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Determination of the Static Stability of Seaplanes

By

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Determination of the Static Stability of Seaplanes

by

A.M. Tomaszewski, Inz.lotn. (Warsaw)

SUMMARY

This report describes graphical methods for the determination of the water performance of seaplane hulls and floats when at rest and at low taxying speeds. The methods are applied to the estimation of water lines with and without the slow and rapid application of external thrust and torque (roll) for zero wind and wave conditions.

A detailed example is given for the case of a small twin float seaplane. The method can be used for the determination of the effect of any known statically or dynamically applied forces or moments, and in any known sea and wind conditions.

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1 Introduction

In the course of research and development work on the design of hulls in the R.A.E. seaplane tank an examination has been made of the methods of determining the static buoyancy and flotation characteristics. A graphical statics method has been found very useful which is not novel but is not widely applied in this country. It is considered to be as accurate and to give results more rapidly than the more arithmetical methods.

A description of the method is given in this report, it is illustrated in detail by an example of its application to the design of floats for a small twin float seaplane. No particular merit is claimed for the floats in the form used in this report, their lines being based on flying boat hull design. Relevant details of the seaplane are given in Table I, and lines and dimensions of the floats in Figure 1.

2 Method and Design Cases Considered

The method consists generally in determining the buoyancy, moment of buoyancy and centre of buoyancy of the float or hull for a series of water lines chosen to cover a wide range of attitudes and drafts. The whole determination is shown graphically after Bonjean's method so that the distribution of buoyancy is immediately available for any required water line. New various methods of obtaining the area and first moment of area under a curve are given, the usefulness of each depending on the available data and instruments, as well as the accuracy required.

Knowing the basic buoyancy characteristics, the selection of any two conditions from C.G. height above step, C.G. distance forward of step and attitude make possible the determination of the third by a simple graphical method. The corresponding draft and centre of buoyancy are then also known.

From the location of the float or hull relative to the aircraft, then the design conditions appropriate to full engine power under displacement conditions can be examined. Those chosen are,

(1) effect of thrust on attitude, both for the static equilibrium condition and dynamic case (suddenly applied),

(2) effect of thrust at low taxying speed,

(3) effect of torque on angle of roll.

All these estimates are made graphically, results being tabulated.

For practical purposes it is convenient to express all forces in terms of the equivalent volume of water which has the same weight, taking the weight of a cu.ft. of fresh water as 62.5 lbs. This avoids any confusion of units.

3 Determination of Buoyancy, Longitudinal Moment, and Centre of Buoyancy in Terms of Attitude and Draft

3.1 Distribution of buoyancy

The method of determining the basic characteristics of buoyancy in terms of attitude and draft is that due to Bonjean, descriptions of the method are given in references 1 to 4.

The variation of cross-sectional area with draft up to full immersion is plotted for each of a series of sections on a side elevation of the hull or float. Area is plotted parallel to the keel, local draft is measured normal to the keel with zero at the local keel.

The variation of area with draft for a typical section is illustrated in Fig. 2, where F_z is the area at draft z. The areas can be found by use of a planimeter or analytically. The analytical derivation is given in Table 2 for the stations numbered in Fig. 1. The results for the different stations are given graphically in Fig. 6.

The results for all sections are collected together in the Bonjean diagram in Fig. 7. The same scale is used as in the derivation in Fig. 6. This is the basic figure from which the distribution of buoyancy for any possible combinations of attitude and draft may be obtained.

3.2 Distribution of Buoyancy for given Water Lines

To obtain the buoyancy distribution over a required range of attitudes and drafts, convenient water lines are drawn on a side elevation of the float in Fig. 8 drawn to the same scale as in Figs. 6 and 7. Fig. 3 illustrates definitions of co-ordinates of the sections. The draft is measured at the step normal to the datum line, defined as the tangent to the keel at the step. The attitude is measured relative to the same datum line, positive nose up. The reference datum point at the bows, F.P., is defined as the intersection with the datum line of the normal to the datum drawn through the foremost point in the float. Distances aft of the F.P. are measured in the direction of the water lines concerned.

The water lines chosen for the example were defined by

Attitude α°	Draft ins. model scale			
	d_1	d_2	d_3	d_4
α_1 -3		2.5	3.5	
α_2 0	1.5	2.5	3.5	4.7
α_3 3		2.5	3.5	
α_4 6		2.5	3.5	

Their intersection with the sections together with the corresponding wetted areas F_d are shown in Fig. 8. The latter are obtained by superimposing Fig. 8 on Fig. 7. Results are tabulated in Table 3 and plotted in terms of wetted area against distance from F.P. in Fig. 10 for each water line. The co-ordinates in Fig. 10 are not rectilinear because of the nature of the derivation of the results and also the requirements for centre of buoyancy calculations. To facilitate their plotting a special scale is used, as shown in Fig. 9. It is there shown how the axes change because draft is measured normal to the datum line, but distance from F.P. parallel to the water line. For convenience the abscissa is given in terms of the station number, a scale of distance is provided, and for each draft a subsidiary scale is plotted for convenience in the numerical integration. The intervals "$d\ell$" used in the subsidiary scales are chosen to suit the nature of the curves.

Fig.10 therefore gives the distribution of buoyancy for the particular water lines chosen. From these the total lift or buoyancy Δ is represented by the area under the curve, the moment of buoyancy M_Δ about the F.P. by the first moment, and the distance of the centre of buoyancy from the F.P. "ℓ_Δ", by their quotient.

These areas and first moments may be obtained by valuation as given in Appendix I, Simpson's Rule, a method of graphical integration given in Appendix II or a planimeter. The graphical integration method is illustrated in Figs.11 and 12 respectively for area and first moment, and compared with the results of the first method tabulated in Table 4 for the water line $\alpha = 0^\circ$ and $d = 3.5$ ins. There is very good agreement. The tabulation method of Appendix I has been used for the other water lines for demonstration purposes, and the calculations are tabulated in Table.4. The stations used for the valuation method are shown in Fig.6.

Results for buoyancy, moment of buoyancy and centre of buoyancy are tabulated in Table 5 and plotted in Figs.13, 14, against draft for fixed attitude.

4 Location of Float Relative to C.G. and Wings

The following method of locating a float or hull relative to a seaplane was that used in Poland in the Experimental Aircraft Workshops, D.W.L. (R.W.D.)5.

In the static condition, for a float seaplane of all up weight of A, and distance of C.G. aft of F.P. ℓ_W, it is necessary that for each float,

$$\text{Buoyancy } \Delta_1 = A/2$$

$$\text{Moment of buoyancy} = A/2 \cdot \ell_W$$

$$\text{Centre of buoyancy } \ell_W = \ell_\Delta$$

The distances ℓ_W and ℓ_Δ are measured parallel to the water line from the F.P. position (see Fig.19). In practice in a float seaplane, the floats are normally designed for a total buoyancy equal to twice the all up weight, i.e. a reserve buoyancy of 100 per cent. From the distribution of buoyancy and moment of buoyancy given in Figs.13 and 14, assuming a required buoyancy corresponding to 202 inches^3 of water, the variation of moment and draft with attitude is plotted in Figs.15 and 16 respectively.

Determination of the setting of the float relative to the C.G. can then be made graphically as follows.

Plot as in Fig.17 the vector distances of the centre of buoyancy from the F.P. point for the chosen attitudes of -3°, 0°, 3° and 6°. Then if the distance of the C.G. above the step be defined by propeller clearance as 12.4 ins. model scale, and the floating angle of the float is similarly chosen to be 4°, the distance of the C.G. forward of the step for equilibrium can be immediately deduced to be 3.18 ins., and the draft 2.93 ins. model scale. Similarly, use of this method will give the height of the C.G. for a predetermined distance forward of the step, or the floating angle for a given C.G. position. The last case is the one usually required.

The location of the float datum line with that of the seaplane is determined by the requirements of hydro and aerodynamic characteristics of the seaplane in take off, landing and cruising flight[1,2,6]. The aerodynamic characteristics of the small seaplane considered are illustrated in Fig.5. In the absence of knowledge of the trim angles in take off and landing, it is useful to define an angle of security[1] which is the difference between the angle at which the seaplane wing stalls and that corresponding to the two step landing case. If this angle $\alpha_{sec} = 3^\circ$, the angle between the wing chord and float datum required is given by

$$\alpha_p = \alpha C_{L_{max}} - \alpha_1 - \alpha_{sec} = 6^\circ$$

where $\alpha C_{L_{max}}$ = stalling angle of wing relative to heel to heel line of the float, 19°

and α_1 = heel to heel angle of float, 10°

The required fuselage to wing datum angle is then

$$\alpha_f = \alpha_p - \alpha_w = 3^\circ\ 10'$$

where α_w = wing setting to fuselage datum = $2^\circ\ 50'$.

The float setting has therefore been taken as 3° nose down to the fuselage datum.

The final float location on the seaplane is shown in Fig.18, together with the static water line.

5 Effect of Thrust Moment on Attitude

The chosen cases have been stated to be (1) the effect of full engine thrust moment on attitude at zero speed whether applied slowly or rapidly (2) the attitude at a low taxying speed. The method of solution, once the generalised buoyancy quantities are known, is to equate moments for static equilibrium and work done by moments for dynamic equilibrium. The angles to trim are obtained graphically. All moments due to air forces are neglected.

5.1 Zero Water Speed, Thrust Applied Slowly

To satisfy static equilibrium conditions, Fig.19, it is necessary that[1,2]

$$\Delta_1 = A/2 - T_{v_1} . \sin \overline{3 + \alpha} \qquad (1)$$

$$M_{\Delta_1} + M_{T_{v_1}} + M_{A/2} = 0 \qquad (2)$$

where T_{v_1} is propeller thrust for one float in cu ins. of water.

α is incidence of float datum

$M_{T_{v_1}}$ is moment due to thrust for one float in ins.^{4} of water.

$M_{W/2}$ is moment due to weight of aircraft per float in ins.^{4} of water.

Taking moments about the C.G., for the small seaplane

$$T_{v_1} = 68.6 \text{ ins.}^3$$

$$M_{T_{v_1}\,C.G.} = 92.6 \text{ ins.}^4$$

$$M_{\Delta_1\,C.G.} = \Delta_1\left(\ell_w - \ell_{\Delta_1}\right)$$

where $M_{\Delta_1\,C.G.}$ is moment of buoyancy about the C.G. position,

ℓ_w and ℓ_{Δ_1} are respectively the distances of the buoyancy and weight aft of the F.P., measured along the water line.

ℓ_w may be found graphically from Fig.18 for all values of α.

$$\ell_\Delta = \frac{M_{\Delta_1}}{\Delta_1}$$

M_{Δ_1} is obtained for a range of α from Fig.15, and Δ_1 for the same range, from Fig.13, satisfying condition (1) above. The resulting values of ℓ_Δ are given in Table 6, and values of $M_{\Delta_1\,C.G.}$ in Table 7.

The buoyancy moment with respect to the C.G., $M_{\Delta_1\,C.G._1}$ is plotted in Fig.22 against α for the thrust case, and the intersection with the thrust moment gives the required angle of trim. For the seaplane considered, the thrust moment depresses the attitude from 4° to $3^\circ\,3'$ nose up, the draft changing to $d = 2.78$ ins. (Fig.16). The resultant water line, is shown in Fig.18.

5.2 Zero Water Speed, Thrust Applied Rapidly

For equilibrium, it is now necessary that the work done by the thrust moment in the resulting movement, from static equilibrium engine off, be equal to the work done by the moment of buoyancy[1,2]. This assumes that moments of inertia, aerodynamic and hydrodynamic damping forces are negligible.

$$\text{Then} \quad \int M_{T_{v_1}\,C.G.} \cdot d\alpha = \int M_{\Delta_1\,C.G.} \cdot d\alpha \qquad (3)$$

where $M_{T_{v_1}\,C.G.}$ is thrust moment about C.G.

M_{Δ_1} C.G. is buoyancy moment about C.G.

$d\alpha$ is change of attitude.

The values of the integrals are plotted against attitude in Fig.22. The attitude decreases from 4° to 2° 31' nose up, the draft to 2.755 ins. (Fig.16). The water line is shown in Fig.18. In practice the resultant attitude will be between 2° 30' (dynamic case) and 3° 3' (static case) because of the assumptions made.

5.3 Taxying at 10 m.p.h., Thrust Applied Slowly

Since conditions are steady[1], equilibrium conditions are the same as for the case of no forward speed, if the added forces due to air lift and drag, and water drag be included. It is assumed that the floats or hull are still in the displacement region, or that the water forces are still predominately hydro-static. Then, from Fig.20

$$T_{v_1} \cdot \cos \overline{3 + \alpha} = D_{v_1} + R_{v_1} \tag{4}$$

$$\Delta_1 = \Delta/2 - T_{v_1} \cdot \sin \overline{3^{\circ} + \alpha} - L_{v_1} \tag{5}$$

$$M_{\Delta_1 \, C.G.} + M_{T_{v_1} \, C.G.} + M_{L_{v_1} \, C.G.} + M_{D_{v_1} \, C.G.} + M_{R_{v_1} \, C.G.} = 0 \tag{6}$$

where R_v is water resistance per float.

D_{v_1} is air drag of seaplane per float.

L_{v_1} is air lift of seaplane per float.

Neglecting moments of air forces about the C.G.

$$M_{\Delta_1 \, C.G.} + M_{T_{v_1} \, C.G.} + M_{R_{v_1} \, C.G.} = 0 \tag{7}$$

Approximately, in this condition, for the fifth scale seaplane considered.

$$R = 0.1 \, \Delta$$

$$\ell_R = 11.2 \text{ inches (distance of } R_v \text{ from C.G.)}$$

$$V_{tax} = 6.6 \text{ f.p.s.} = \text{taxying speed.}$$

Therefore

$$R_{v_1} = 20.2 \text{ (inches)}^3$$

and

$$M_{R_{v_1}\,C.G.} = 226 \text{ (inches)}^4.$$

The assumed air lift and drag per float is tabulated in Table 8, and plotted in Fig.23 for the small seaplane considered. Then the thrust required for steady taxying is

$$T_{v_1} = \frac{D_{v_1} + R_{v_1}}{\cos \overline{3^\circ + \alpha}}$$

The calculated values of the lift, drag and moments are given in Table 9 for a range of attitudes and the moments plotted in Fig.24. The resultant taxying attitude is 1° 12' nose up, and draft 2.672 ins. Fig.16, and the corresponding water line is shown in Fig.18. In practice the attitude will be more nose up than this because of the presence of some hydrodynamic lift.

6 Effect of Torque on Angle of Roll, at Zero Forward Speed

The final design case considered for hydrostatic stability is the angle of roll produced, at zero speed, by the engine torque at full thrust. This is done graphically, using the basic information on lifts and moments with known applied thrust and thrust moment. For a twin float seaplane, for equilibrium, from Fig.21,

$$\Delta_1 + \Delta_2 = A - T_v \sin \overline{3^\circ + \alpha} \qquad (8)$$

$$M_{T_v\,C.G.} = M_{\Delta_1}\,C.G. + M_{\Delta_2}\,C.G. = M_\Delta\,C.G. \qquad (9)$$

$$Q = \Delta_2 .\ a_2 - \Delta_1 .\ a_1 \qquad (10)$$

where Δ_1, Δ_2 are respective lift on the two floats,

M is the moment for two floats,

Q is the applied torque,

a_1, a_2 = respective distances of the centres of buoyancies of the two floats from the C.G. of the seaplane,

and $a_1 = L_1 \cos \overline{\beta - \theta}$

$a_2 = L_1 \cos \overline{\beta + \theta}$ (see Fig.21).

The estimation consists in

(a) determining the relationship between the drafts of the two floats to satisfy the condition of total buoyancy for a range of attitudes,

(b) determining the rolling moment due to the different drafts of the two floats for a range of attitude,

(c) deducing the angle of roll, for the applied engine torque, in terms of attitude,

(d) deducing the equilibrium attitude for the design conditions.

The geometry is given in Figs.18, 21 and 25. Step by step calculations are set out in Table 10. The angle of roll for equilibrium is deduced in Fig.26 for attitudes of 0°, 3° and 6° in terms of the respective drafts of the two floats. The resultant total water moments are plotted in Fig.27 against attitude and equilibrium attitudes deduced in terms of draft. Finally Fig.28 gives the required attitude for trim at the equilibrium angle of roll by the superimposition of the draft attitude relationship required for longitudinal and rolling moments respectively. The angle of roll is 34', angle of trim 2° 57'. The consequent transverse water line is given in Fig.28.

7 Conclusions

The graphical methods described give a complete picture of the nature of the buoyancy forces in a form immediately useful to any design problem in the displacement region, i.e. low taxying speeds. The method does not involve the calculation of metacentric heights.

Its application to the case of a small twin float seaplane shows how the more usual calculations for trim can be made of attitude and roll under different engine conditions in zero wind and wave conditions. The layout of tables and graphs is a useful guide to the application of the method.

The cases of wind and waves can be simply considered using the same basic data, if suitable design conditions be defined. Information on the sea and wind conditions found in practice is given in references 8 to 14. Fairly complete data are also required on the aerodynamic forces and moments in yaw and roll for a range of attitudes with ground interference.

The use of the energy principle enables calculations to be made on the effect of wind gusts, anchor and towing loads, which must be considered as of a transient nature.

List of Symbols

Angles

i°	=	incidence of mean chord
α°	=	attitude (trim)
α_1°	=	angle between float datum and heel to heel line
α_w°	=	setting of mean chord of wings relative to fuselage datum
$\alpha^{\circ}C_{L_{max}}$	=	incidence of mean chord for maximum coefficient of lift
α°_{sec}	=	angle of security for take-off and landing
α°_{p}	=	angle between mean chord and float datum
α°_{f}	=	angle between fuselage datum and float datum
θ°	=	angle of roll due to engine torque
β°	=	see Fig. 21

Lengths

$\bar{c}$	=	wing mean chord
z	=	local draught
d	=	draught
$h_{C.G.}$	=	height of C.G. above float datum
$s_{C.G.}$	=	distance of C.G. from step
ℓ_{Δ}	=	distance of buoyancy from F.P.
ℓ_W	=	distance of weight of aircraft from F.P.
r_T	=	distance of thrust from C.G.
r_R	=	distance of water resistance from C.G.
r_L	=	distance of air lift from C.G.
r_D	=	distance of air drag from C.G.
ℓ_f	=	distance between floats
ℓ_{xn}	=	see Fig. 3
X_n	=	see Fig. 3
a_1	=	lateral distance from Δ_1 to C.G.
a_2	=	lateral distance from Δ_2 to C.G.
L_1	=	see Fig. 21

List of Symbols (contd.)

Areas

F_d = "wetted" cross sectional area relative to the water line

F_z = "wetted" cross sectional area at draught z

S = wing gross area

Speed

V = forward speed of aircraft

V_{tax} = taxying speed

Density

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

ρ = 0.002378 $slugs/ft^3$ density of air

Forces

W = all up weight of aircraft in lb

A = all up weight of aircraft in volume of fresh water

T = thrust in lb

T_v = thrust in volume of fresh water

T_{v_1} = thrust in volume of fresh water for one float

R = water resistance in lb

R_v = water resistance in volume of fresh water

R_{v_1} = water resistance in volume of fresh water for one float

L = air lift in lb

L_v = air lift in volume of fresh water

L_{v_1} = air lift in volume of fresh water for one float

D = air drag in lb

D_v = air drag in volume of fresh water

D_{v_1} = air drag in volume of fresh water for one float

Δ = buoyancy in volume of fresh water

Δ_1 = buoyancy of first float in volume of fresh water

Δ_2 = buoyancy of second float in volume of fresh water

Δ_h = hydrodynamical buoyancy

Moments

M_{T_v} C.G.	=	moment of thrust relative to C.G. in (inches)^4
$M_{T_{v_1}}$ C.G.	=	moment of thrust for one float relative to C.G. in (inches)^4
M_{R_v} C.G.	=	moment of water resistance relative to C.G. in (inches)^4
$M_{R_{v_1}}$ C.G.	=	moment of water resistance for one float relative to C.G. in (inches)^4
M_{D_v} C.G.	=	moment of air drag relative to C.G. in (inches)^4
$M_{D_{v_1}}$ C.G.	=	moment of air drag for one float relative to C.G. in (inches)^4
M_{L_v} C.G.	=	moment of air lift relative to C.G. in (inches)^4
$M_{L_{v_1}}$ C.G.	=	moment of air lift for one float relative to C.G. in (inches)^4
M_{Δ} C.G.	=	moment of buoyancy relative to C.G.
M_{Δ} F.P.	=	moment of buoyancy relative to F.P.
M_{Δ_1} C.G	=	moment of buoyancy for one float relative to C.G.
M_{Δ_2} C.G.	=	moment of buoyancy for second float relative to C.G.
M_{Δ_1} F.P.	=	moment of buoyancy for one float relative to F.P.
M_{Δ_2} F.P.	=	moment of buoyancy for second float relative to F.P.

Power

P	=	engine power during take-off in B.H.P.
n	=	maximum permissible r.p.m. during take-off

Non-dimensional

C_L	=	coefficient of air lift
C_D	=	coefficient of air drag
Res	=	reserve of buoyancy in %

General

W.L.	=	water line
C.G.	=	centre of gravity
F.P.	=	forward position of float on float datum

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Appendix I

A Graphical Analytical Method of Determining Area and First Moment

This method is described in many publications[1,2,3] and is an accurate and useful method when suitable planimeters are not available.

Given the curve AB in Fig. 31, suppose we wish to know the area S under this curve and its first moment M about $x = 0$. Then

$$S = \int_A^B f(x)\ dx \qquad (1)$$

$$M = \int_A^B f(x)\ x\ dx \qquad (2)$$

Dividing A_1B_1 the projection onto the x axis, into a sufficient whole number of equal parts of length d, the equations (1) and (2) may be replaced by

$$S = d.\sum_A^B f(x) \qquad (3)$$

$$M = d.\sum_A^B f(x)\ \ell_x \qquad (4)$$

Calculations are then made in tabular form, the necessary ordinates being measured off the curves.

Appendix II

Graphical Integration of Area and First Moment

This method has been described generally[7] and is quite accurate if the drawing is done with precision.

Suppose we have area A_1ABB_1 Fig. 29. Draw thin strips of the area parallel to the y axis and let their centre lines have lengths f_1, f_2 ... From the ends of these centre lines on curve $A.B_1$ draw perpendicular lines to the y axis and join the intersections of these lines with the y axis to a point O_1. Draw for each strip parallel lines to $O_1\ 1_1$, $O_1\ 2_1$ as in Fig. 29.

From similarity of triangles

$$f_1 \times dx = y_1 \times \ell$$

$$f_2 \times dx = y_2 \times \ell$$

$$f_3 \times dx = y_3 \times \ell$$

$$f_n \times dx = y_n \times \ell$$

$$\overline{\int_A^B f(x) \times dx = \ell \times \sum_A^B y}$$

but

$$\sum_A^B y = B_1\ B_2$$

If scale of $\qquad f(x) = 1{:}n$

$\qquad\qquad x = 1{:}m$

scale of area $\qquad = 1{:}m.n$

Then area $A_1ABB_1 = m.n \times \ell \times B_1\ B_2$.

The method of graphical integration of the static moment of area A_1ABB_1 relative to the y axis is shown in Fig. 30. From the ends of the centre lines of the strips on curve A.B. draw perpendicular lines to a line parallel to the y axis, yy'. Join the intersections of these lines with line yy' to O, and mark on the centre lines the intersections with these lines, 1_2, 2_2 ..... From points 1_2, 2_2, 3_2, ... draw perpendicular lines to the y axis. Intersections of these lines with the y axis, 1_3, 2_3, 3_3,..... are joined to point O_1. For each strip draw parallel lines to $O_1 1_3$, $O_1 2_3$, $O_1 3_3$ ..... as in Fig. 30.

From similarity of triangles

$$
\text{(A)}\quad
\begin{array}{l}
f_1 \times r_1 = Z_1 \times h \\
f_2 \times r_2 = Z_2 \times h \\
\text{-----------------} \\
f_n \times r_n = Z_n \times h
\end{array}
\qquad
\text{(B)}\quad
\begin{array}{l}
Z_1 \times dx = y_1 \times \ell \\
Z_2 \times dx = y_2 \times \ell \\
\text{-----------------} \\
Z_n \times dx = y_n \times \ell
\end{array}
$$

From (A) and (B)

$$
\begin{array}{l}
f_1 \times r_1 \times dx = \ell \times h \times y_1 \\
f_2 \times r_2 \times dx = \ell \times h \times y_2 \\
\text{-------------------------} \\
f_n \times r_n \times dx = \ell \times h \times y_n \\
\hline
\end{array}
$$

$$M = \int_A^B f(x) \times r_x \times dx = \ell \times h \times \sum_A^B yx$$

but

$$\sum_A^B yx = B_1B_2$$

If scale of

$$f(x) = 1:m$$

$$x = 1:n$$

scale of

$$M = 1 \cdot n^2m$$

and

$$M = n^2m \times \ell \times h \times B_1B_2.$$

Table 1

Particulars of small float seaplane

Setting of wing mean chord to fuselage datum	$\alpha_\omega = 2^\circ\ 50'$
Wing incidence for maximum lift coefficient	$\alpha\ C_{L_{max}} = 19^\circ$
Angle between float datum and heel to heel line	$\alpha_1 = 10^\circ$
Angle of security during take off and landing	$\alpha_{sec} = 3^\circ$

(Defined as difference between $\alpha\ C_{L_{max}}$ and maximum wing incidence in take off and landing.)

