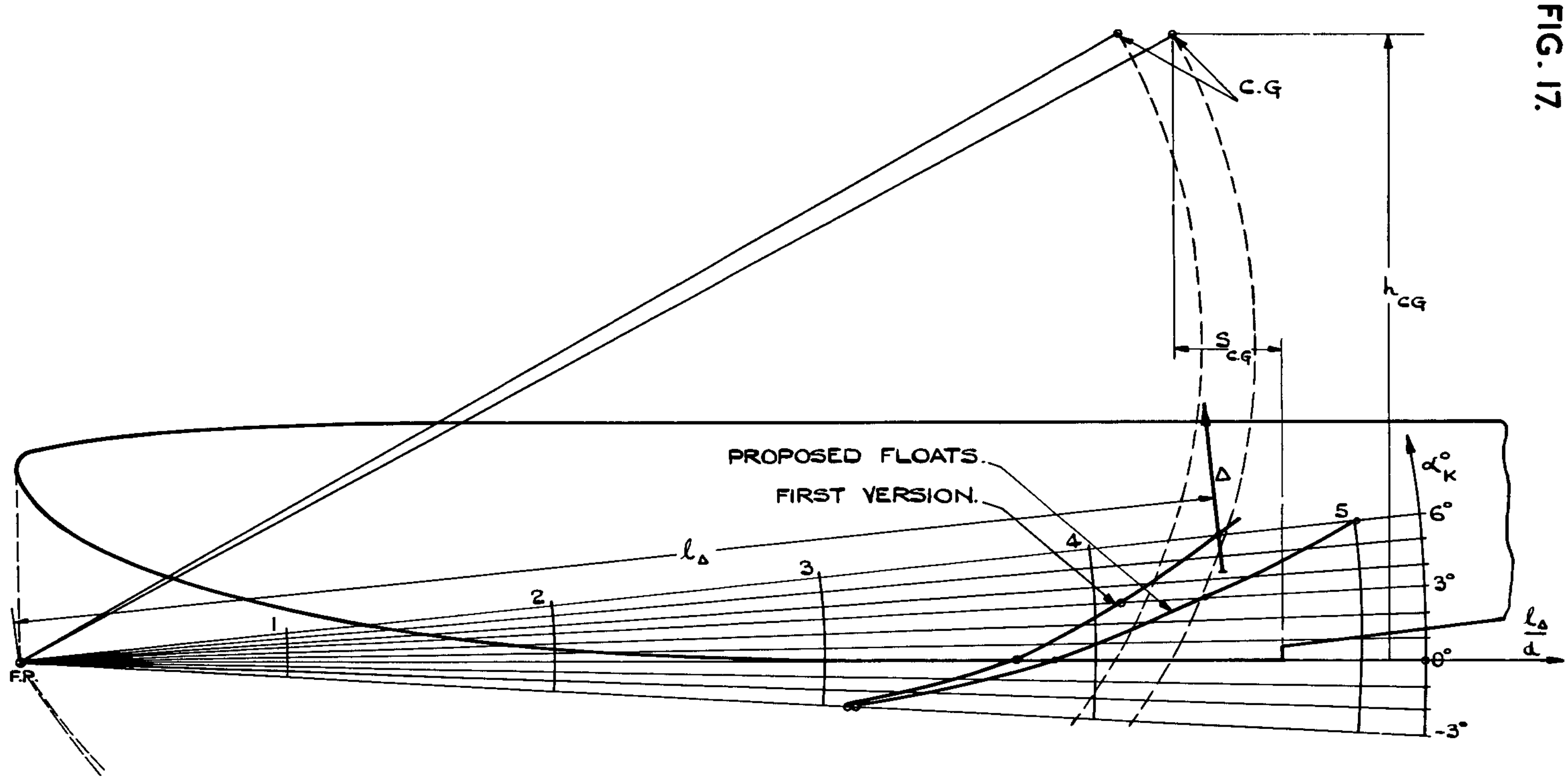


FIG. 16. VARIATION OF DRAFT WITH ATTITUDE AND STATIC BEAM LOADING COEFFICIENT.

FIG. 17.



VARIATION OF DISTANCE OF BUOYANCY FROM F.P. FOR CONSTANT STATIC BEAM LOADING COEFFICIENT ($C_{\Delta_0} = 1 \cdot 5.$)

C.P. No. 15
2154
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