	Full Scale	Fifth Scale
Wing mean chord $\bar{c}$	61.5 ins.	12.3 ins.
Height of C.G. above float datum $h_{C.G.}$	62.0 ins.	12.4 ins.
Distance between float centre lines ℓ_f	77.5 ins.	15.5 ins.
Height of thrust line above C.G. ℓ_T	6.75 ins.	1.35 ins.
Wing area gross S	185 feet^2	106.5 ins.^{2}
All up weight W	1820 lb	14.6 lb
Maximum take off thrust T	620 lb	4.96 lb
" " " power	131 BHP	
Maximum nose down pitching moment for take off thrust $M_{T\ C.G.}$	349 lb ft	6.70 lb ins.
Maximum nose down pitching moment for take off torque Q	246 lb ft	4.73 lb ins.

Forces and Moments expressed in terms of volume of water (62.5 lb per ft^3)

All up weight - per float model scale	202 cu ins.
Maximum thrust on take off - per float model scale	68.6 cu ins.
Maximum pitching moment for thrust - per float model scale	92.6 (ins)^4
Maximum torque moment for thrust - per float model scale	131 (ins)^4
Total buoyancy per float	440 cu ins.

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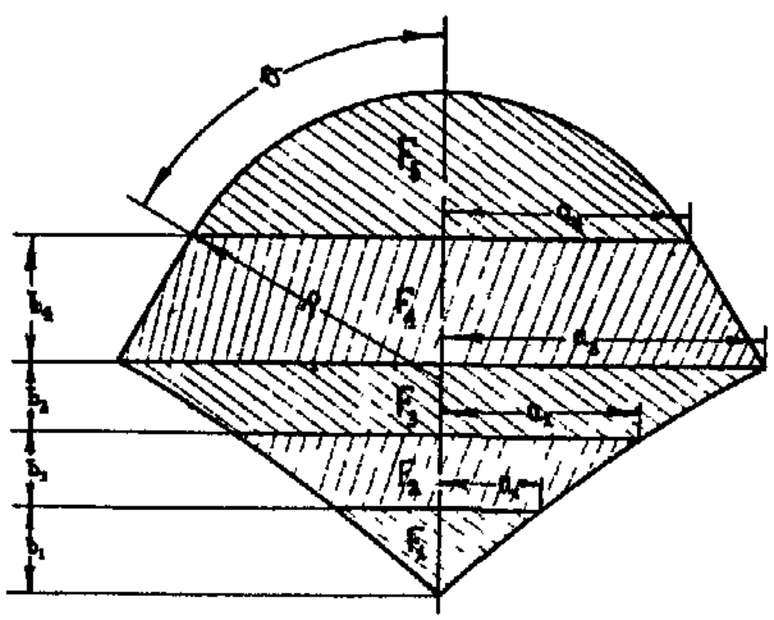
CALCULATION OF CROSS SECTIONAL AREAS AT FLOAT STATIONS

Stations	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	a_1	b_1	a_2	b_2	a_3	b_3	a_4	b_4	R	θ	$2\times\theta$	(1)+(9)	(3)+(5)	(5)+(7)	(9)²
	inches	inches	inches	inches	inches	inches	inches	inches	inches	(°)	(°)	inches	inches	inches	(inches)²
(FP)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
(1)	0.27	0.42	0.57	0.42	0.57	—	0.33	0.19	0.57	36°30'	73°	0.84	—	0.90	0.324
(2)	0.41	0.59	0.81	0.59	0.81	—	0.47	0.29	0.81	36°30'	73°	1.22	—	1.28	0.656
(3)	0.32	0.54	0.69	0.54	1.13	0.54	0.75	0.36	1.13	41°30'	83°	1.01	1.82	1.88	1.276
(4)	0.43	0.71	0.95	0.71	1.56	0.70	1.21	0.42	1.56	50°	100°	1.38	2.51	2.77	2.434
(5)	0.49	0.76	1.10	0.76	1.85	0.76	1.55	0.46	1.85	57°30'	115°	1.59	2.95	3.40	3.422
(6)	0.57	0.74	1.25	0.72	2.08	0.72	1.95	0.37	2.08	70°20'	140°40'	1.82	3.33	4.03	4.330
(7)	0.62	0.68	1.33	0.66	2.25	0.66	2.24	0.11	2.25	85°30'	171°	1.95	3.58	4.49	5.060
(8)	0.65	0.60	1.41	0.59	2.38	0.59	2.38	0.22	2.38	—	—	2.06	3.79	4.76	5.660
(9)	0.64	0.52	1.44	0.54	2.48	0.54	2.48	0.46	2.48	—	—	2.08	3.92	4.96	6.150
(10)	0.66	0.47	1.48	0.46	2.54	0.46	2.54	0.69	2.54	—	—	2.14	4.02	5.08	6.450
(11)	0.69	0.44	1.50	0.42	2.59	0.42	2.59	0.79	2.59	—	—	2.19	4.09	5.18	6.720
(12)	0.71	0.42	1.47	0.40	2.60	0.42	2.60	0.86	2.60	—	—	2.18	4.07	5.20	6.760
(20)	0.71	0.42	1.47	0.40	2.60	0.42	2.60	0.86	2.60	—	—	2.18	4.07	5.20	6.760
(20c)	0.82	0.44	1.52	0.43	2.59	0.43	2.59	0.53	2.59	—	—	2.34	4.11	5.18	6.720
(21)	2.56	1.28	—	—	2.56	—	2.56	0.20	2.56	—	—	—	—	5.12	6.560
(22)	2.49	1.28	—	—	2.49	—	2.49	0.01	2.49	—	—	—	—	4.98	6.210
(23)	2.40	1.28	—	—	2.40	—	2.33	0.37	2.40	77°	154°	—	—	4.73	5.760
(24)	2.24	1.28	—	—	2.24	—	2.19	0.28	2.24	75°	150°	—	—	4.43	5.020
(25)	2.02	1.26	—	—	2.02	—	1.96	0.29	2.02	74°	148°	—	—	3.98	4.085
(26)	1.75	1.18	—	—	1.75	—	1.51	0.18	1.75	78°	156°	—	—	3.26	3.070
(27)	1.41	1.02	—	—	1.41	—	1.41	0.03	1.41	—	—	—	—	2.82	1.990
(28)	1.04	0.79	—	—	1.04	—	1.04	0.33	1.04	—	—	—	—	2.08	1.480
(29)	0.61	0.47	—	—	0.61	—	0.61	0.79	0.61	—	—	—	—	1.22	0.372
(30)	0.21	0.16	—	—	0.21	—	0.21	1.13	0.21	—	—	—	—	0.42	0.044

Stations	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)
	$2\times\theta$	sin (11)	½×(15)	(16)−(17)	(18)×(19)	(1)×(2)	(12)×(4)	(13)×(6)	(14)×(8)	π×(18)	(21)+(22)	(26)+(23)	(27)+(24)	(28)+(20/25)
	radians		(inches)²		(inches)²	(inches)²	(inches)²	(inches)²	(inches)²	(inches)²	(inches)²	(inches)²	(inches)²	(inches)²
(FP)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
(1)	1.2741	0.9563	0.162	0.3178	0.0514	0.1132	0.353	—	0.1710	—	0.6662	—	0.8372	0.8886
(2)	1.2741	0.9563	0.328	0.3178	0.1041	0.2418	0.588	—	0.3710	—	1.2298	—	1.6000	1.7049
(3)	1.4488	0.9925	0.638	0.4560	0.2902	0.1730	0.546	0.982	0.6760	—	0.7190	1.701	2.377	2.6672
(4)	1.7454	0.9848	1.217	0.7606	0.9130	0.3030	0.980	1.755	1.1630	—	1.283	3.038	4.201	5.1140
(5)	2.0070	0.9063	1.711	1.0907	1.8650	0.3720	1.210	2.240	1.5620	—	1.582	3.822	5.384	7.2490
(6)	2.4550	0.6338	2.165	1.8212	3.9400	0.4210	1.310	2.400	1.4900	—	1.731	4.131	5.621	9.5610
(7)	2.9834	0.1564	2.530	2.8270	7.1600	0.4210	1.130	2.360	0.4940	—	1.551	3.911	4.405	11.5650
(8)	—	—	2.830	—	—	0.3500	1.215	2.235	1.0450	8.88	1.605	3.840	4.885	13.7650
(9)	—	—	3.075	—	—	0.3325	1.081	2.115	2.2800	9.70	1.4135	3.5285	5.8085	15.5085
(10)	—	—	3.225	—	—	0.3160	0.924	1.850	3.510	10.20	1.234	3.144	6.654	16.8540
(11)	—	—	3.360	—	—	0.3040	0.920	1.720	4.090	10.55	1.224	2.944	7.034	17.5840
(12)	—	—	3.380	—	—	0.2980	0.872	1.710	4.476	10.60	1.170	2.880	7.350	17.9500
(20)	—	—	3.380	—	—	0.2980	0.872	1.710	4.470	10.60	1.170	2.880	7.350	17.9500
(20c)	—	—	3.360	—	—	3.6400	1.005	1.770	2.750	10.55	1.366	3.136	5.886	16.4360
(21)	—	—	3.280	—	—	3.2800	—	—	1.022	10.30	—	—	4.302	14.6020
(22)	—	—	3.105	—	—	3.1900	—	—	0.050	9.75	—	—	3.240	12.9900
(23)	2.6878	0.4384	2.880	2.2494	6.460	3.0750	—	—	1.750	—	—	—	4.825	11.2850
(24)	2.6180	0.5000	2.510	2.1180	5.460	2.8620	—	—	1.240	—	—	—	4.102	9.5620
(25)	2.5834	0.5299	2.044	2.0531	4.210	2.5750	—	—	1.155	—	—	—	3.730	7.9400
(26)	2.7228	0.4067	1.535	2.3161	3.550	2.0320	—	—	0.987	—	—	—	2.619	6.1690
(27)	—	—	0.995	—	—	1.4300	—	—	0.085	3.12	—	—	1.515	4.6350
(28)	—	—	0.741	—	—	0.8200	—	—	0.687	2.320	—	—	1.507	3.8270
(29)	—	—	0.186	—	—	0.2800	—	—	0.965	0.584	—	—	1.245	1.8290
(30)	—	—	0.022	—	—	0.0336	—	—	0.475	0.069	—	—	0.5086	0.5776



$F_1 = a_1 \times b_1 =$ (21) for all stations

$F_2 = (a_1 + a_2) \times b_2 =$ (22) for stations (1) till (20)

$F_3 = (a_2 + a_3) \times b_3 =$ (23) for stations (3) till (20c)

$F_4 = (a_3 + a_4) \times b_4 =$ (24) for all stations

$F_5' = \frac{R^2}{2} \times (2\theta_{rad} - \sin 2\theta) =$ (20) for stations (1) till (7) and (23) till (26)

$F_5'' = \frac{\pi \times R^2}{2} =$ (25) for stations (8) till (22) and (27) till (30)

TABULATED VALUES OF WETTED CROSS SECTIONAL AREAS OF FLOAT FOR A RANGE OF ATTITUDES AND DRAFTS.

Station.	30	31	32	33	34	35	36	37	38	39
	$\alpha = -3°$		$\alpha = 0°$				$\alpha = 3°$		$\alpha = 6°$	
	$d_2 = 2.5''$	$d_3 = 3.5''$	$d_1 = 1.5''$	$d_2 = 2.5''$	$d_3 = 3.5''$	$d_4 = 4.7''$	$d_2 = 2.5''$	$d_3 = 3.5''$	$d_2 = 2.5''$	$d_3 = 3.5''$
FP	—	—	—	—	—	—	—	—	—	—
1	0.40	0.8886	—	—	0.15	0.8886	—	—	—	—
2	1.00	1.7049	—	—	0.65	1.7049	—	—	—	—
3	1.50	2.6672	—	0.10	1.10	2.6672	—	0.05	—	—
4	2.80	5.00	—	0.50	2.50	5.1140	—	0.40	—	—
5	4.30	7.05	0.15	1.30	4.15	7.249	0.15	1.25	—	0.10
6	6.10	9.10	0.45	2.50	6.25	9.561	0.50	2.70	—	0.55
7	7.40	10.90	0.85	3.95	7.80	11.565	1.05	4.45	0.15	1.35
8	9.10	12.65	1.60	5.65	9.85	13.765	2.30	6.70	0.475	3.10
9	10.40	14.20	2.40	7.10	11.60	15.5085	3.70	8.45	1.60	5.10
10	11.30	15.45	3.30	8.35	12.95	16.854	5.25	10.10	2.28	7.05
11	11.55	15.70	4.25	9.15	13.55	17.584	6.50	11.05	3.90	8.60
12	11.70	15.85	4.30	9.50	14.00	17.950	7.15	11.95	4.90	9.78
13	11.30	15.55	4.30	9.50	14.00	17.950	7.40	12.20	5.40	10.30
14	11.00	15.30	4.30	9.50	14.00	17.950	7.65	12.45	5.95	10.80
15	10.80	15.10	4.30	9.50	14.00	17.950	8.00	12.70	6.55	11.32
16	10.65	14.95	4.30	9.50	14.00	17.950	8.35	13.10	7.25	11.95
17	10.15	14.65	4.30	9.50	14.00	17.950	8.50	13.20	7.60	12.32
18	9.95	14.45	4.30	9.50	14.00	17.950	8.85	13.30	8.30	12.90
19	9.65	14.30	4.30	9.50	14.00	17.950	9.15	13.70	8.70	13.46
20	9.50	14.00	4.30	9.50	14.00	17.950	9.50	14.00	9.50	14.00
20½	8.30	12.95	2.45	8.50	13.10	16.436	8.40	13.15	8.70	13.15
21	5.60	10.55	2.10	6.10	11.00	14.602	6.40	11.15	6.90	11.45
22	3.80	8.70	1.45	4.85	9.50	12.89	5.55	10.00	6.35	10.55
23	2.45	6.50	0.75	3.20	7.65	11.285	4.30	8.55	5.40	9.45
24	1.16	4.60	0.15	2.40	6.00	9.562	3.40	7.15	4.75	8.10
25	0.70	2.90	—	1.60	4.70	7.94	2.50	6.05	3.95	7.15
26	—	1.70	—	0.90	3.15	6.169	1.80	4.65	3.15	5.85
27	—	0.90	—	0.40	2.00	4.635	1.25	3.45	2.40	4.635
28	—	0.35	—	—	1.30	3.827	0.75	2.90	2.10	3.827
29	—	—	—	—	0.70	1.829	0.45	1.55	1.25	1.829
30	—	—	—	—	0.25	0.5776	0.25	0.60	0.50	0.5776
31	—	—	—	—	—	—	—	—	—	—

(ALL VALUES IN THIS TABLE IN $(\text{INCHES})^2$)

CALCULATION OF BUOYANCY, MOMENT OF BUOYANCY, AND CENTRE OF BUOYANCY FOR

$\alpha = -3°$; $d = 2\ 5''$

Section	(40)	(41)	(42)	(43)	(44)	(45)
	dl	F_{dn}	l_{xn}	$F_{dn} \times l_{xn}$	$F_{dn} \times dl$	$F_{dn} \times l_{xn} \times dl$
	inches	(inches)^2	inches	(inches)^3	(inches)^3	(inches)^4
1	1 0	——	0.806	——	0 425	0 2143
2	1 0	1 30	1 36	1 77	——	——
3	1 0	2.15	2 36	5 07	——	——
4	1 0	3.10	3 36	10 40	——	——
5	1 0	4 00	4 36	17 40	——	——
6	1 0	4.92	5 36	26.40	——	——
7	1 0	5 90	6 36	37 50	——	——
8	1 0	6.80	7 36	50 00	——	——
9	1 0	7.70	8 36	64 40	——	——
10	1 0	8.70	9 36	81 40	——	——
11	1 0	9.55	10 36	98.80	——	——
12	1 0	10.35	11 36	117 50	——	——
13	1 0	10 95	12 36*	135 10	——	——
14	1.0	11 40	13.36	152 50	——	——
15	1 0	11 68	14 36	167 40	——	——
16	1.0	11 80	15 36	181 20	——	——
17	1.0	11 65	16.36	190 30	——	——
18	1.0	11 30	17 36	196.00	——	——
19	1.0	11.05	18.36	202 00	——	——
20	1.0	10.75	19.36	208 00	——	——
21	1 0	10 50	20 36	213 50	——	——
22	1.0	10 30	21 36	220 00	——	——
23	1.0	10 05	22 36	224 50	——	——
24	1 0	9 85	23.36	230 00	——	——
25	0.9	9 65	24 29	——	8.69	211 00
26	0.1	9 30	24 69	——	0.93	22 95
27	1 0	7 60	25 36	192 30	——	——
28	1 0	5 30	26 36	139 40	——	——
29	1 0	4.10	27 36	112 00	——	——
30	1.0	3.35	28 36	95 00	——	——
31	1.0	2 55	29 36	74 80	——	——
32	1 0	1 70	30 36	51 60	——	——
33	1 0	1 00	31 36	31 36	——	——
34	1 0	0 72	32 36	23 28	——	——
35	1 0	0 45	33 36	15 00	——	——
36	0 3	——	33 94	——	0 30	10 17
		221.47		3364 78	10 075	233.19

BUOYANCY $\Delta_d = 234\ 5$ (INCHES)^3

MOMENT OF BUOYANCY $M_\Delta = 3800$ (INCHES)^4 ABOUT F P

CENTRE OF BUOYANCY $\ell_\Delta = 16\ 4$ INCHES FROM F P

$\alpha = -3°$; $d = 3\ 5''$

Section	(46)	(47)	(48)	(49)	(50)	(51)
	dl	F_{dn}	l_{xn}	$F_{dn} \times l_{xn}$	$F_{dn} \times dl$	$F_{dn} \times l_{xn} \times dl$
	inches	(inches)^2	inches	(inches)^3	(inches)^3	(inches)^4
1	1 0	——	0 246	——	0 975	0 240
2	1 0	2 70	1 280	3 558	——	——
3	1 0	3 90	2 28	8 890	——	——
4	1 0	5 10	3 28	16 720	——	——
5	1 0	6.25	4 28	26 800	——	——
6	1 0	7 45	5 28	39 30	——	——
7	1.0	8 60	6.28	54 00	——	——
8	1 0	9 80	7 28	71 25	——	——
9	1 0	10 55	8 28	90 75	——	——
10	1 0	12 07	9 28	111 80	——	——
11	1 0	13 07	10 28	134 20	——	——
12	1.0	14 00	11 28	158 00	——	——
13	1 0	14 70	12 28	180 50	——	——
14	1 0	15 26	13 28	202 20	——	——
15	1.0	15 60	14 28	222 60	——	——
16	1 0	15 79	15 28	240 80	——	——
17	1 0	15 78	16.28	256 70	——	——
18	1 0	15 62	17 28	270 00	——	——
19	1 0	15 40	18.28	281 50	——	——
20	1.0	15 20	19 28	293 00	——	——
21	1 0	15 00	20 28	304 60	——	——
22	1 0	14 78	21 28	314 50	——	——
23	1 0	14 55	22 28	324 20	——	——
24	1 0	14 35	23 28	334 50	——	——
25	1.0	14 16	24 28	344 00	——	——
26	0 15	14 00	24 855	——	2 10	52 30
27	0 85	13 10	25 355	——	11 13	282 00
28	1.0	10 75	26 28	282 50	——	——
29	1.0	9 35	27 28	255 20	——	——
30	1.0	8 35	28 28	236 00	——	——
31	1.0	7 20	29 28	210 50	——	——
32	1.0	5 70	30 28	172 40	——	——
33	1 0	4 30	31.28	134 20	——	——
34	1.0	3 25	32 28	105 00	——	——
35	1 0	2 33	33 28	77 60	——	——
36	1 0	1 67	34 28	57 25	——	——
37	1 0	1 10	35.28	38 85	——	——
38	1 0	0 70	36 28	25 40	——	——
39	1 0	0 40	37 28	14 90	——	——
40	1 10	——	38 146	——	0 154	5 26
		345 16		5902 17	14 36	359.80

BUOYANCY $\Delta_d = 359{\cdot}6$ (INCHES)^3

MOMENT OF BUOYANCY $M_\Delta = 6242$ (INCHES)^4 ABOUT F P

CENTRE OF BUOYANCY $\ell_\Delta = 17\ 36$ INCHES FROM F P

TABLE 4

SHEET 1.

TABLE 4
SHEET 2

$\alpha = 0^\circ$, $d = 1\ 5''$

Section	52	53	54	55	56	57
	dl	F_{dn}	l_{xn}	$F_{dn} \times l_{xn}$	$F_{dn} \times dl$	$F_{dn} \times l_{xn} \times dl$
	inches	(inches)^2	inches	(inches)^3	(inches)^3	(inches)^4
1	0 6	——	3.8	——	0 015	0 057
2	1 0	0 10	4 5	0 45	——	——
3	1 0	0 25	5 5	1 375	——	——
4	1 0	0.45	6 5	2 922	——	——
5	1 0	0.75	7 5	5.625	——	——
6	1 0	1.15	8 5	9 780	——	——
7	1 0	1 65	9 5	15 69	——	——
8	1 0	2 18	10 5	22 90	——	——
9	1 0	2 75	11.5	31 65	——	——
10	1 0	3 30	12 5	41 25	——	——
11	1 0	3 90	13 5	52 60	——	——
12	1.0	4 26	14 5	61 70	——	——
13	1 0	4 28	15.5	66 40	——	——
14	8.2	4 30	20 2	——	35 26	712.00
15	0 2	3 20	24 5	——	0 64	15 68
16	0 2	2 60	24 7	——	0 52	12 84
17	0 2	2 40	24 9	——	0 48	11 90
18	1 0	2 25	25 5	57 40	——	——
19	1 0	1 90	26 5	50 40	——	——
20	1 0	1 55	27 5	42 60	——	——
21	1 0	1 10	28 5	31 40	——	——
22	1 0	0 70	29. 5	20 60	——	——
23	1 0	0 35	30 5	10 66	——	——
24	4 5	——	31 15	——	0 045	1.40
		46.82		525 40	36 96	755 98

$\Delta = 83\ 78\ (\text{INCHES})^3 \quad M_d = 1281\ (\text{INCHES})^4$

$\ell_\Delta = 15\ 32$ INCHES.

$\alpha = 0^\circ$, $d = 2\ 5''$

Section	58	59	60	61	62	63
	dl	F_{dn}	l_{xn}	$F_{dn} \times l_{xn}$	$F_{dn} \times dl$	$F_{dn} \times l_{xn} \times dl$
	inches	(inches)^2	inches	(inches)^3	(inches)^3	(inches)^4
1	0 9	——	1 7	——	0 045	0 0765
2	1 0	0 35	2 5	0 875	——	——
3	1 0	0 70	3 5	2 450	——	——
4	1 0	1 15	4 5	5 175	——	——
5	1 0	1 70	5 5	9 350	——	——
6	1 0	2 60	6 5	16 900	——	——
7	1 0	3.60	7 5	27 000	——	——
8	1 0	4.68	8 5	39 800	——	——
9	1 0	5 70	9 5	59 100	——	——
10	1 0	6 70	10 5	70 400	——	——
11	1 0	7 68	11 5	88 400	——	——
12	1 0	8 40	12 5	105 000	——	——
13	1 0	8 95	13 5	120 800	——	——
14	1 0	9 30	14 5	134 800	——	——
15	1 0	9 48	15 5	147 000	——	——
16	8.4	9 50	20 2	——	79 80	1610 00
17	0 6	8 65	24 7	——	5 19	128 00
18	1 0	7 25	25.5	184 9	——	——
19	1 0	6 05	26 5	160 0	——	——
20	1 0	5 05	27 5	138.9	——	——
21	1 0	4 20	28 5	119 6	——	——
22	1 0	3 45	29 5	101 5	——	——
23	1 0	2 75	30 5	83 8	——	——
24	1 0	2 15	31 5	67 7	——	——
25	1 0	1 65	32 5	53 6	——	——
26	1 0	1 20	33 5	40 2	——	——
27	1 0	0 85	34 5	29 3	——	——
28	1 0	0 55	35 5	19 5	——	——
29	1 0	0 25	36 5	9.12	——	——
30	1 0	——	37 233	——	0 035	1 304
		103.34		1805 17	85 07	1738 38

$\Delta = 188\ 4\ (\text{INCHES})^3 \quad M_d = 3544\ (\text{INCHES})^4$

$\ell_\Delta = 18\ 85$ INCHES

$\alpha = 0°$; $d = 35"$

Section	64	65	66	67	68	69
	dl	F_{dn}	l_{xn}	$F_{dn} \times l_{xn}$	$F_{dn} \times dl$	$F_{dn} \times l_{nx} \times dl$
	inches	$(\text{inches})^2$	inches	$(\text{inches})^3$	$(\text{inches})^3$	$(\text{inches})^4$
1	0 9	——	0 7	——	0 27	0 189
2	1 0	1 05	1 5	1 51	——	——
3	1 0	1.95	2 5	4 88	——	——
4	1 0	2 90	3.5	10 15	——	——
5	1 0	3 95	4 5	17 75	——	——
6	1 0	5 10	5 5	28.05	——	——
7	1 0	6.35	6. 5	41 20	——	——
8	1 0	7 60	7 5	57 00	——	——
9	1 0	8 85	8 5	75 20	——	——
10	1 0	10 10	9 5	96 00	——	——
11	1 0	11 25	10 5	118 00	——	——
12	1 0	12 15	11 5	139.50	——	——
13	1 0	12 95	12 5	162 00	——	——
14	1 0	13 50	13 5	182 20	——	——
15	1.0	13 85	14 5	201 00	——	——
16	1.0	13 98	15 5	216 50	——	——
17	8 4	14 00	20 2	——	117 50	3442 000
18	0.6	13 20	24 7	——	7 92	195.000
19	1 0	11 90	25 5	304 00	——	——
20	1 0	10,60	26.5	281 00	——	——
21	1 0	9 50	27 5	261 00	——	——
22	1 0	8 50	28.5	242 00	——	——
23	1.0	7 50	29. 5	221 00	——	——
24	1 0	6 55	30. 5	199 50	——	——
25	1 0	5.60	31 5	176.50	——	——
26	1 0	4 70	32 5	152 75	——	——
27	1 0	3 90	33 5	130.50	——	——
28	1 0	3 10	34 5	106 80	——	——
29	1 0	2 40	35 5	85 20	——	——
30	1 0	1 85	36 5	67 50	——	——
31	1 0	1 40	37 5	52.50	——	——
32	1 0	1 00	38 5	38 50	——	——
33	1 0	0 70	39 5	27 65	——	——
34	1 0	0 40	40 5	16 20	——	——
35	1 0	0 20	41 5	8 30	——	——
36	0 7	——	42 233	——	0 035	1 478
		330 65		3722 34	0 30	3638 66

$\Delta = 331\ 0\ (\text{INCHES})^3$ $M_d = 7361\ (\text{INCHES})^4$

$l_\Delta = 21\ 8$ INCHES

$\alpha = 0^\circ$; $d = 4\,7''$

TABLE 4.
SHEET 4.

Section	70	71	72	73	74	75	76	77	78	79	80	81	82	83
				71 + 72	$\frac{1}{2}$ × 73	70 × 74		2 × 72	77 + 71	78 : 73	$\frac{1}{3}$ × 70	79 × 80	81 + 76	75 × 82
	dl	F_1	F_2	$F_1 + F_2$	$\frac{1}{2}(F_1 + F_2)$	$\frac{1}{2}(F_1 + F_2)dl$	l_{x_1}	$2F_2$	$2F_2 + F_1$	$\frac{2F_2 + F_1}{F_1 + F_2}$	$\frac{1}{3}dl$			
	inches	(inches)^2	(inches)^2	(inches)^2	(inches)^2	(inches)^3	inches	(inches)^2	(inches)^2		inches	inches	inches	(inches)^4
1	0 4	——	1 00	——	0 50	0 25	——	——	——	——	——	0 133	0 133	0 0392
2	0 6	1 00	2.00	3 00	1 50	0 90	0 40	4.00	5 00	1 665	0 20	0 333	0 733	0.6600
3	1 0	2 00	3 40	5 40	2 70	2.70	1.00	6.80	8 80	1 63	0.333	0 543	1.543	4 170
4	7 2	3 40	13 62	17 02	8 51	61 20	2.00	27 24	30.64	1 80	2 40	4 32	6 320	386 500
5	0.8	13.62	14 60	28 22	14 11	11.29	9 20	29 20	42 82	1 516	0 266	0 404	9 604	108 800
6	1 0	14 60	15 64	30 24	15 12	15 12	10 00	31 28	45 88	1 53	0 333	0.505	10 530	159 000
7	1 0	15 64	16 56	32 20	16 10	16 10	11 00	33 12	48 76	1 51	0 333	0 504	11 504	185 500
8	1.0	16 56	17 20	33 76	16 88	16 88	12.00	34 40	50 96	1 505	0 333	0 504	12 504	211 500
9	1 0	17 20	17 64	34 84	17 42	17 42	13 00	35 28	52 48	1 505	0 333	0 500	13 500	235 500
10	1 0	17 64	17 90	35 54	17 57	17 57	14 00	35 80	53 44	1 505	0 333	0 500	14 500	255 000
11	1 0	17 90	17 95	35 85	17 925	17 925	15 00	——	——	——	——	0 500	15 500	278 000
12	8.4	17 95	17 95	——	17 95	151.00	16 00	——	——	——	——	4 200	20 200	3050 000
13	0 4	17 95	16 60	34 55	17 275	6.91	20.40	33 20	51 15	1 48	0 133	0 1975	20 597	142 000
14	0 4	16 60	15 75	32 35	16 175	6 47	20 80	31 50	48 10	1.485	0 133	0 198	20 998	135 400
15	0.4	15 75	15 075	30 825	15 424	6 17	21 20	30 15	45 90	1 488	0 133	0 198	21 398	131 800
16	0.4	15 075	14 65	29 725	14 862	5 95	21 60	29 30	44 375	1 490	0 133	0 198	21 798	129 500
17	8 0	14 650	6.45	21 100	10 55	84 40	30 00	12 90	27 55	1.31	2 660	3.490	33 490	2830 000
18	2 0	6 45	4 55	11 00	5 50	11 00	34 00	9 10	15 55	1.415	0.666	0 942	34 942	384.000
19	2 0	4.55	2 80	6 35	3 175	6 35	36 00	5 60	10 15	1 60	0 666	1 062	37 062	235.000
20	1.0	2 80	2 05	4 85	2 425	2 425	38.00	4 10	6 90	1 435	0 333	0 478	38 478	93 500
21	1.0	2 05	1 35	3 40	1 700	1 70	39 00	2 70	4 75	1 395	0 333	465	39 465	67.100
22	1.0	1 35	0.75	2 10	1 050	1 05	40.00	1 50	2 85	1 355	0 333	452	40.452	42 400
23	1 0	0 75	0 30	1 05	0 525	0.525	41 00	0 60	1.35	1 285	0 333	4 28	41 428	21 700
24	0 7	0 30	——	——	——	0.105	42.00	——	——	——	——	4 67	42 467	4 450
						440 41								9001 5

l_Δ = 20·5 INCHES FROM FP
Δ = 440·41 (INCHES)^3
M_Δ = 9001 (INCHES)^4 ABOUT FP

$\alpha = 3^{\circ}$; $d = 2\ 5''$

Section	(84) dl	(85) F_{dn}	(86) l_{xn}	(87) $F_{dn} \times l_{xn}$	(88) $F_{dn} \times dl$	(89) $F_{dn} \times l_{xn} \times dl$
	inches	(inches)^2	inches	(inches)^3	(inches)^3	(inches)^4
1	0 7	—	3 827	—	0 028	0 107
2	1 0	0 15	4 56	0 684	—	—
3	1 0	0 30	5 56	1 665	—	—
4	1 0	0 60	6. 56	3 935	—	—
5	1 0	1 02	7. 56	7 710	—	—
6	1 0	1 68	8 56	14 380	—	—
7	1 0	2 50	9 56	24 900	—	—
8	1 0	3 45	10 56	36.400	—	—
9	1 0	4 12	11 56	47 700	—	—
10	1 0	4 90	12 56	61 600	—	—
11	1 0	5 55	13.56	75 250	—	—
12	1 0	6 20	14. 56	90,300	—	—
13	1 0	6 75	15 56	105.000	—	—
14	1 0	7 32	16. 56	121 200	—	—
15	1 0	7 80	17 56	136.900	—	—
16	1 0	8 10	18. 56	150.200	—	—
17	1 0	8 30	19 56	162 200	—	—
18	1 0	8 52	20 56	175 000	—	—
19	1 0	8 80	21.56	189 500	—	—
20	1 0	9 10	22.56	205 200	—	—
21	0.7	9 40	23 41	—	6 580	154 00
22	0 3	9 25	23.91	—	2.760	66 00
23	1 0	7 50	24 56	184 000	—	—
24	1 0	6 55	25 56	167 200	—	—
25	1 0	5 80	26 56	154 000	—	—
26	1 0	5.30	27 56	146 000	—	—
27	1 0	4 75	28. 56	135 900	—	—
28	1 0	4 20	29 56	124 000	—	—
29	1 0	3 70	30 56	113 000	—	—
30	1 0	3 15	31 56	99 300	—	—
31	1 0	2 60	32 56	84 500	—	—
32	1.0	2 05	33 56	68 650	—	—
33	1 0	1 60	34 56	55 200	—	—
34	1 0	1 30	35 56	46 150	—	—
35	1 0	1 00	36. 56	36 560	—	—
36	1 0	0 80	37 56	30 000	—	—
37	1 0	0 60	38 56	23.100	—	—
38	1 0	0 40	39.56	15 800	—	—
39	1 0	0 15	40 56	6 080	—	—
40	1.7	—	41 627	—	0 051	2 100
		147 01		3118 66	9 419	222 1

Δ = 156 4 (INCHES)^3 Md = 3341 (INCHES)^4

ℓ_{Δ} = 21 4 INCHES

$\alpha = 3^{\circ}$; $d = 3\ 5''$

Section	(90) dl	(91) F_{dn}	(92) l_{xn}	(93) $F_{dn} \times l_{xn}$	(94) $F_{dn} \times dl$	(95) $F_{dn} \times l_{xn} \times dl$
	inches	(inches)^2	inches	(inches)^3	(inches)^3	(inches)^4
1	0 55	—	1 907	—	0 25	0 0 477
2	1 0	0 20	2 59	0 518	—	—
3	1 0	0 60	3 59	2 155	—	—
4	1 0	1 20	4 59	5 510	—	—
5	1 0	2.00	5 59	11 180	—	—
6	1 0	3 05	6 59	20 080	—	—
7	1 0	4 20	7 59	31 820	—	—
8	1 0	5 65	8 59	48 530	—	—
9	1 0	7 15	9 59	68 500	—	—
10	1 0	8 45	10 59	89 400	—	—
11	1 0	9 55	11 59	110 600	—	—
12	1.0	10 50	12 59	132 000	—	—
13	1.0	11 20	13.59	152 000	—	—
14	1 0	11 75	14 59	171 500	—	—
15	1.0	12 10	15 59	188 500	—	—
16	1 0	12 40	16 59	205 600	—	—
17	1 0	12 65	17 59	222 300	—	—
18	1 0	12 85	18 59	238 500	—	—
19	1 0	13 00	19 59	254 500	—	—
20	1.0	13 15	20 59	270 500	—	—
21	1.0	13 35	21 59	288 000	—	—
22	1.0	13.65	22 59	308 000	—	—
23	0.5	13 90	23. 34	—	6 95	162 00
24	0 5	13 60	23 84	—	6 80	162 00
25	1 0	12 40	24 59	305 000	—	—
26	1.0	11 20	25 59	286 200	—	—
27	1 0	10 30	26 59	274 000	—	—
28	1.0	9 60	27 59	264 500	—	—
29	1 0	8 82	28 59	252 000	—	—
30	1 0	8 08	29 59	238 000	—	—
31	1 0	7 32	30 59	223 500	—	—
32	1 0	6 52	31 59	205 800	—	—
33	1 0	5 80	32 59	188 760	—	—
34	1 0	5 05	33 59	169 500	—	—
35	1.0	4 30	34 59	148.500	—	—
36	1 0	3 65	35 59	129 750	—	—
37	1 0	3 18	36 59	116 500	—	—
38	1.0	2.90	37 59	109 000	—	—
39	1 0	2 55	38 59	98 300	—	—
40	1.0	2.00	39 59	79 180	—	—
41	1 0	1 00	40 59	40 590	—	—
42	1 0	0 30	41 59	12 460	—	—
43	0 7	—	42 323	—	0 035	1 4800
		286 62		5961 74	13 81	325 5

Δ = 300 4 (INCHES)^3 Md = 6287 (INCHES)^4

ℓ_{Δ} = 20 9 INCHES

TABLE 4.
SHEET 5.

$\alpha^\circ = 6^\circ$; $d = 2.5''$

Section	(96) dl inches	(97) F_{dm} (inches)^2	(98) l_m inches	(99) $F_{dm}\times l_m$ (inches)^3	(100) $F_{dm}\times dl$ (inches)^3	(101) $F_{dm}\times l_m\times dl$ (inches)^4
1	1 0	—	7 746	—	0.10	0.7746
2	1 0	0.30	8 58	2 57	—	—
3	1 0	0.60	9 58	5 74	—	—
4	1 0	1 075	10 58	11 36	—	—
5	1 0	1735	11 58	20 10	—	—
6	1 0	2 70	12 58	33 98	—	—
7	1 0	3 65	13 58	49 60	—	—
8	1 0	4 36	14 58	63 60	—	—
9	1 0	5 00	15. 58	77 90	—	—
10	1 0	5 60	16 58	93 40	—	—
11	1.0	6.15	17 58	108 10	—	—
12	1 0	6 70	18. 58	124 30	—	—
13	1 0	7 20	19 58	141 00	—	—
14	1 0	7 80	20 58	160.38	—	—
15	1 0	8.25	21 58	180 00	—	—
16	1 0	8 92	22 58	201 00	—	—
17	0 4	9 35	23 28	—	3 74	87 10
18	0 6	9.00	23 78	—	5 40	128 20
19	1 0	8 00	24 58	196 50	—	—
20	1 0	7 07	25 58	180 80	—	—
21	1 0	6 50	26 58	172 50	—	—
22	1 0	6 05	27 58	166 50	—	—
23	1 0	5.60	28 58	160 00	—	—
24	1 0	5 18	29 58	153 00	—	—
25	1 0	4 72	30 58	144 00	—	—
26	1 0	4.30	31 58	135 50	—	—
27	1 0	3 90	32 58	126 80	—	—
28	1 0	3 45	33 58	115 60	—	—
29	1 0	2.95	34 58	101 80	—	—
30	1 0	2.50	35 58	88 80	—	—
31	1 0	2.30	36 58	84 10	—	—
32	1 0	2 10	37 58	78 90	—	—
33	1 0	1 60	38 58	61 70	—	—
34	1 0	1 10	39 58	43 50	—	—
35	1 0	0 65	40 58	26 35	—	—
36	1 0	0 27	41 58	10 80	—	—
37	1 1	—	42 447	—	0.0826	3 506
		138.08		3219 21	9.32	219 5

Δ = 147 4 (INCHES)^3 M_Δ = 3439 (INCHES)^4

l_Δ = 23 3 INCHES

$\alpha^\circ = 6^\circ$, $d = 3.5''$

Section	(102) dl inches	(103) F_{dm} (inches)^2	(104) l_m inches	(105) $F_{dm}\times l_m$ (inches)^3	(106) $F_{dm}\times dl$ (inches)^3	(107) $F_{dm}\times l_m\times dl$ (inches)^4
1	1 3	—	4 748 *	—	0 13	0 617
2	1 0	0 30	5 68	1 705	—	—
3	1 0	0 60	6.68	4 005	—	—
4	1 0	1 20	7 68	9 218	—	—
5	1 0	2 35	8 68	20 400	—	—
6	1 0	3 80	9 68	36 750	—	—
7	1 0	5 60	10 68	59 800	—	—
8	1 0	6 87	11 68	80 200	—	—
9	1 0	8 06	12 68	102 800	—	—
10	1 0	8 95	13 68	122 200	—	—
11	1 0	9 70	14 68	142 200	—	—
12	1 0	10.26	15 68	160 500	—	—
13	1 0	10 75	16.68	179 000	—	—
14	1 0	11 20	17 68	198 000	—	—
15	1 0	11 68	18 68	218 100	—	—
16	1 0	12 11	19 68	237 000	—	—
17	1 0	12 65	20.68	262 000	—	—
18	1 0	13 15	21 68	285 500	—	—
19	1.0	13.68	22 68	310 100	—	—
20	1 0	13 15	23 68	312 000	—	—
21	1.0	11 95	24 68	295 000	—	—
22	1 0	11 10	25 68	285 000	—	—
23	1 0	10.05	26. 68	280 100	—	—
24	1 0	9 85	27 68	281 500	—	—
25	1 0	9 20	28 68	264 000	—	—
26	1 0	8 60	29. 68	255 200	—	—
27	1 0	7.95	30 68	243 900	—	—
28	1 0	7 35	31 68	232 800	—	—
29	1.0	6 72	32 68	219 600	—	—
30	1 0	6 10	33 68	205.100	—	—
31	1 0	5.50	34.68	190 100	—	—
32	1.0	4 98	35 68	174 900	—	—
33	1.0	4 20	36 68	154 000	—	—
34	1 0	3 50	37 68	131 800	—	—
35	1 0	2 50	38 68	96 800	—	—
36	1 0	1 52	39 68	60 380	—	—
37	1 0	0 80	40 68	32 450	—	—
38	1 0	0 35	41 68	14 550	—	—
39	1 1	—	42 547	—	0 11	4 680
		287 21		6170 57	0 24	5 297

Δ = 2674 (INCHES)^3 M_Δ = 6176 (INCHES)^4

l_Δ = 23·1 INCHES

TABLE 4
SHEET 6.

TABLE 5

	(108)	(109)	(110)	(111)	(112)
	α	d	Δ_1	$M_{\Delta FP}$	l_Δ
	(°)	inches	(inches)^3	(inches)^4	inches
(1)	-3°	2 5	231 54	3799.9613	16 40
(2)		3.5	359 61	6241.9680	17 36
(3)	0°	1 5	83 780	1281 2790	15.32
(4)		2.5	188 410	3543.5505	18 85
(5)		3.5	330 95	7361 0070	21 80
(6)		4 7	440 41	9001 5132	20 50
(7)	3°	2 5	156 429	3340 8710	21.40
(8)		3.5	300.430	6287 3707	20.90
(9)	6°	2.5	147 40	3438.78	23 30
(10)		3.5	267.450	6175 86	23 10

RESULTS OF CALCULATION OF BUOYANCY, MOMENT, AND CENTRE OF BUOYANCY, FOR RANGE OF ATTITUDES AND DRAFTS

TABLE 6.

	(113)	(114)	(115)	(116)
	α	$M_{\Delta FR}$	Δ_1	l_Δ
	(°)	(inches)^4	(inches)^3	inches
(1)	- 3°	3275	202	16 20
(2)	0°	3900	202	19.33
(3)	3°	4300	202	21.30
(4)	6°	4700	202	23 25

MOMENT AND CENTRE OF BUOYANCY FOR STATIC LOAD ON WATER FOR RANGE OF ATTITUDES

TABLE 7

	(117)	(118)	(119)	(120)	(121)	(122)	(123)	(124)	(125)
	α	$\sin(3°+\alpha°)$	$\frac{T}{W}\sin(3°+\alpha°)$	$\Delta_1=\frac{A}{2}-\frac{T}{W}\sin(3+\alpha)$	l_W	$M_{\Delta FP}$	l_Δ	$l_W - l_\Delta$	$M_{\Delta CG}$
				(115) - (119)				(121) - (123)	
	(°)		(inches)^3	(inches)^3	inches	(inches)^4	inches	inches	(inches)^4
(1)	-3°	0 0000	0 00	202 00	20 45	3250	16 10	4.35	878 0
(2)	0°	0.0523	3 59	198 41	21 16	3850	18 20	2 96	587 0
(3)	3°	0.1045	7 17	194 83	21 80	4150	21.30	0 50	97 4
(4)	6°	0 1564	10 72	191 28	22 35	4470	23 38	-1.03	-198 0

ESTIMATION OF STATIC MOMENT OF BUOYANCY ABOUT C G FOR ENGINE ON CASE

TABLE 8.
ESTIMATED AIR LIFT & DRAG OF SEAPLANE AT 10 M.P.H.

	126	127	128	129	130
	i°	C_L	C_D	L_{V1}	D_{V1}
	(°)			$(\text{inches})^3$	$(\text{inches})^3$
1	0°	0.09	0.027	0.46	0.148
2	2°	0.25	0.028	1.30	0.148
3	6°	0.57	0.046	2.99	0.240
4	10°	0.89	0.073	4.65	0.382
5	15°	1.29	0.112	6.75	0.586

TABLE 9.

TABLE 9.
ESTIMATION OF MOMENTS DUE TO BUOYANCY THRUST & DRAG OF FLOAT FOR A RANGE OF ALTITUDES.

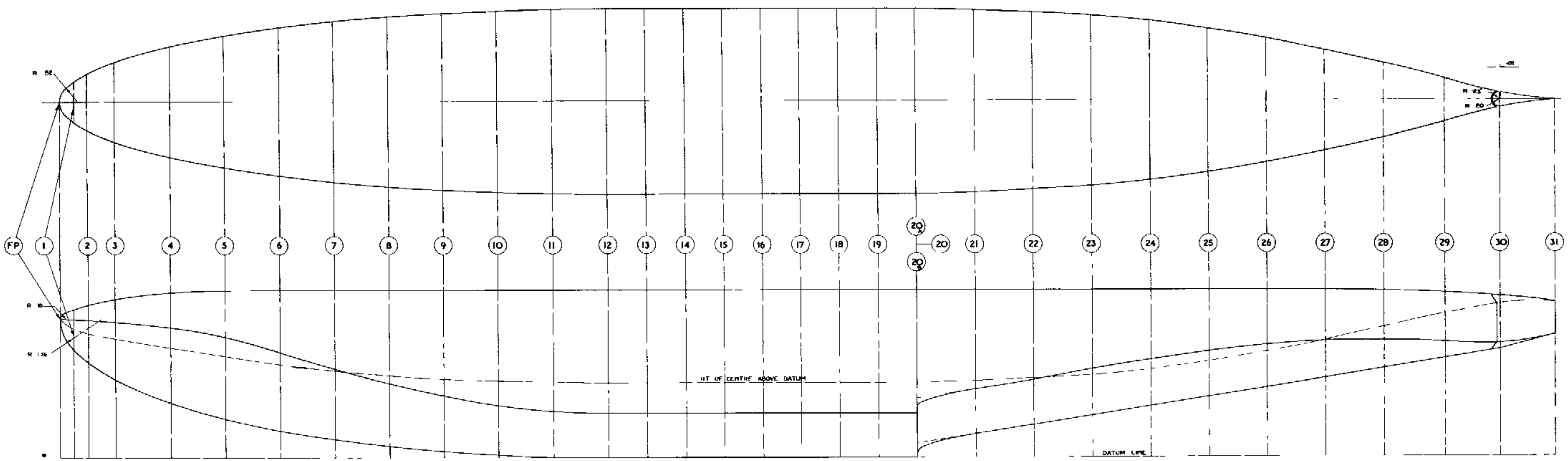
			1	2	3	4
131	α°	(°)	-3°	0°	3°	6°
132	L_{V1}	$(\text{inches})^3$	1.56	2.94	4.20	5.40
133	D_{V1}	$(\text{inches})^3$	0.16	0.24	0.34	0.46
134	R_{V1}	$(\text{inches})^3$	20.2	20.2	20.2	20.2
135	M_{RCG}	$(\text{inches})^4$	226.24	226.24	226.24	226.24
136	$3^\circ + \alpha^\circ$	(°)	0°	3°	6°	9°
137	$\sin(3^\circ + \alpha^\circ)$		0.00	0.052	0.104	0.156
138	$\cos(3^\circ + \alpha^\circ)$		1.00	0.998	0.994	0.988
139	$R_{V1} + D_{V1}$	$(\text{inches})^3$	22.36	22.44	22.54	22.66
140	$T_{V1} = \frac{R_{V1} + D_{V1}}{\cos(3^\circ + \alpha^\circ)}$	$(\text{inches})^3$	22.36	22.47	22.66	22.94
141	$M_{TV1CG} = T_{V1} \times \tau_T$	$(\text{inches})^4$	30.18	30.33	30.59	30.97
142	$T_{V1} \times \sin(3^\circ + \alpha^\circ)$	$(\text{inches})^3$	0.00	1.17	2.37	3.59
143	$\Delta_1 = \frac{\Delta}{2} - L_{V1} - T_{V1} \times \sin(3^\circ + \alpha^\circ)$	$(\text{inches})^3$	200.44	197.89	195.43	193.01
144	$M_{\Delta_1 FD}$	$(\text{inches})^4$	3200	3900	4250	4600
145	$l_\Delta = \frac{M_{\Delta FD}}{\Delta}$	inches	15.85	19.45	21.30	23.20
146	l_W	inches	20.45	21.16	21.80	22.35
147	$l_W - l_\Delta$	inches	4.60	1.71	0.50	-0.85
148	$M_{\Delta 1CG} = \Delta_1 \times (l_W - l_\Delta)$	$(\text{inches})^4$	928.0	343.0	99.5	-168.5
149	$M_{TV1CG} + M_{RV1CG}$	$(\text{inches})^4$	253.5	253.6	253.7	253.9

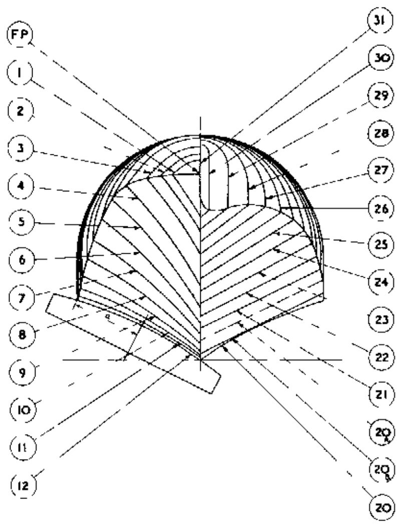
CALCULATIONS OF ANGLE OF ROLL.

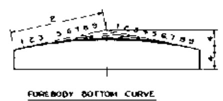
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
150	$\alpha°$	(°)	0°					3					6°				
151	d_2	inches	2.6	2.7	2.8	2.9	3.0	2.7	2.8	2.9	3.0	3.1	2.7	2.8	2.9	3.0	3.1
152	A	(inches)^3	404					404					404				
153	l_w	inches	21.16					21.8					22.35				
154	$T_r \times \sin(3°+\alpha°)$	(inches)^3	7.18					14.34					21.44				
155	$A - T_r \times \sin(3°+\alpha°)$	(inches)^3	396.82					389.66					382.54				
156	Δ_2	(inches)^3	202	215	230	245	258	185	197.5	211	227.5	242	175	182	195	207	220
157	Δ_1	(inches)^3	194.82	181.82	166.82	151.82	138.82	204.66	191.16	178.66	163.16	147.66	207.54	200.54	185.54	175.54	162.54
158	d_1	inches	2.53	2.46	2.33	2.22	1.9	2.84	2.76	2.66	2.54	2.42	3.01	3.0	2.85	2.74	2.64
159	$d_2 - d_1$	inches	0.07	0.24	0.47	0.68			0.04	0.24	0.46				0.05	0.26	0.46
160	$tg\,\theta = \frac{d_2 - d_1}{l_r}$		0.00451	0.0155	0.0303	0.0439			0.00268	0.0155	0.0297				0.00323	0.0168	0.0297
161	$M_{\Delta_1 cz}$	(inches)^4	3630	3400	3050	2750	2000	3800	4050	3800	3460		4000	4250	4380	4100	3820
162	$M_{\Delta_2 cr}$	(inches)^4	3930	4300	4700	5050	5450	4350	4200	4520	4820		4850	4800	4540	4810	5100
163	$M_{\Delta_1 cz} + M_{\Delta_2 cz}$	(inches)^4	7560	7700	7750	7700	7450	8250	8250	8320	8280		8850	9050	8930	8910	8920
164	$l_A = \frac{M_{\Delta_1 cz} + M_{\Delta_2 cz}}{A - T_r \times \sin(3°+\alpha°)}$	inches	19.05	19.40	19.52	19.35	18.90	21.25	21.25	21.40	21.22		23.15	23.65	23.35	23.30	23.29
165	$l_w - l_A$	inches	2.11	1.76	1.64	1.81	2.26	0.55	0.55	0.40	0.58		-1.71	-2.21	-1.00	-0.95	-0.94
166	$M_{\Delta cz} = (A - T_r \sin(3°+\alpha°))(l_w - l_A)$	(inches)^4	837	693	650	719	897	214	244	155.5	226		-654	-850	-382.5	-363	-359
167	θ	(°)	15'	53'	1°45'	2°30'			9'	53'	1°40'				14'	58'	1°40'
168	$\beta - \theta$	(°)	50°15'	49°37'	48°45'	48°			50°29'	49°37'	48°50'				50°19'	49°32'	48°50'
169	$\beta + \theta$	(°)	50°45'	51°23'	52°15'	53°			50°39'	51°29'	52°10'				50°41'	51°28'	52°10'
170	$\cos(\beta - \theta)$		0.6394	0.6480	0.6593	0.6691			0.6360	0.6480	0.6582				0.6373	0.6480	0.6582
171	$\cos(\beta + \theta)$		0.6327	0.6240	0.6122	0.6018			0.6338	0.6240	0.6133				0.6328	0.6220	0.6133
172	$a_1 = l_1 \times \cos(\beta - \theta)$	inches	7.8	7.9	8.05	8.16			7.75	7.90	8.03				7.89	7.9	8.03
173	$a_2 = l_1 \times \cos(\beta + \theta)$	inches	7.72	7.61	7.47	7.55			7.74	7.61	7.48				7.74	7.60	7.48
174	$\Delta_2 \times a_2$	(inches)^4	1558	1635	1720	1848			1530	1604	1700				1540	1571	1645
175	$\Delta_1 \times a_1$	(inches)^4	1520	1434	1340	1238			1490	1410	1302				1480	1386	1305
176	$\Delta_2 \times a_2 - \Delta_1 \times a_1$	(inches)^4	38	201	380	610			40	194	398				30	115	340
177	Q	(inches)^4	131.0					131.0					131.0				
178	$M_{T_r z_0}$	(inches)^4	185.2					185.2					185.2				

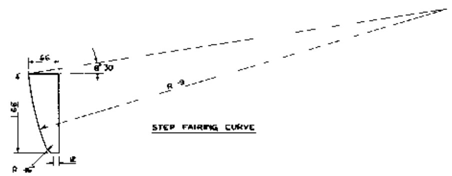
FORWARD SPEED OF SEAPLANE	THRUST	$\alpha°$	$\theta°$	d_2 INCHES	d_1 INCHES
ZERO SPEED	ZERO THRUST	4°	0°	14·65	14 65
ZERO SPEED	FULL THRUST-THROTTLE OPENED VERY SLOWLY-ENGINE TORQUE NEGLECTED	3° 3′	0°	13·91	13 91
ZERO SPEED	FULL THRUST-THROTTLE OPENED VERY SLOWLY, FULL ENGINE TORQUE	2° 57′	34′	14 3	13·53
ZERO SPEED	FULL THRUST-THROTTLE OPENED VERY QUICKLY-ENGINE TORQUE NEGLECTED	2° 31′	0°	13 77	13·77
TAXYING SPEED V_{tax} = 10 M.P.H	ENGINE TORQUE NEGLECTED	1° 12′	0°	13·35	13·35

SUMMARY OF TRIM ANGLES IN PITCH & ROLL FOR DIFFERENT ENGINE CONDITIONS.









STATION F.P.	Nº	FP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		FOREBODY																				
DISTANCE AFT OF F.P.	ℓ	·00	39	78	1·56	3·12	4·68	6·24	7·80	9·36	10·92	12·48	14·04	15·60	16·70	17·80	18·90	20·00	21·10	22·20	23·30	24·40
KEEL H	h_k	3·90	3·04	2·68	2·20	1·56	1·12	78	52	32	18	08	·02	00	THE SAME AS STATION 12							
CHINE H_c	h_c	3·90	3·88	3·86	3·82	3·68	3·40	2·96	2·52	2·10	1·76	1·47	1·30	1·24								
CHINE HALF BREADTH	$\frac{b_c}{2}$	·00	57	81	1·13	1·56	1·85	2·08	2·25	2·38	2·48	2·54	2·59	2·60								
H_t OF CENTRE ABOVE DATUM	h_R	3·90	3·61	3·49	3·34	3·08	2·85	2·62	2·45	2·32	2·22	2·16	2·11	2·10								
RADIUS OF BODY	R	00	57	81	1·13	1·56	1·85	2·08	2·25	2·38	2·48	2·54	2·59	2·60								
	a	·00	51	72	99	1·31	1·47	1·52	1·51	1·50	1·48	1·45	1·45	1·45								

STATION F.P.	Nº	20A	20B	21	22	23	24	25	26	27	28	29	30	31
		AFTERBODY												
DISTANCE AFT OF F.P.	ℓ	24·40	24·40	26·06	27·72	29·38	31·04	32·70	34·36	36·02	37·68	39·24	41·00	42·60
KEEL H	h_k	·40	12	66	92	1·18	1·44	1·70	1·96	2·22	2·48	2·74	3·00	3·42
CHINE H_c	h_c	1·67	1·39	1·91	2·11	2·45	2·73	2·95	3·14	3·24	3·27	3·21	3·16	3·42
CHINE HALF BREADTH	$\frac{b_c}{2}$	2·60	2·60	2·56	2·49	2·40	2·24	2·02	1·75	1·41	1·04	61	21	·00
H_t OF CENTRE ABOVE DATUM	h_R	2·10	2·10	2·14	2·21	2·30	2·46	2·68	2·94	3·27	3·62	4·00	4·29	4·35
RADIUS OF BODY	R	2·60	2·60	2·56	2·49	2·40	2·24	2·02	1·75	1·41	1·04	61	21	00

NAME OF DETAIL PROPOSED FLOATS		JOB "AUSTER" ON FLOATS
MATERIAL - BALSA WOOD		SPEC Nº (LATEST ISSUE)
USED ON SCHEDULES		

GENERAL ARRANGEMENT OF FLOATS FOR A SMALL SEAPLANE (DIMENSIONS FIFTH SCALE.)

FIG. I

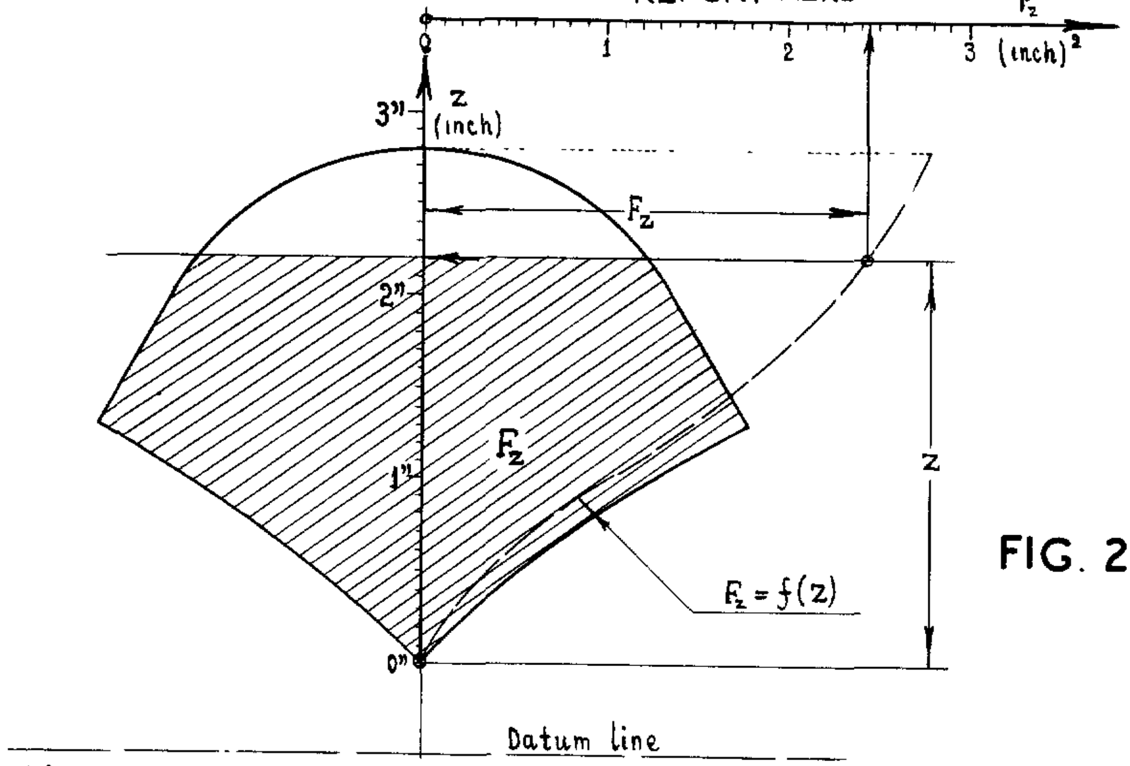
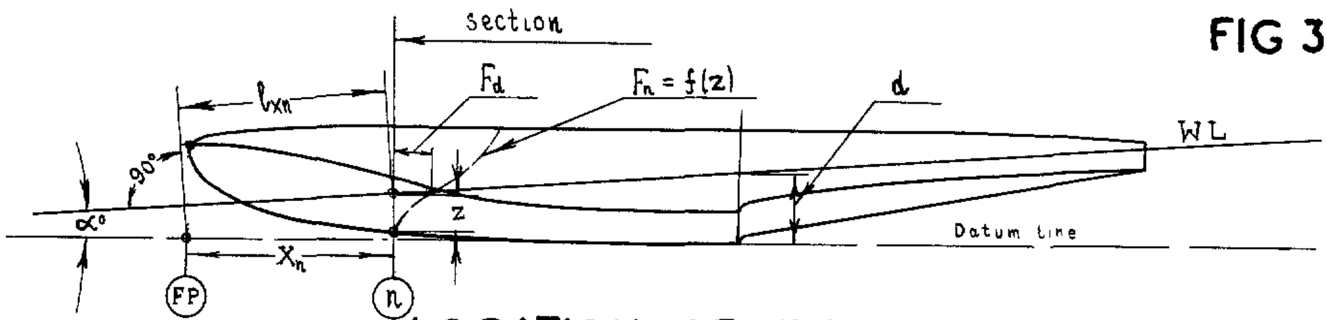


FIG. 2

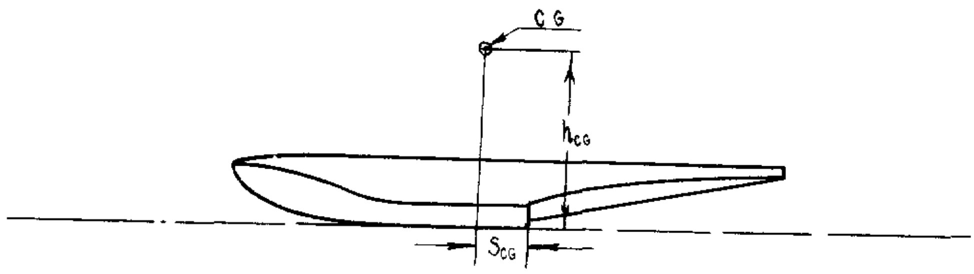
VARIATION OF CROSS SECTIONAL AREA WITH DRAFT AT TYPICAL FLOAT SECTION.

FIG 3.



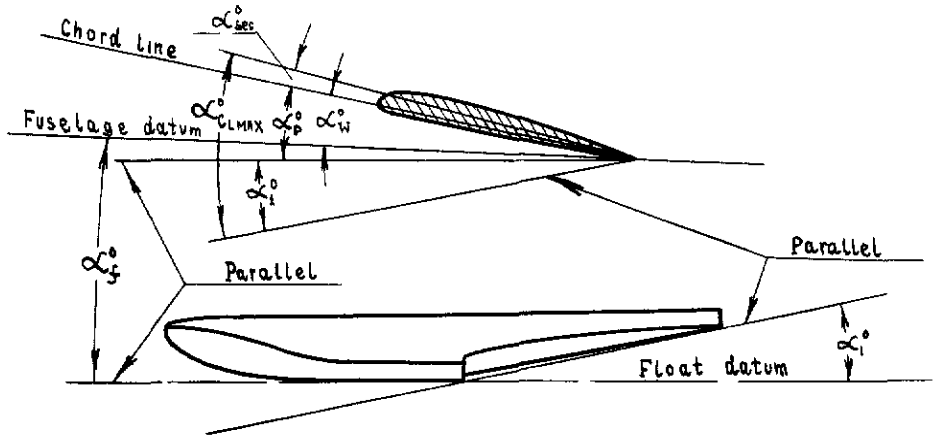
LOCATION OF WETTED CROSS SECTION RELATIVE TO WATERLINE AND DATUM POINT F.P.

FIG. 4



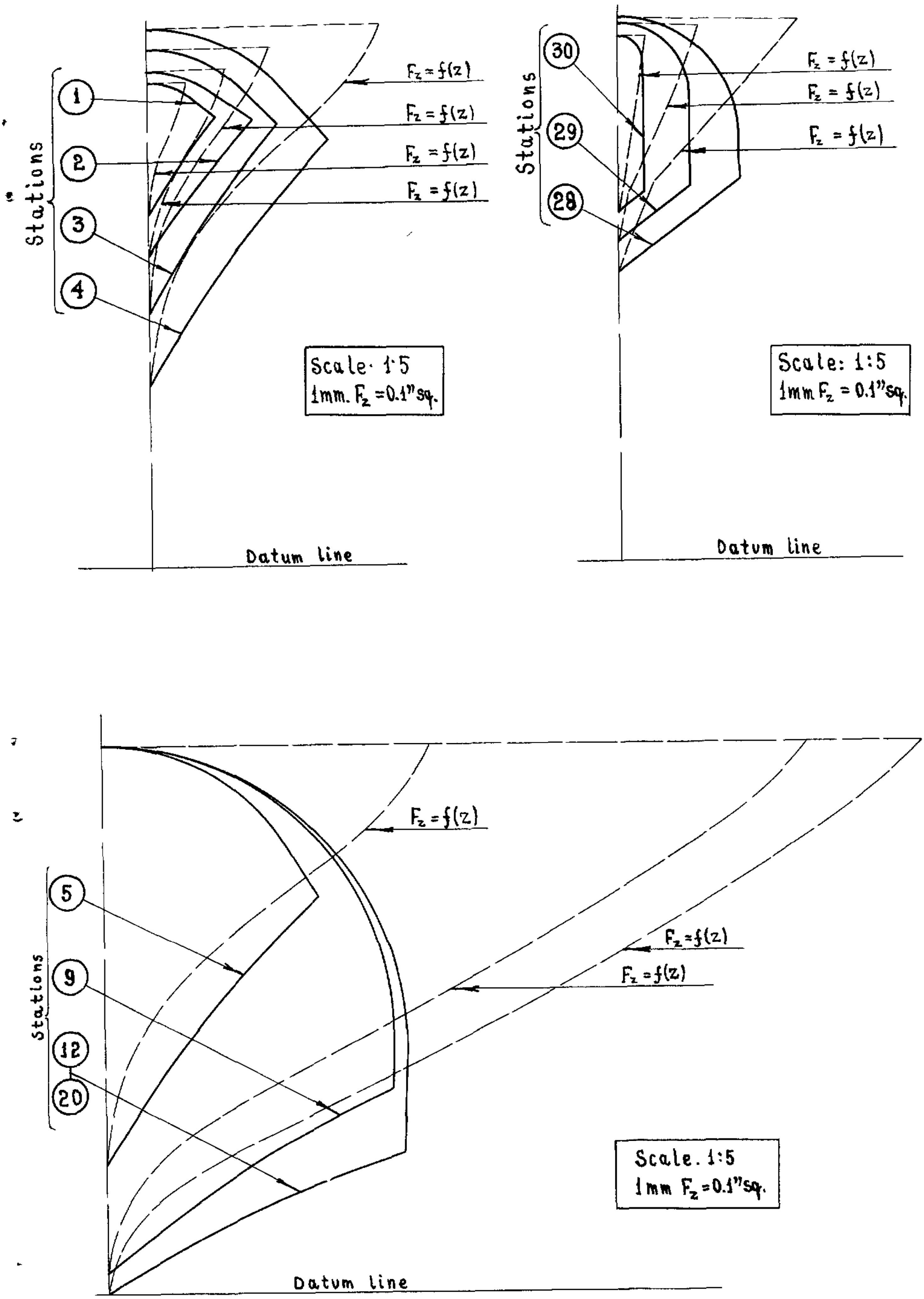
LOCATION OF FLOAT RELATIVE TO C.G. OF SEAPLANE.

FIG 5



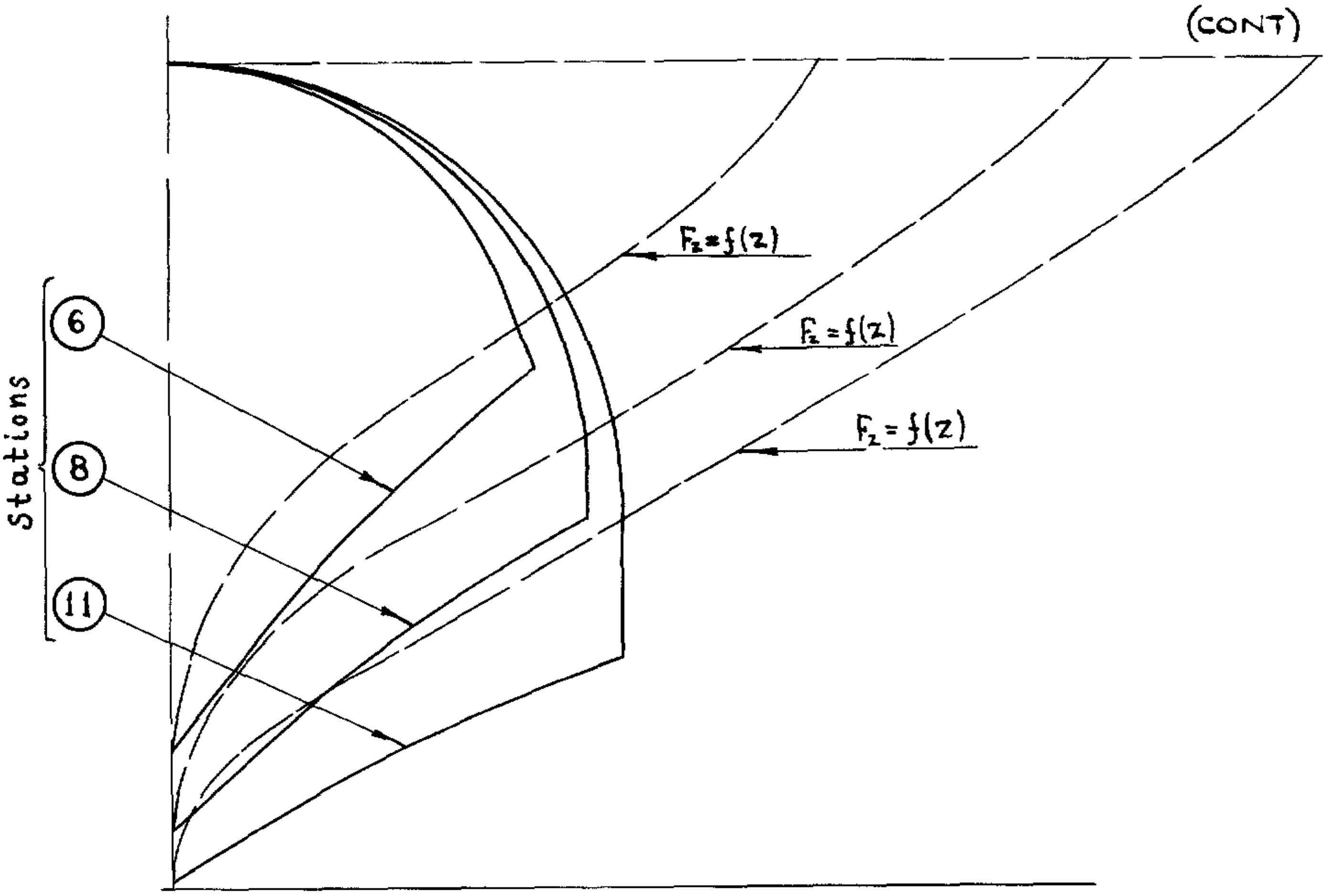
LOCATION OF FLOAT RELATIVE TO WING & FUSELAGE

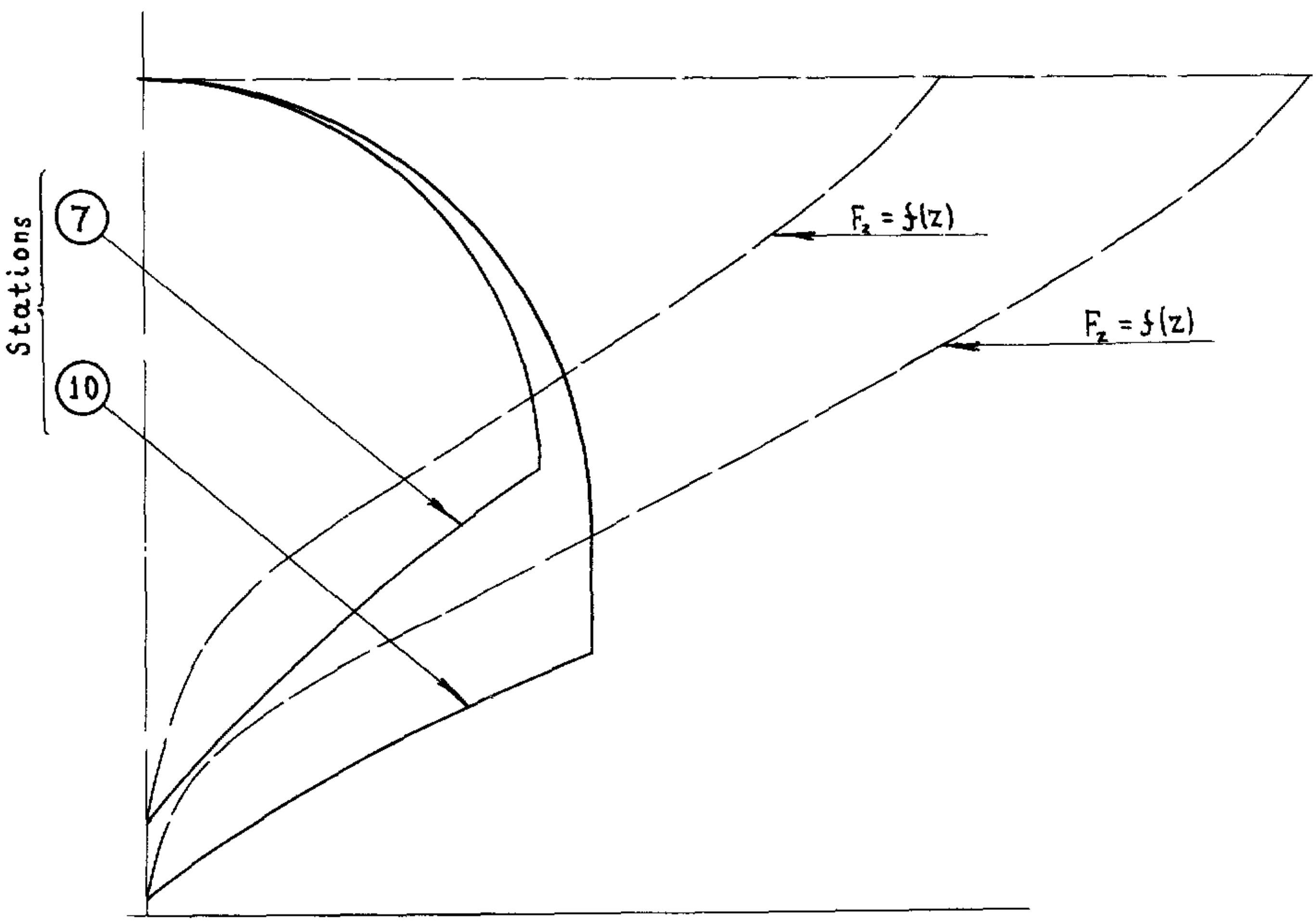
FIG 6



VARIATION OF WETTED CROSS SECTIONAL AREAS OF FLOAT WITH DRAFT.

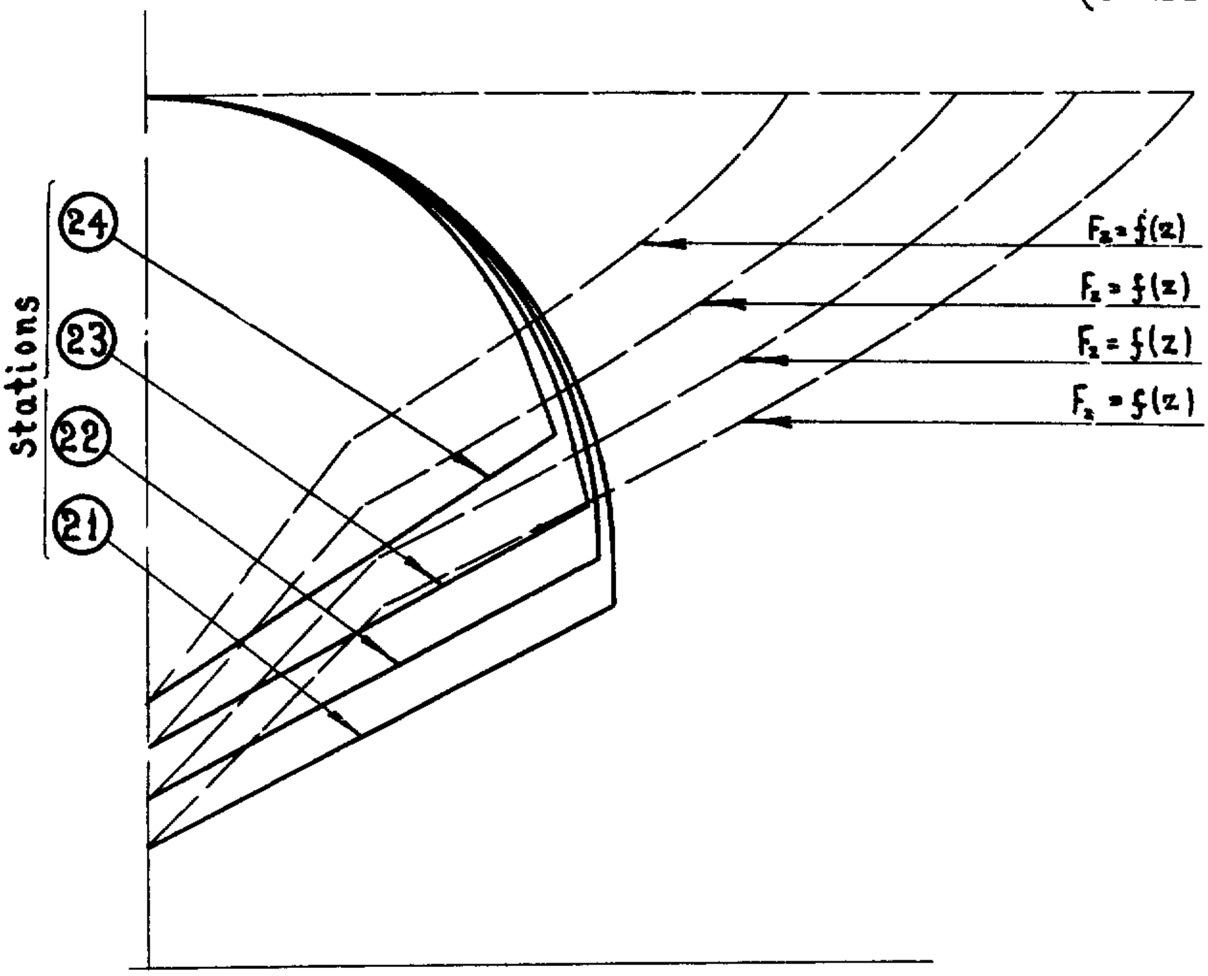
FIG 6
(CONT)

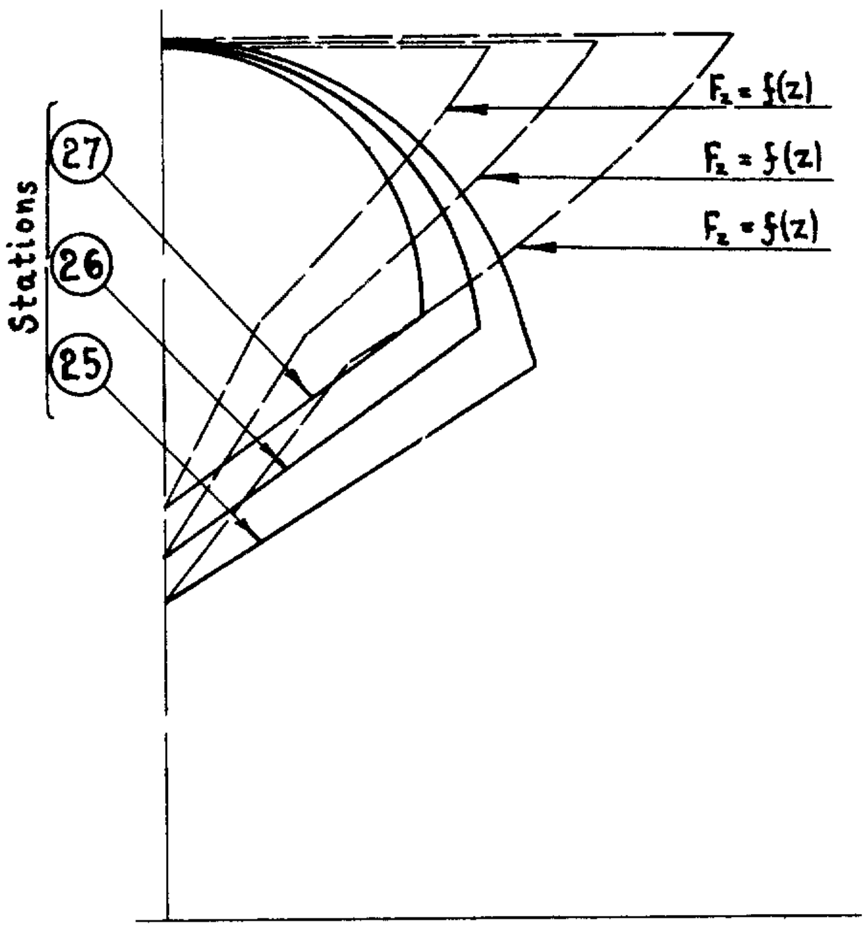




VARIATION OF WETTED CROSS SECTIONAL AREAS OF FLOAT WITH DRAFT.

FIG. 6 (3)
(CONCLUDED)





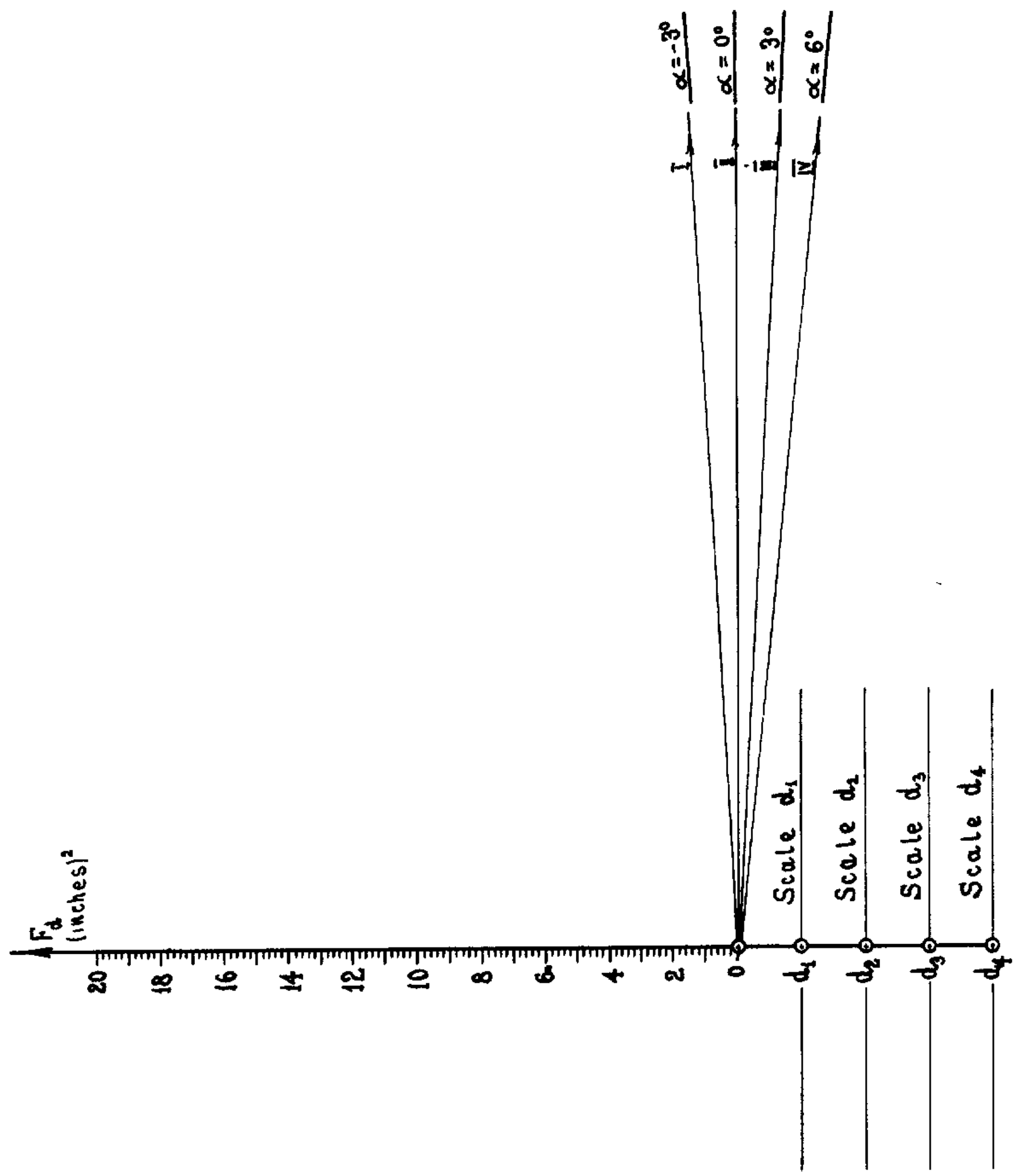
VARIATION OF WETTED CROSS SECTIONAL AREAS OF FLOAT WITH DRAFT.

FIG 7

SIDE ELEVATION OF FLOAT SHEWING DISTRIBUTION OF CROSS SECTIONAL AREA WITH LOCAL DRAFT

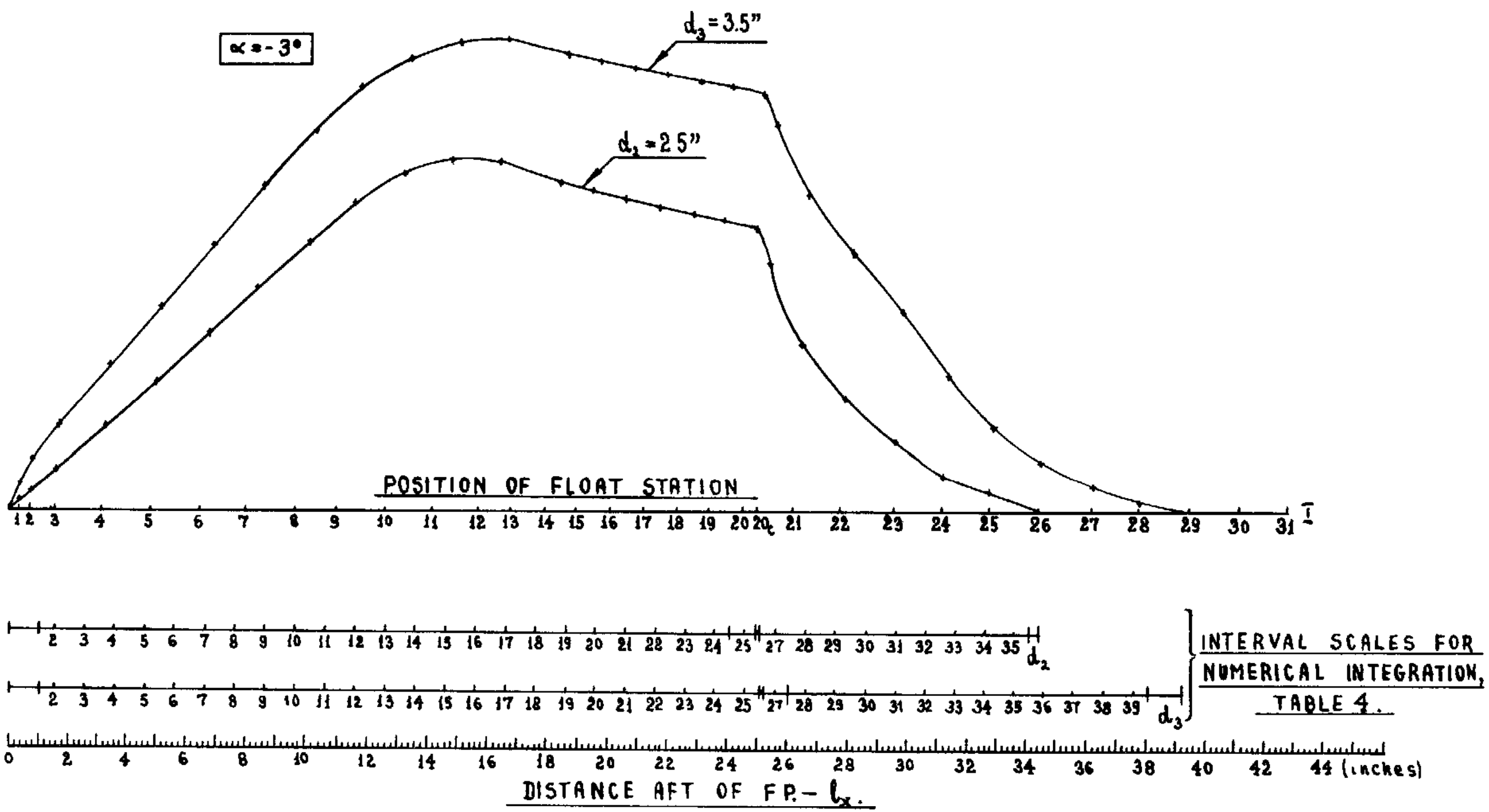
SIDE ELEVATION OF FLOAT SHEWING DISTRIBUTION OF WETTED CROSS SECTION AREAS FOR WATER LINES CORRESPONDING TO A RANGE OF DRAFTS AND ATTITUDES

FIG. 9.



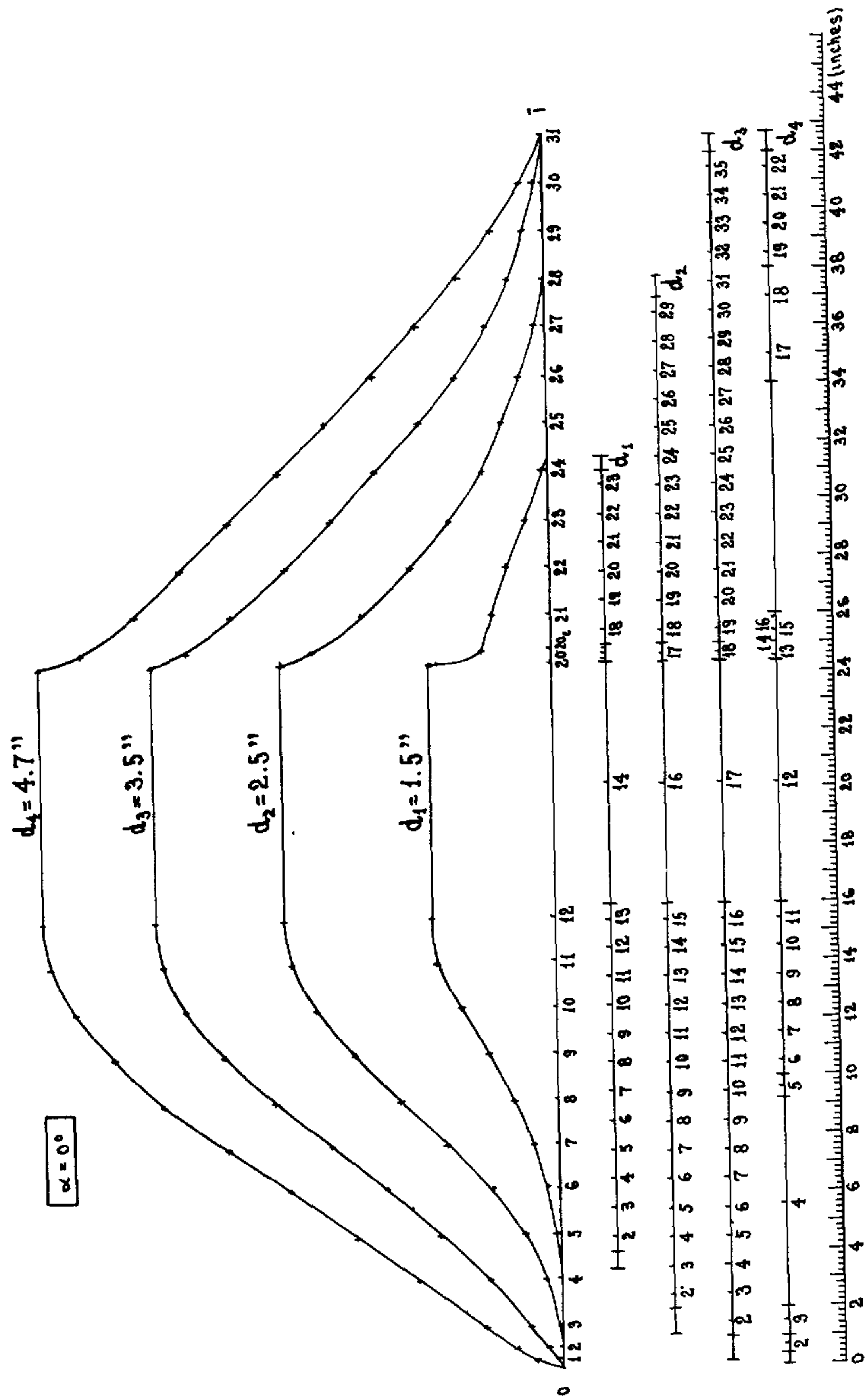
LOCATION OF AXES FOR PLOTTING DISTRIBUTION OF WETTED CROSS SECTIONAL AREAS AT DIFFERENT DRAFTS & ATTITUDES.

FIG 10
(SHEET 1)



GRAPH OF WETTED CROSS SECTIONAL AREA AGAINST DISTANCE FROM F.P. ALONG WATER LINE FOR ATTITUDE -3° DRAFTS 2.5 & 3.5 INS.

FIG. 10.
(SHEET 2)



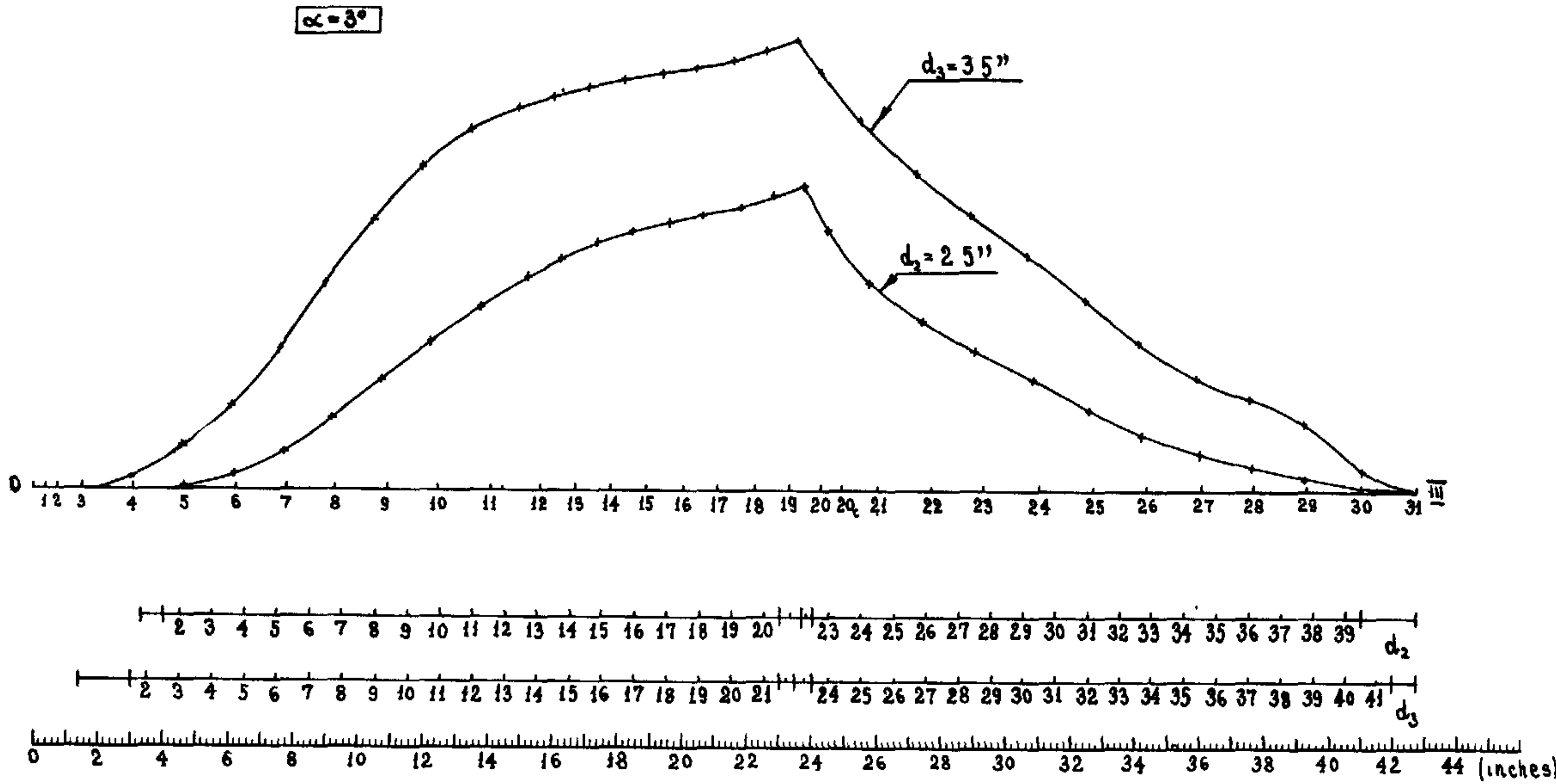


FIG. 10.

SHEET 3

FIG. 10.
(SHEET 4)

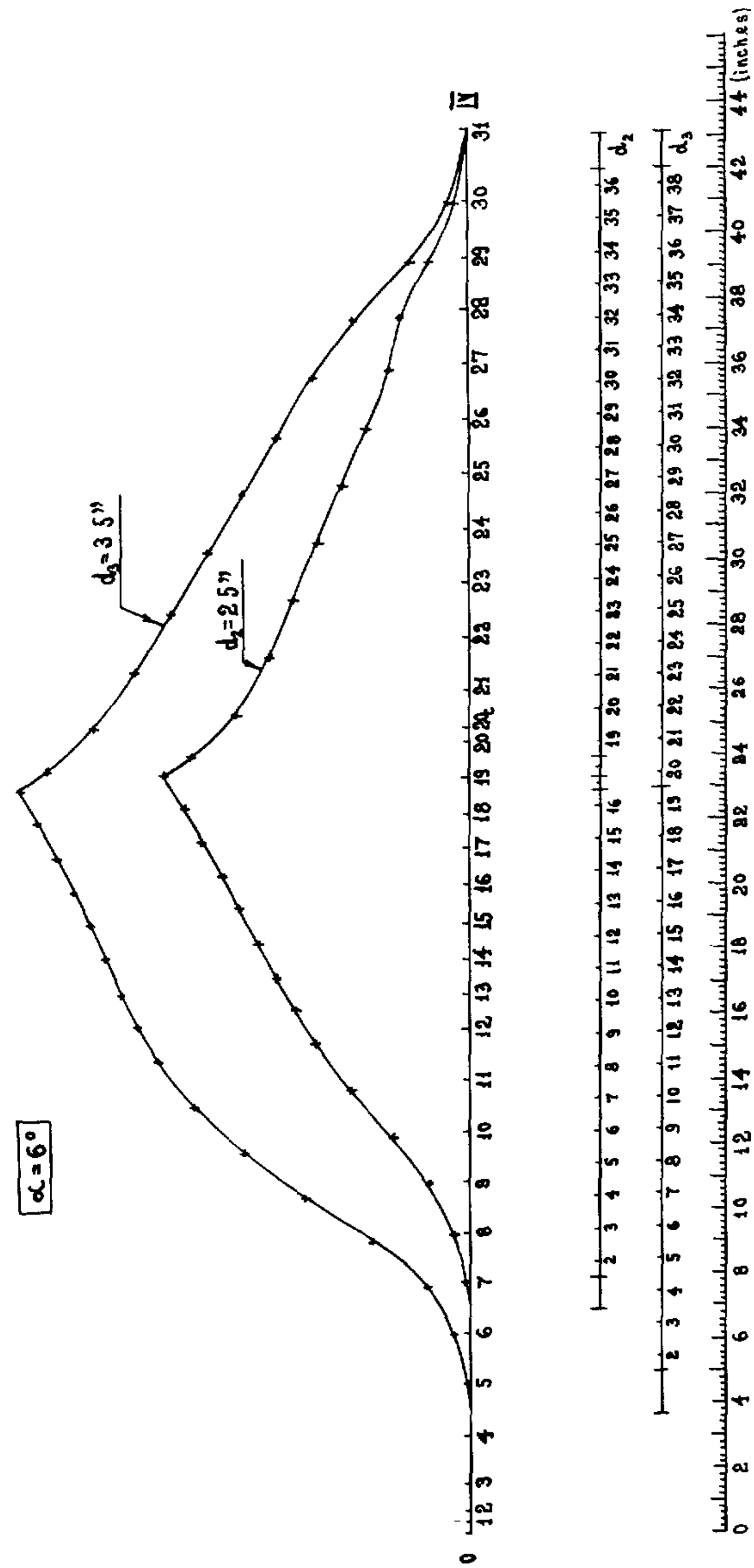
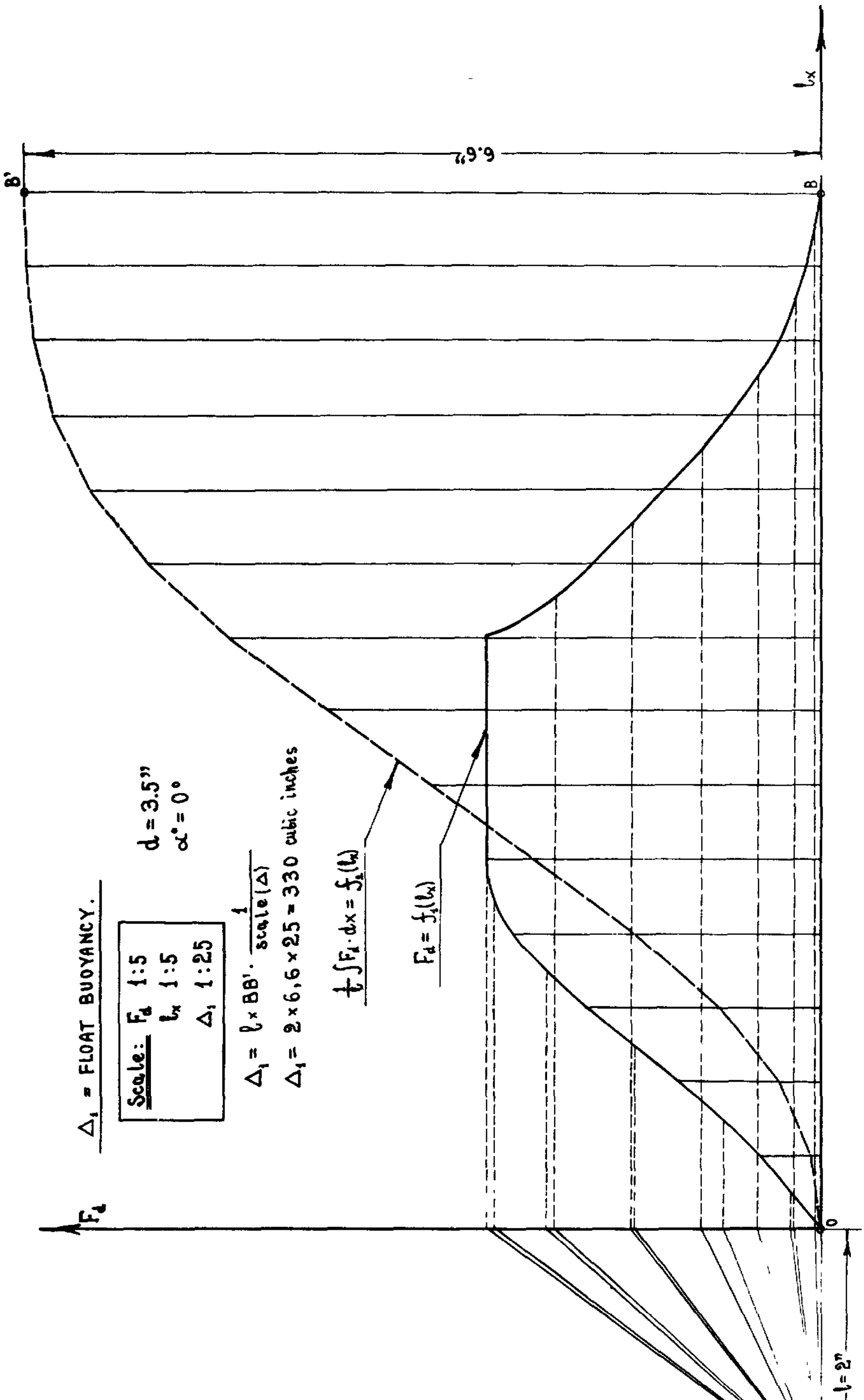
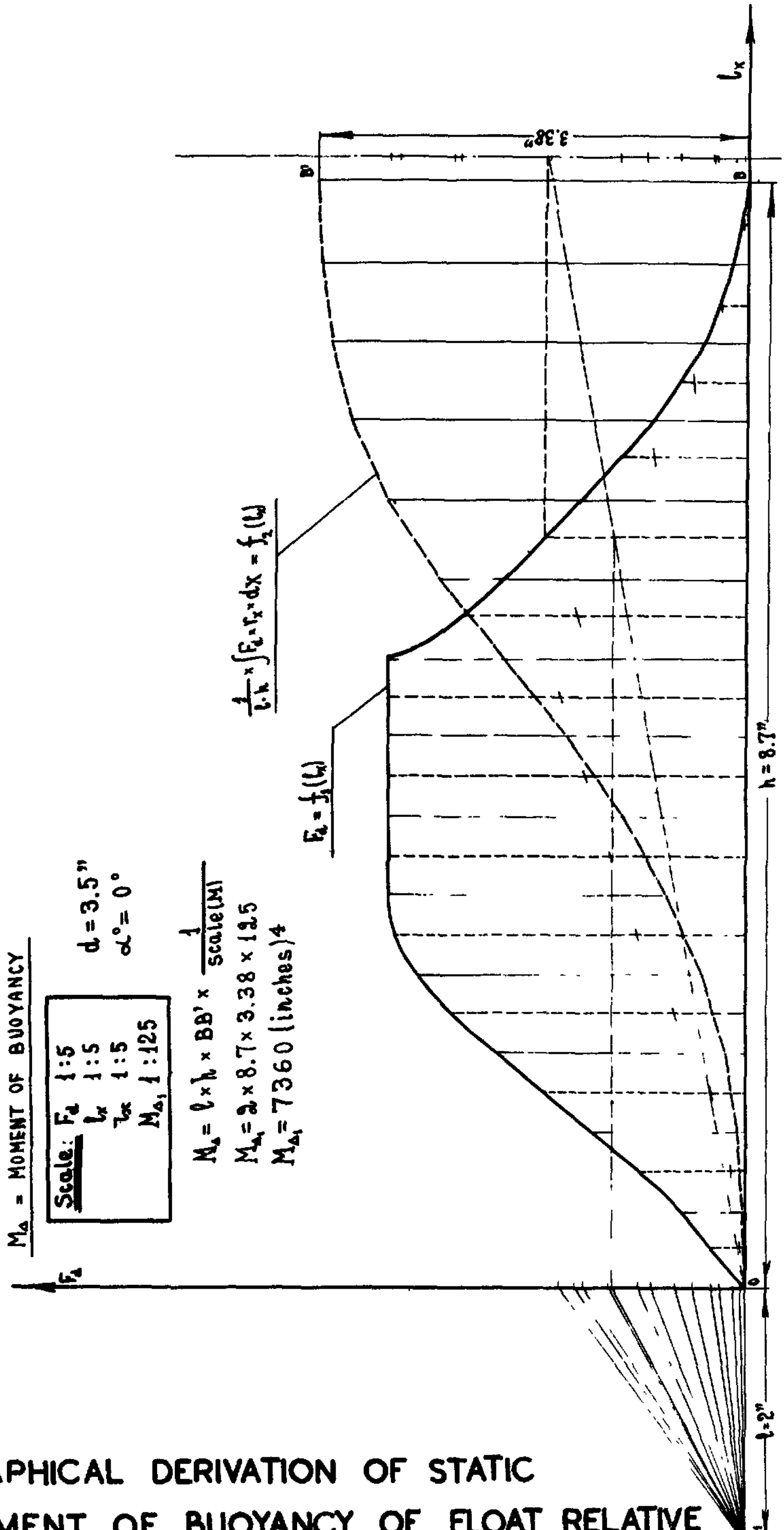


FIG. 11.

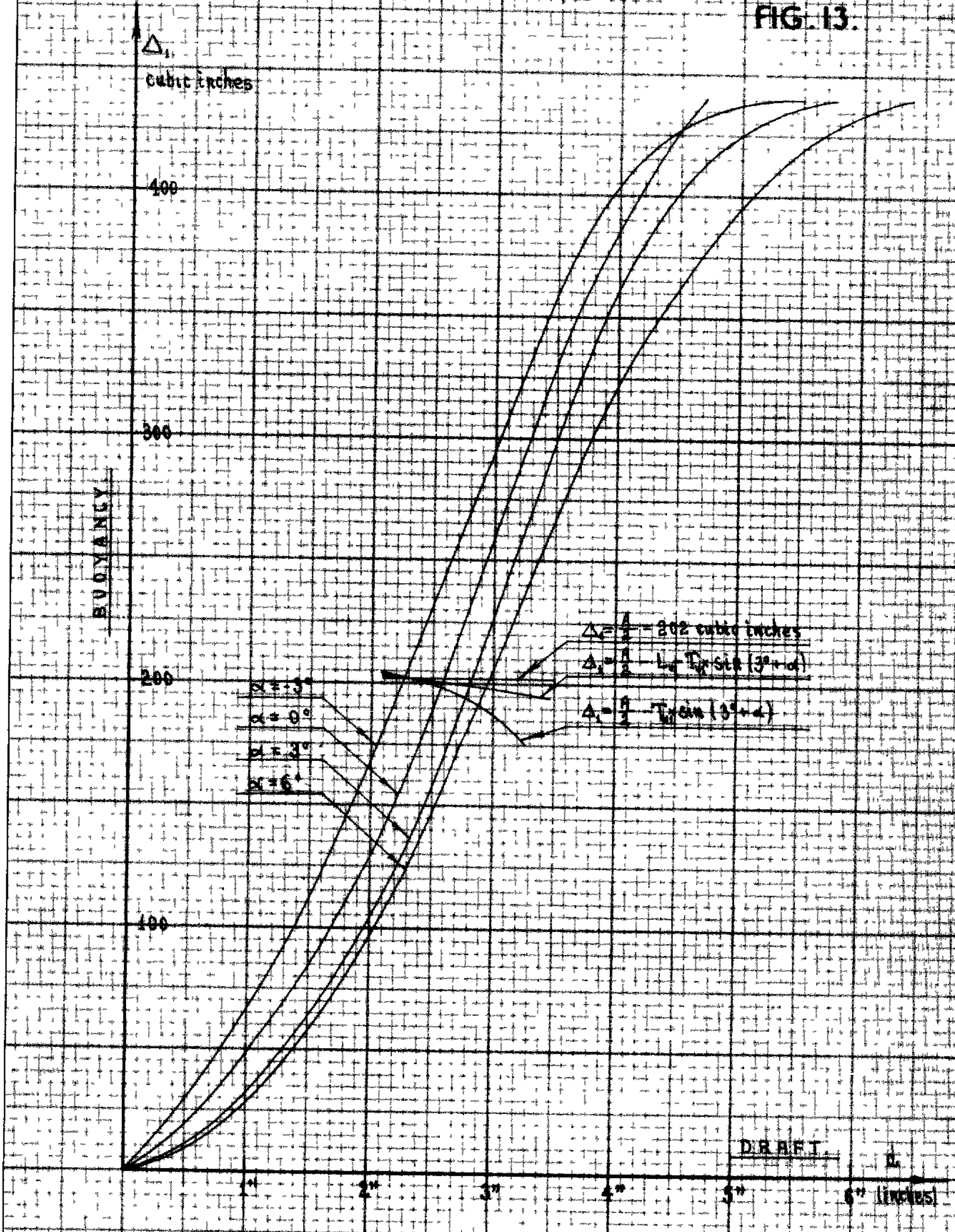


GRAPHICAL DERIVATION OF FLOAT BUOYANCY FOR ZERO ATTITUDE AND DRAFT 3·5 INS. (SEE APPENDIX II.)

FIG.12

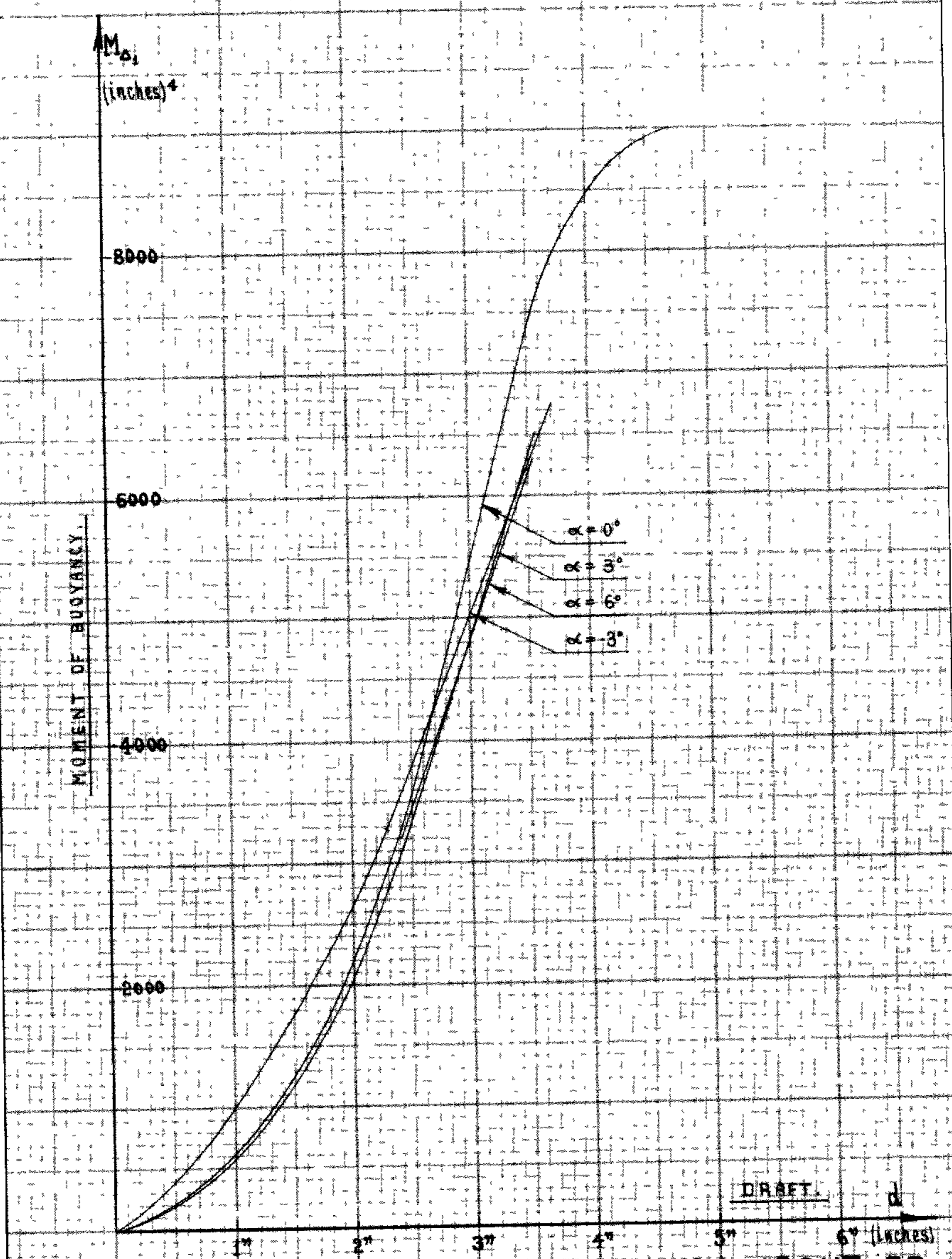


GRAPHICAL DERIVATION OF STATIC MOMENT OF BUOYANCY OF FLOAT RELATIVE TO F.P. FOR ZERO ATTITUDE & DRAFT 3·5INS. (SEE APP. II.)



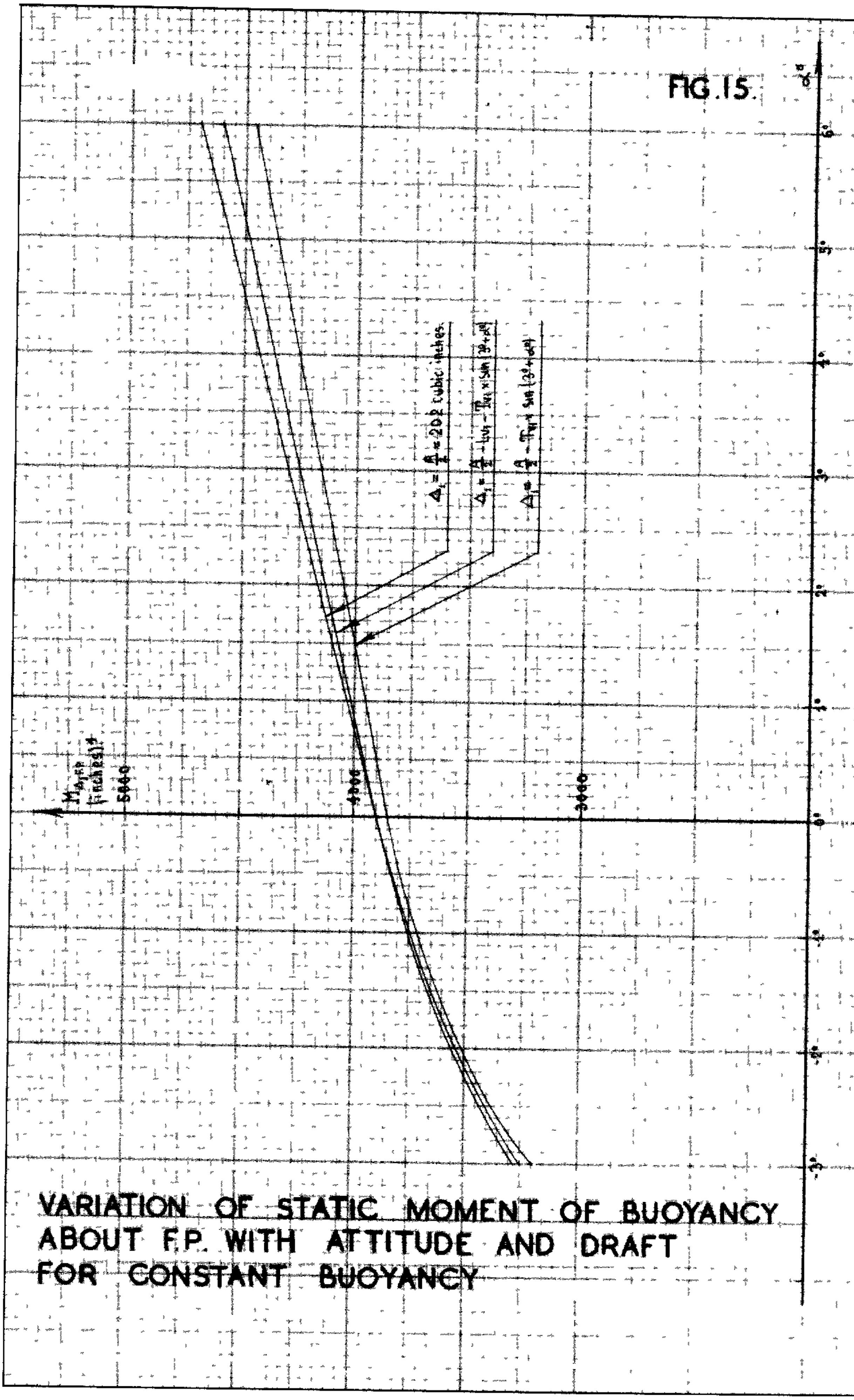
VARIATION OF BUOYANCY OF FLOAT WITH ATTITUDE AND DRAFT.

FIG. 14.



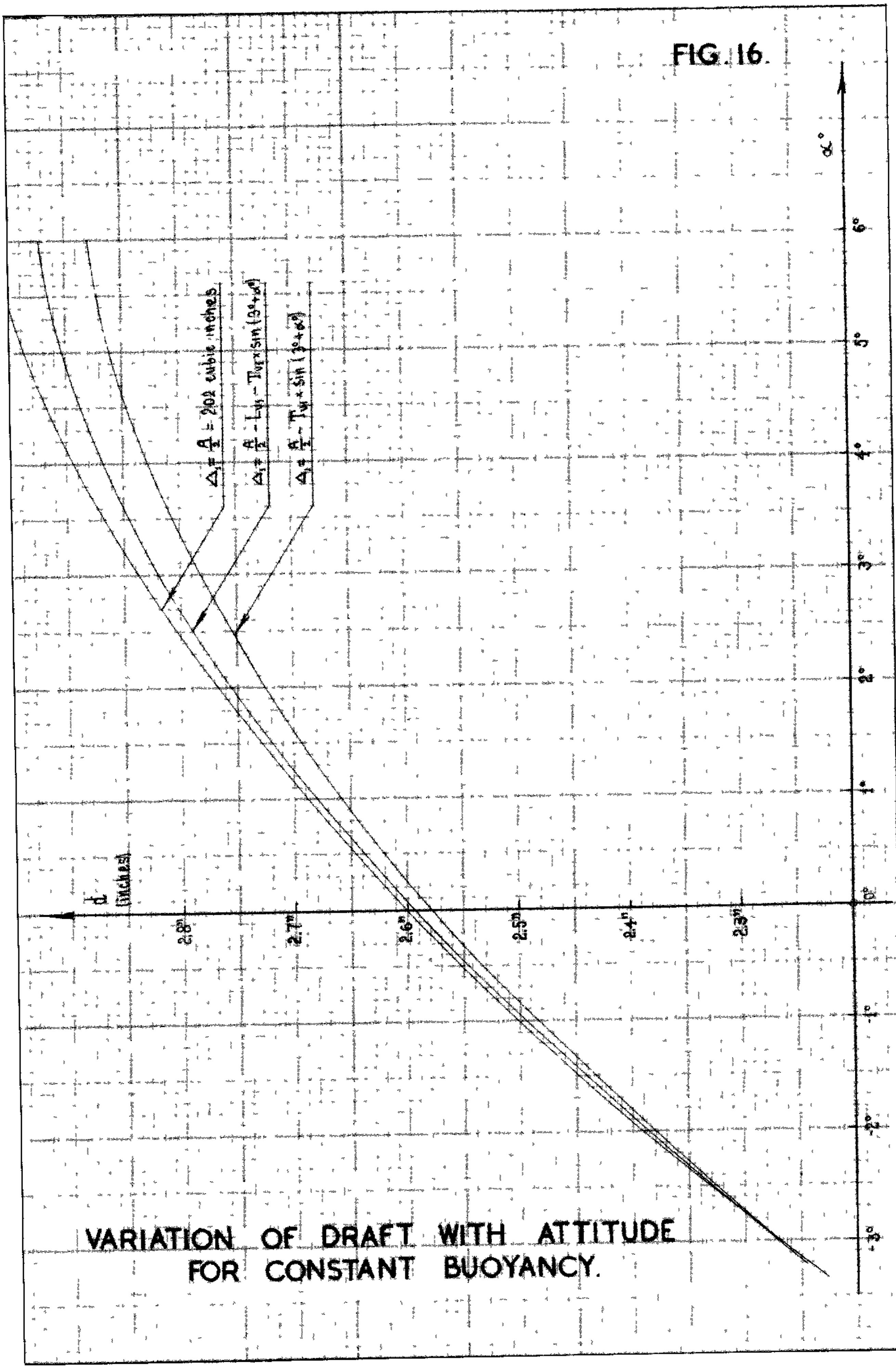
VARIATION OF MOMENT OF BUOYANCY ABOUT F.P. WITH ATTITUDE AND DRAFT.

FIG. 15.

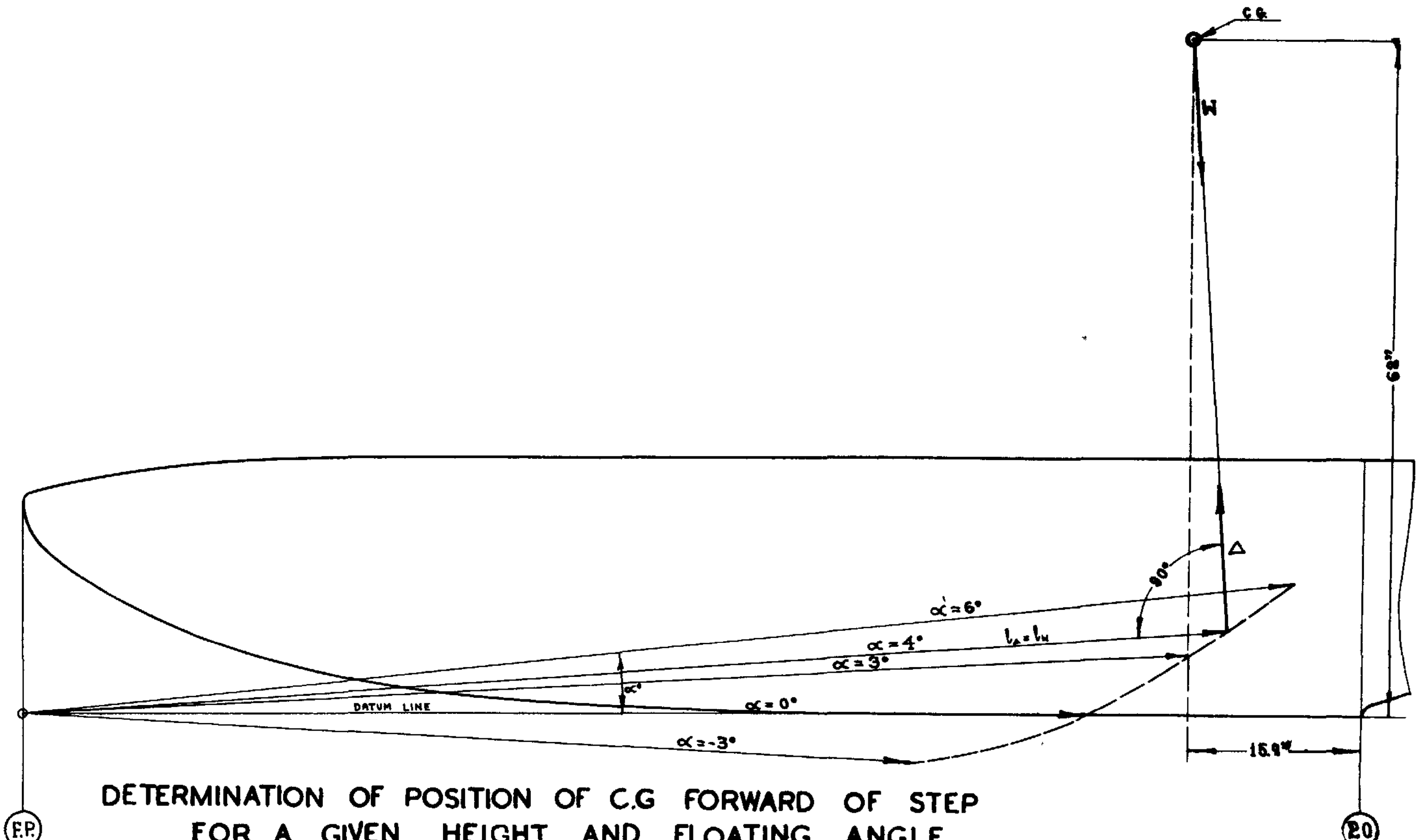


VARIATION OF STATIC MOMENT OF BUOYANCY ABOUT F.P. WITH ATTITUDE AND DRAFT FOR CONSTANT BUOYANCY

FIG. 16.

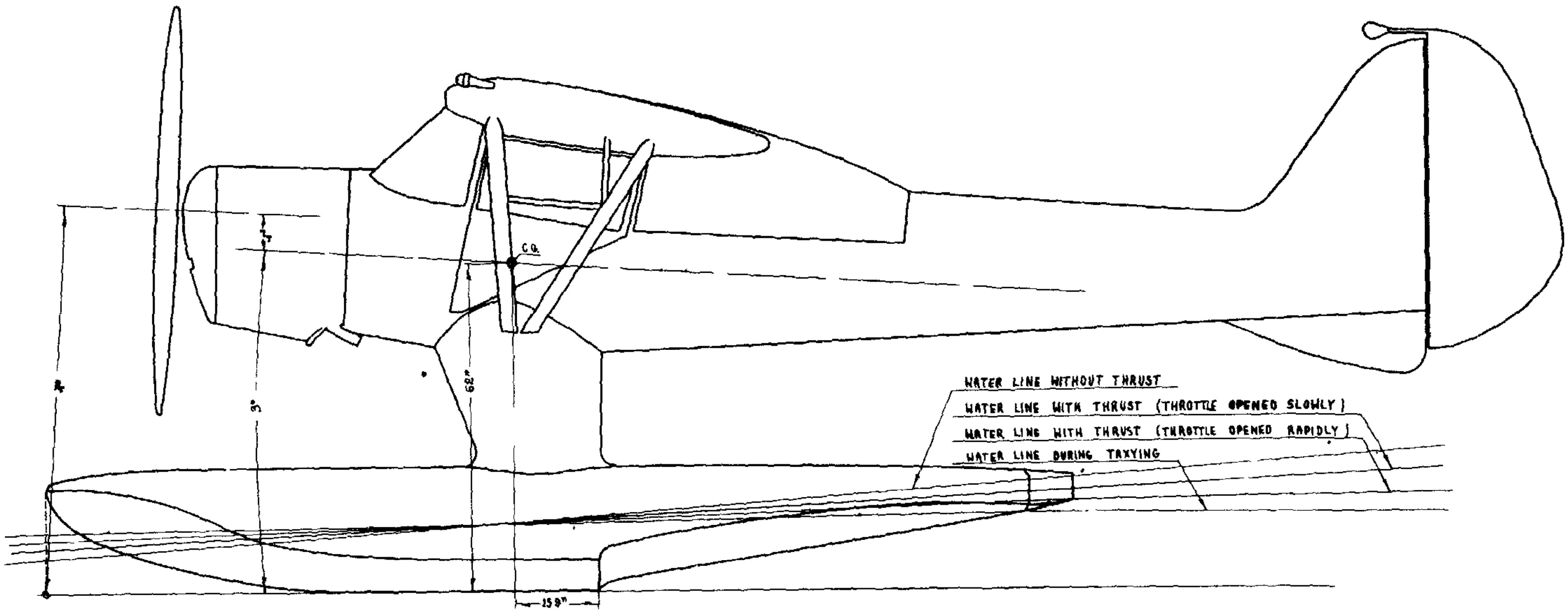


VARIATION OF DRAFT WITH ATTITUDE FOR CONSTANT BUOYANCY.



DETERMINATION OF POSITION OF C.G FORWARD OF STEP
FOR A GIVEN HEIGHT AND FLOATING ANGLE.

FIG. 17.



LOCATION OF FLOAT RELATIVE TO FUSELAGE C.G. & WATERLINES FOR DIFFERENT ENGINE CONDITIONS.

FIG 13.

FIGS. 19. 20 & 21.

FIG. 19.

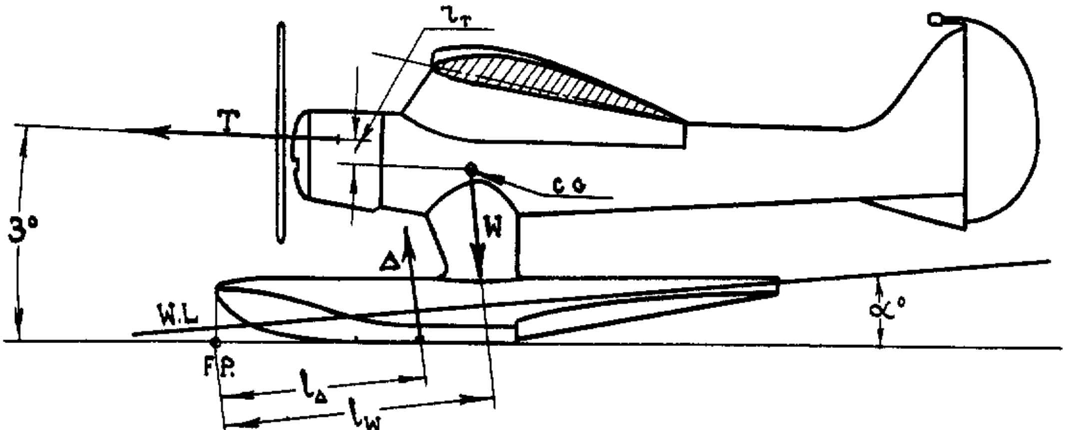


ILLUSTRATION OF LONGITUDINAL FORCES ACTING ON SEAPLANE AT REST.

FIG. 20.

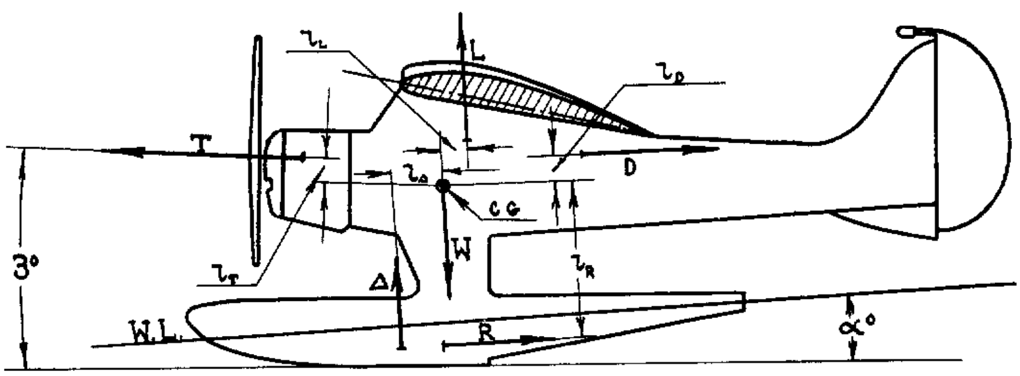


ILLUSTRATION OF LONGITUDINAL FORCES ACTING ON SEAPLANE WHEN TAXYING.

FIG. 21.

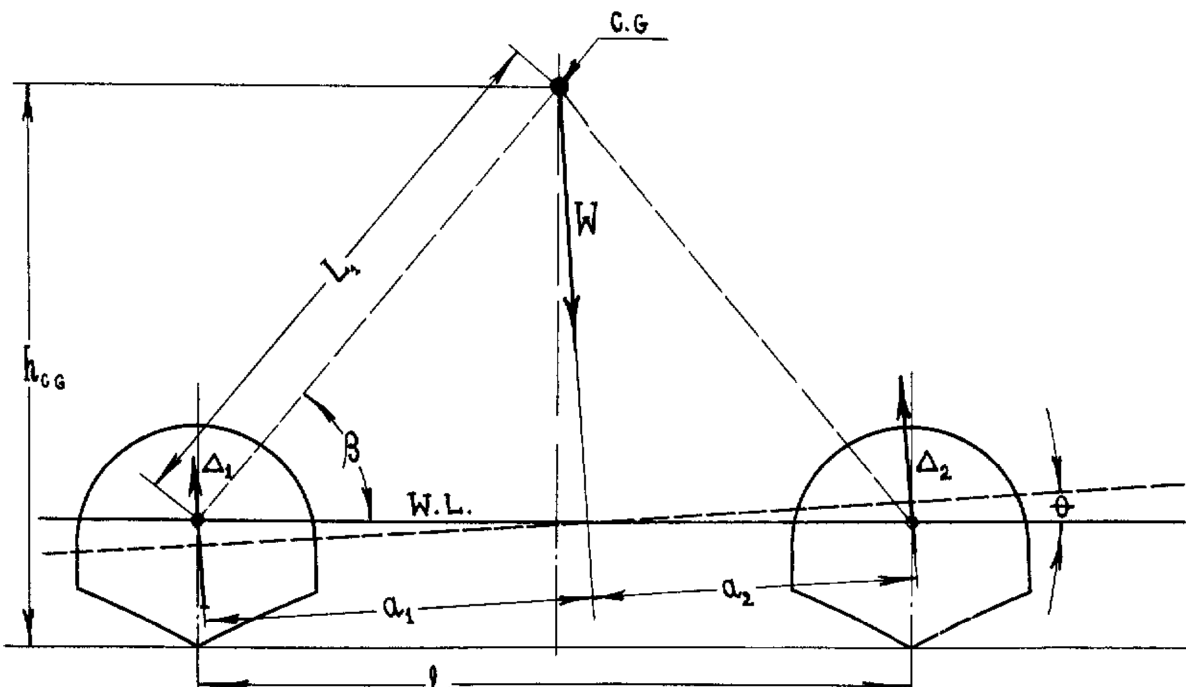
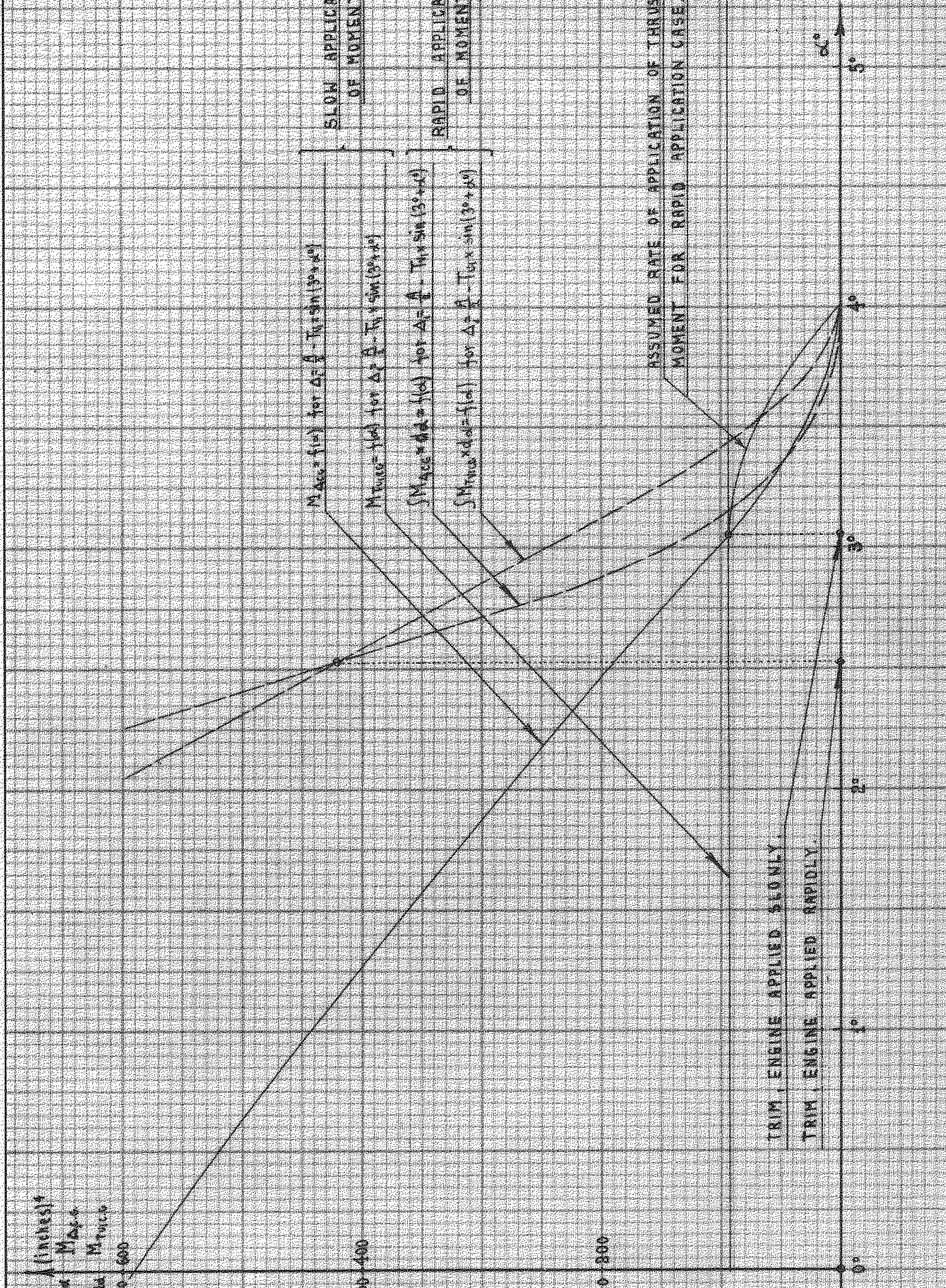


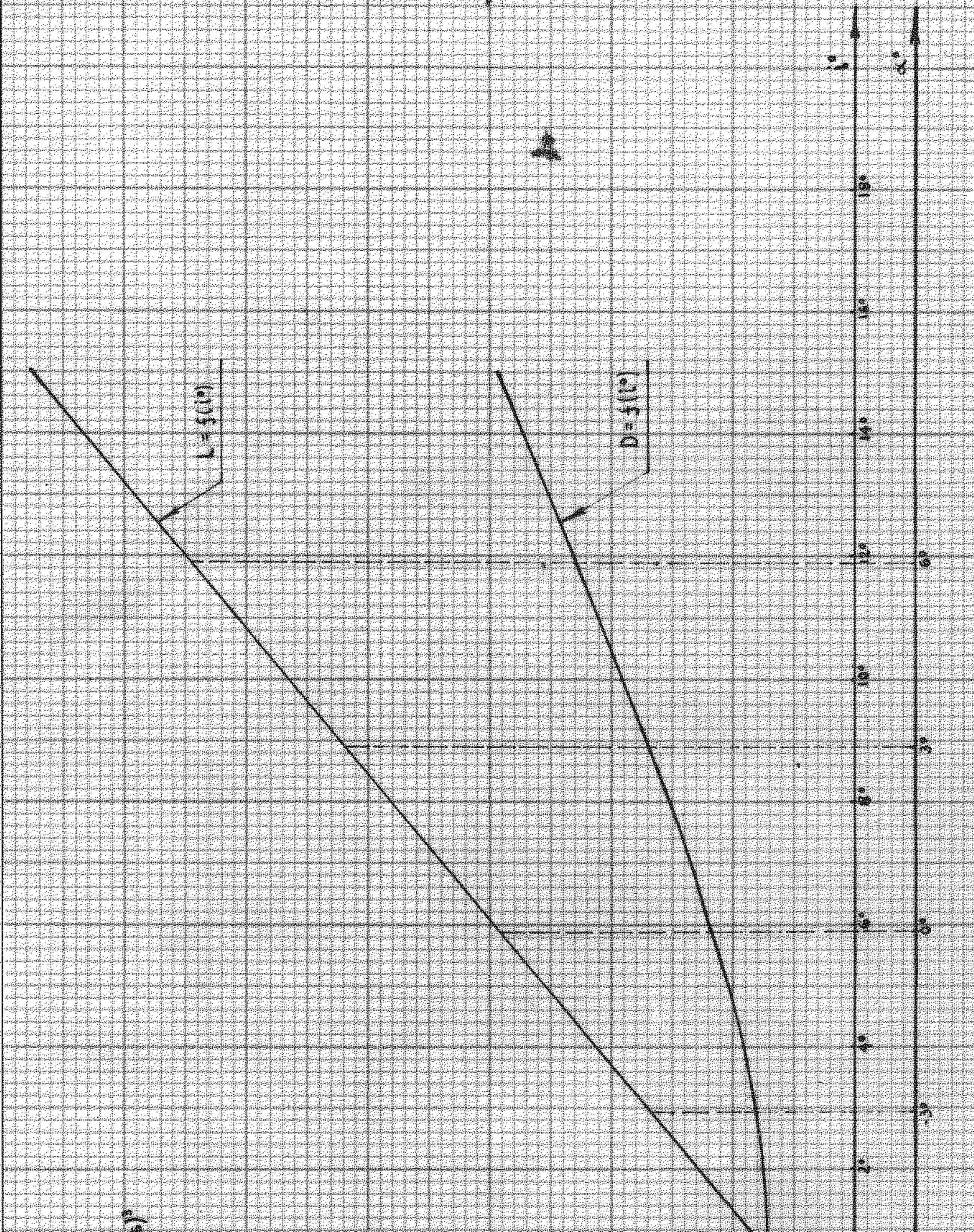
ILLUSTRATION OF TRANSVERSE FORCES ACTING ON SEAPLANE AT REST.

FIG. 22.

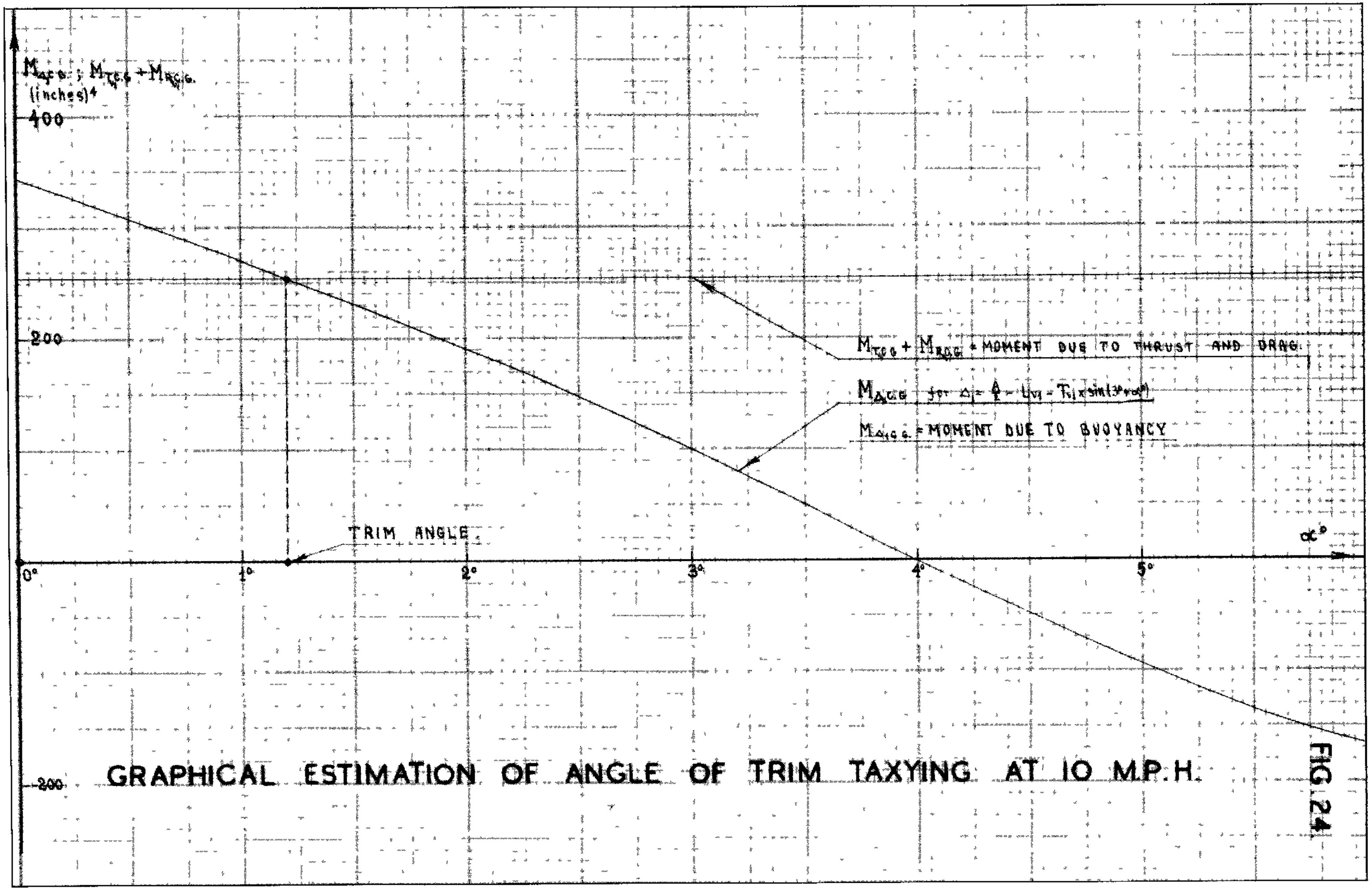


GRAPHICAL ESTIMATION OF ANGLE OF TRIM
FOR FULL STATIC THRUST APPLIED BOTH SLOWLY & RAPIDLY.

FIG. 23.



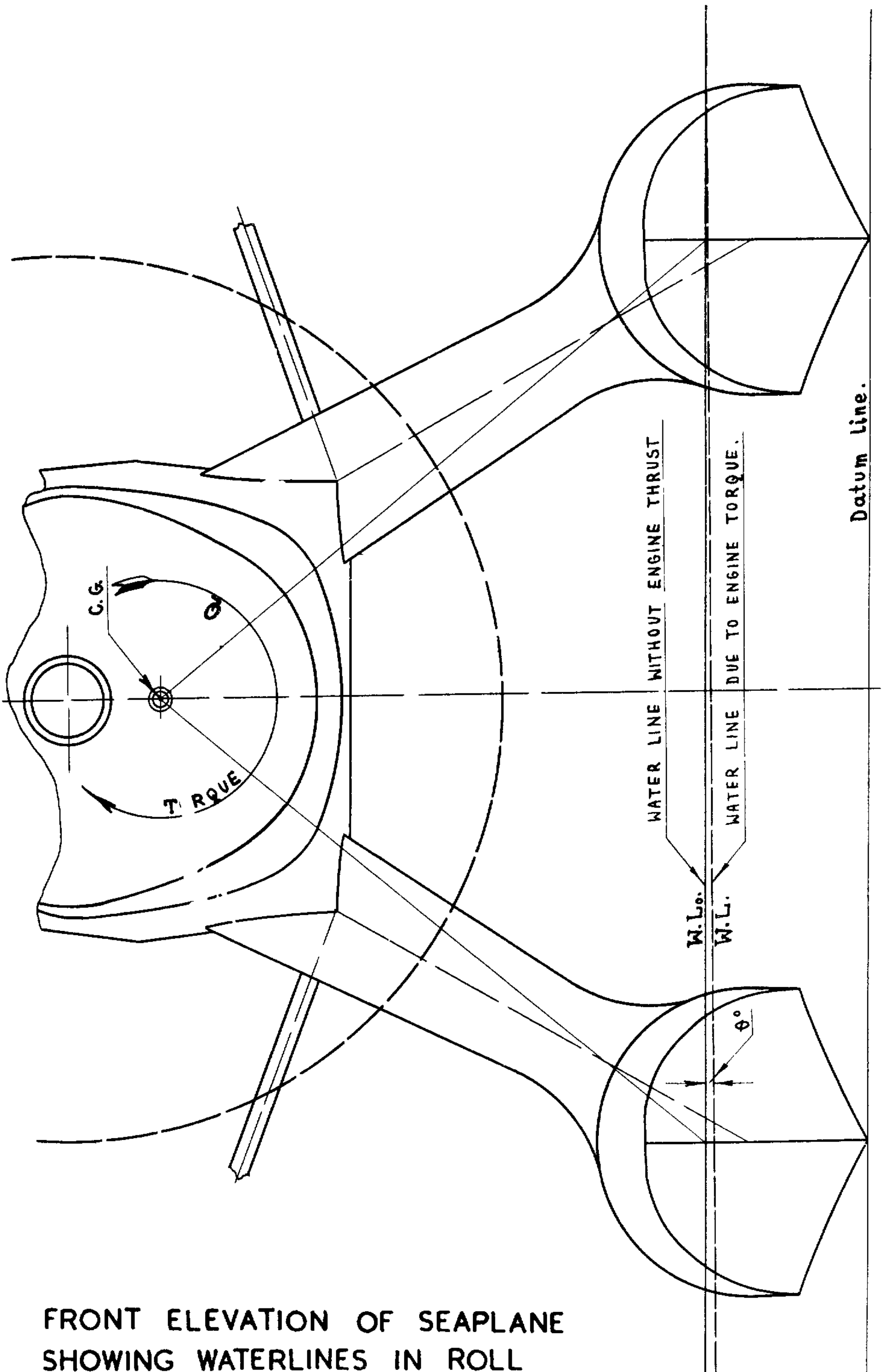
ESTIMATED AIR LIFT AND DRAG FOR SEAPLANE
AT 10 M.P.H.



GRAPHICAL ESTIMATION OF ANGLE OF TRIM TAXYING AT 10 M.P.H.

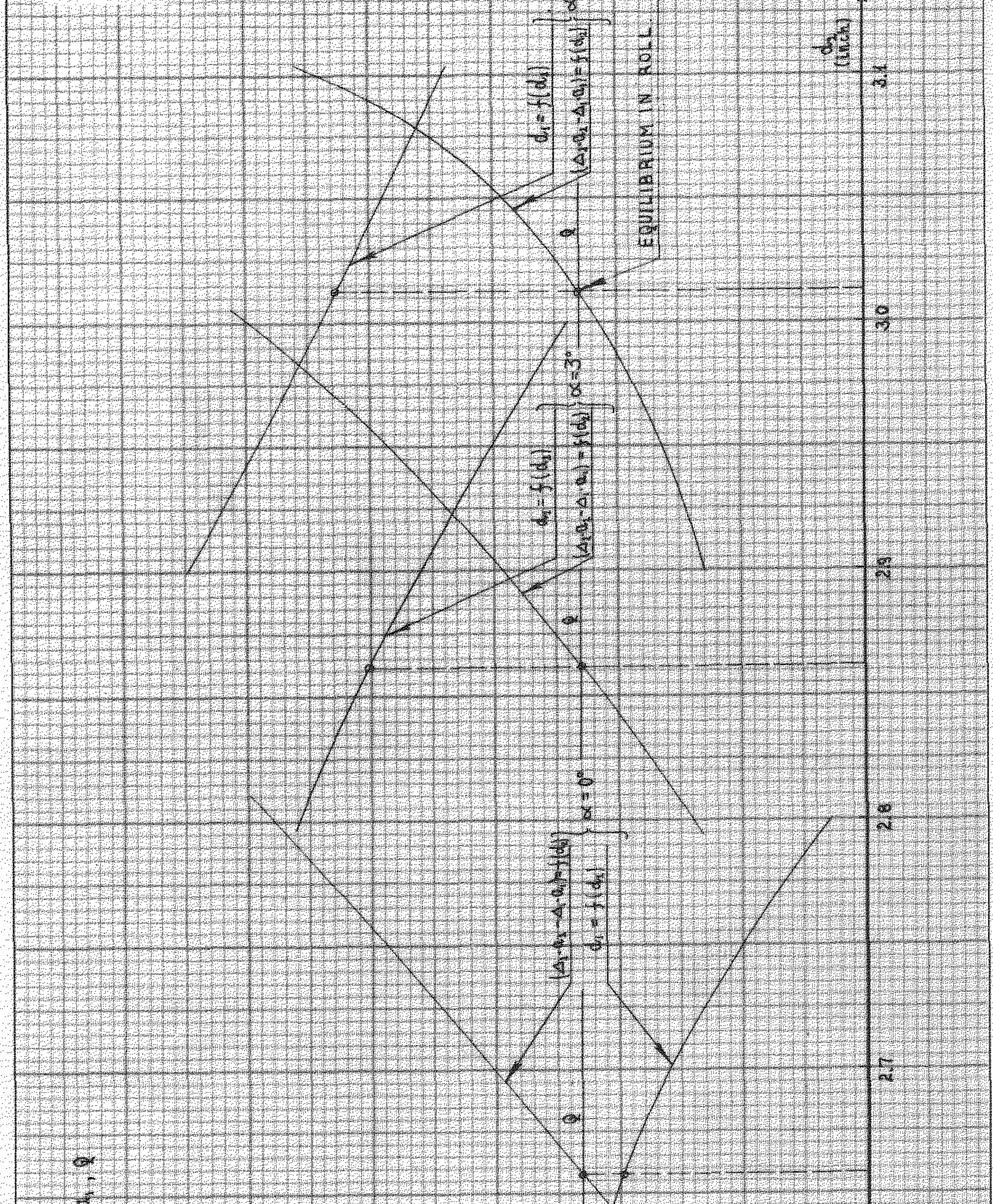
FIG. 24.

FIG. 25



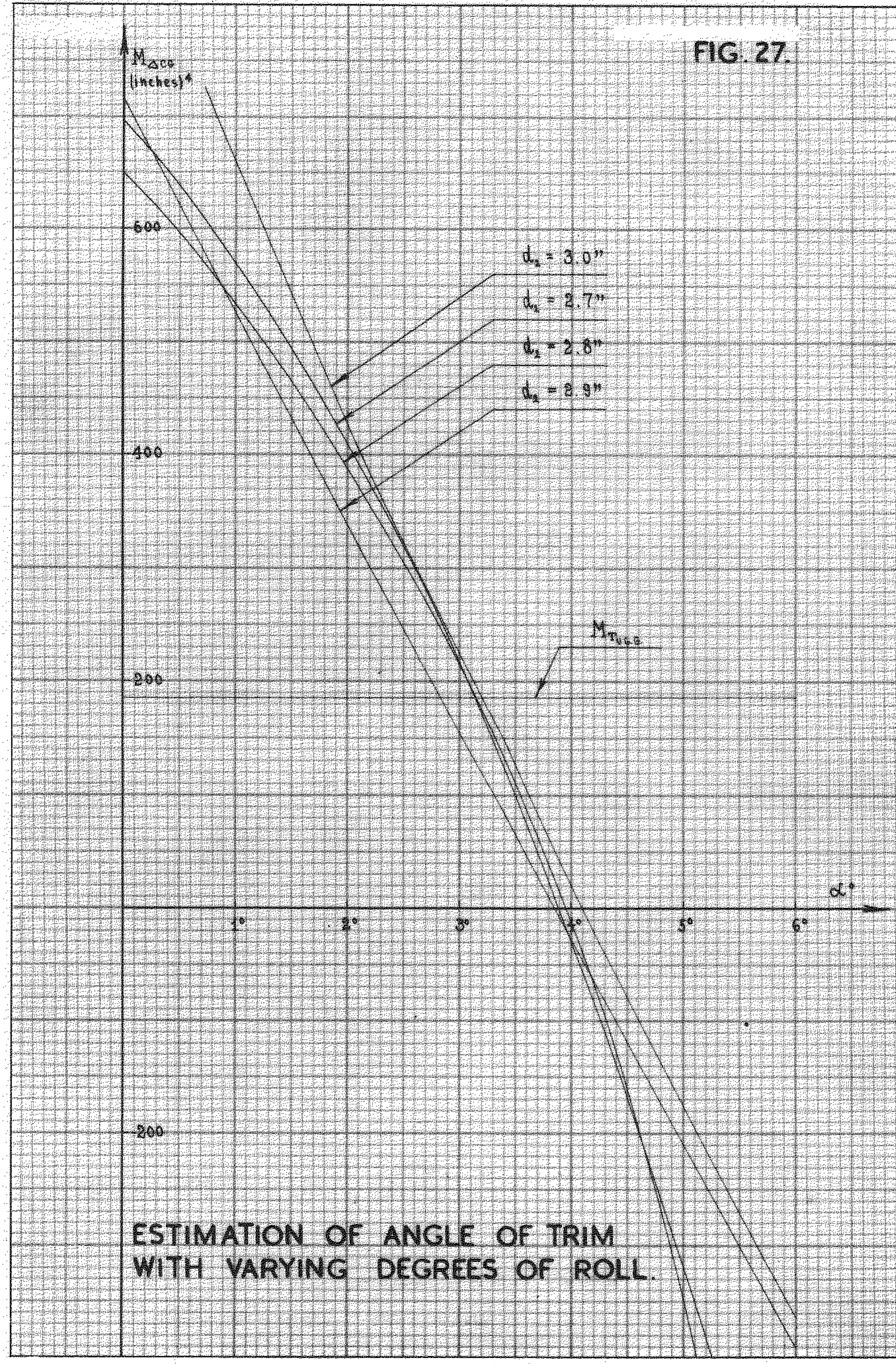
FRONT ELEVATION OF SEAPLANE
SHOWING WATERLINES IN ROLL
WITH FULL ENGINE TORQUE.

FIG. 26.



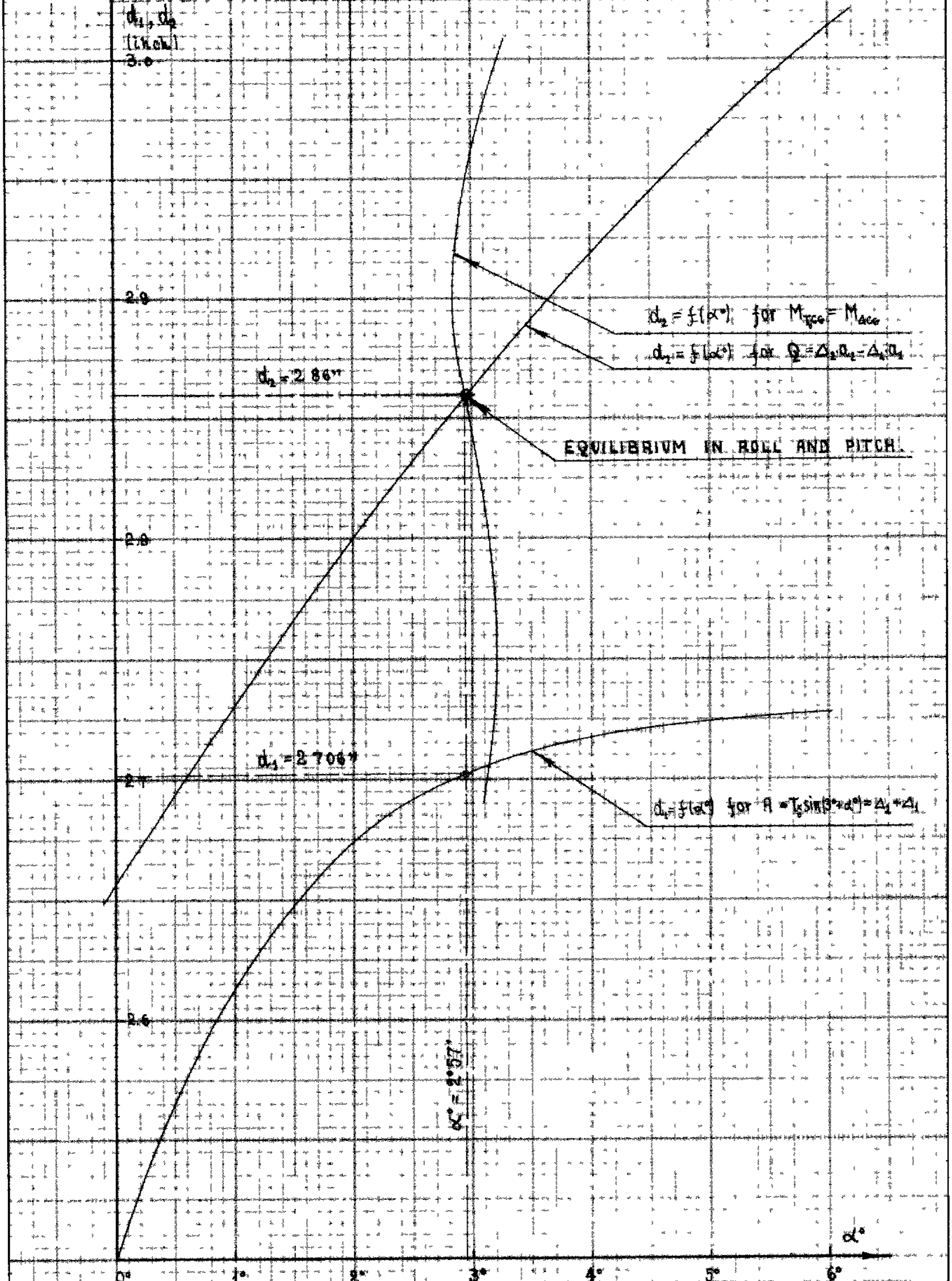
GRAPHICAL ESTIMATION OF ANGLE OF ROLL WITH ENGINE ON FOR RANGE OF ATTITUDES-STATIC CONDIT^{N}.

FIG. 27.



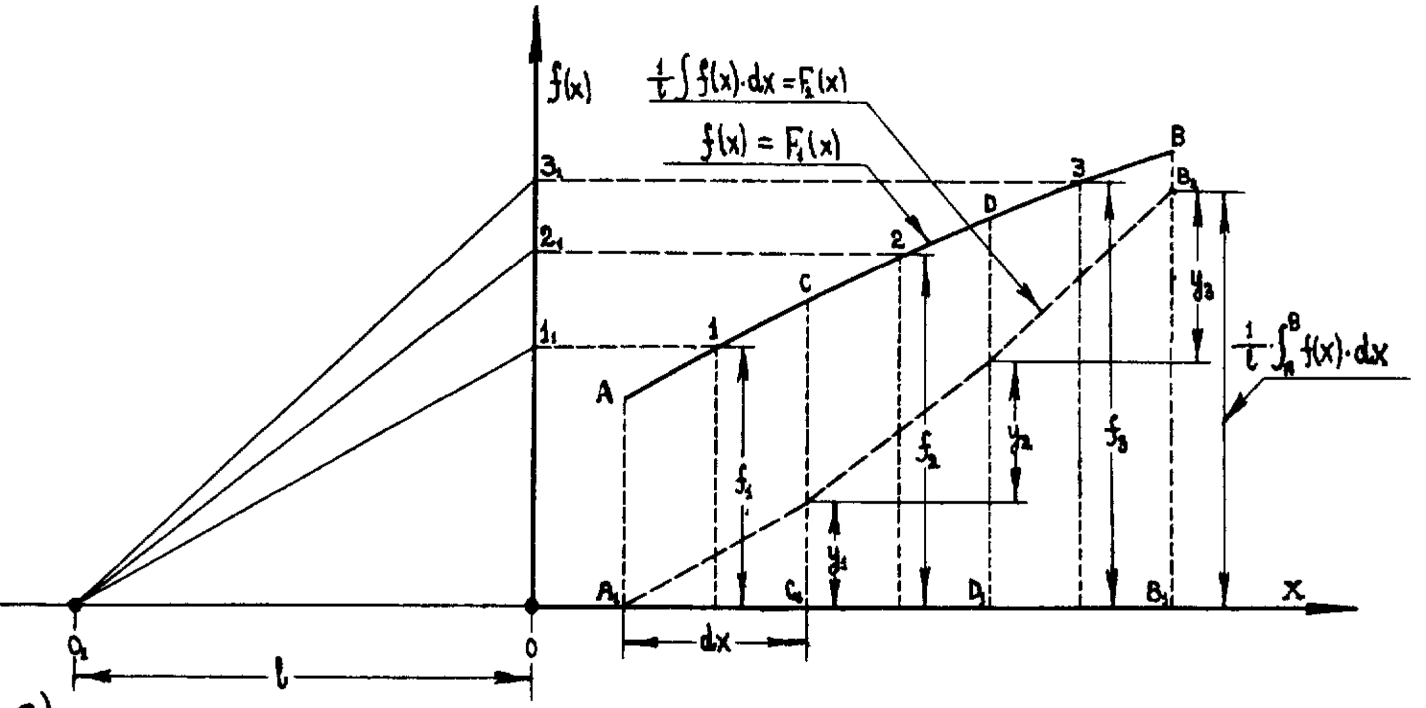
ESTIMATION OF ANGLE OF TRIM WITH VARYING DEGREES OF ROLL.

FIG. 28.



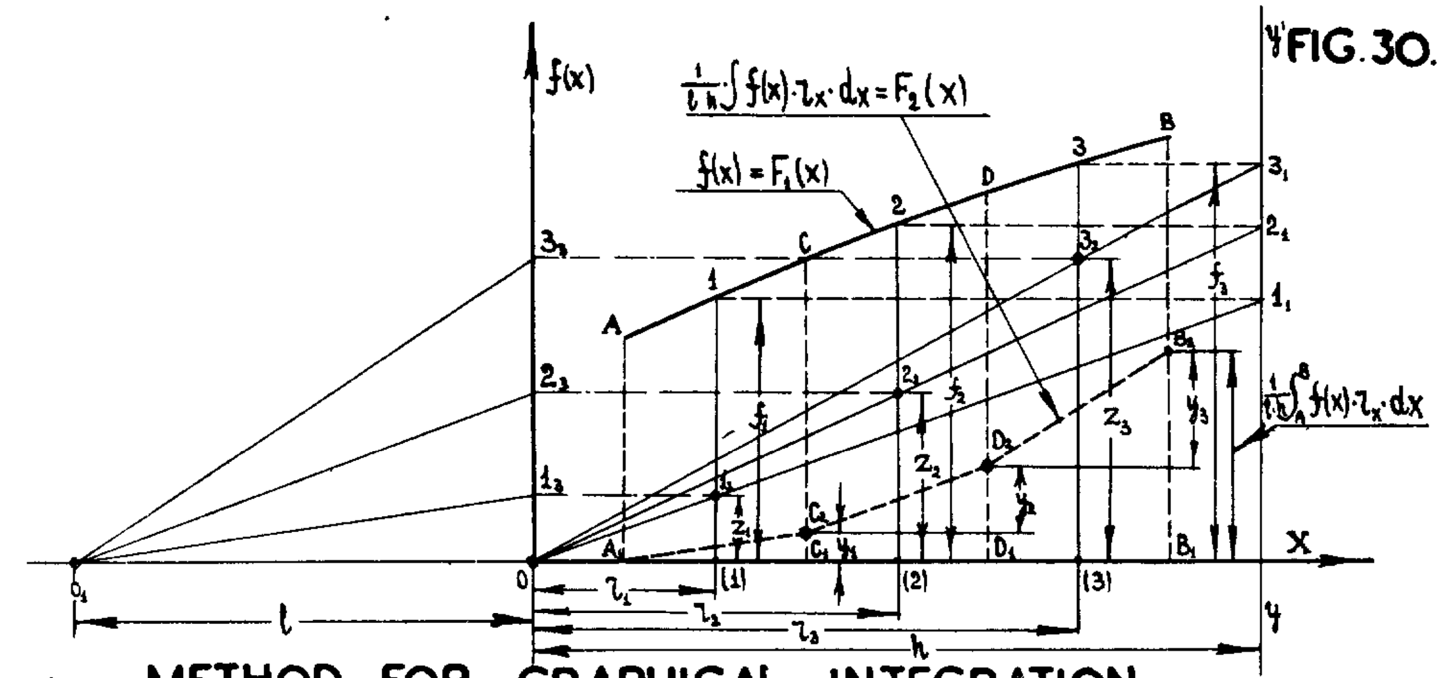
ESTIMATION OF ANGLE OF ROLL OR RELATIVE DRAFTS OF FLOATS FOR EQUILIBRIUM IN PITCH AND ROLL.

FIG. 29.



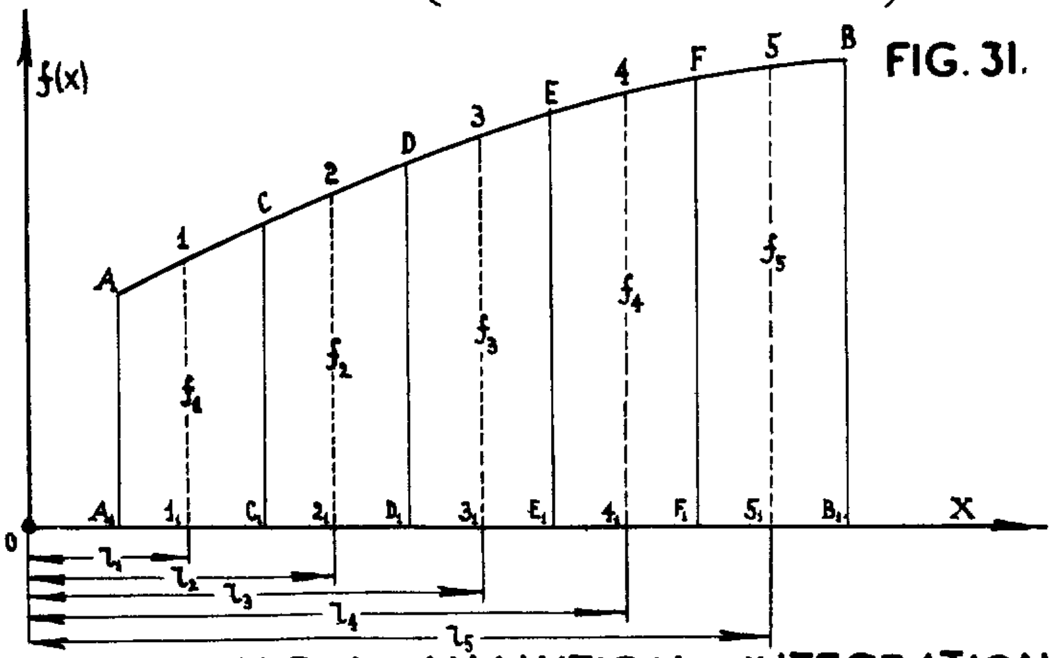
a) METHOD FOR GRAPHICAL INTEGRATION OF AREA (SEE APP. II.)

FIG. 30.



b) METHOD FOR GRAPHICAL INTEGRATION OF MOMENT OF AREA (SEE APPENDIX II.)

FIG. 31.



c) METHOD FOR GRAPHICAL-ANALYTICAL INTEGRATION OF AREA AND MOMENT OF AREA (SEE APP. I.)

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