OPTIMIZED TRAWLER FORMS

By D. J. DOUST, M.Sc., *Member*

7th December, 1962

SYNOPSIS.—*This paper describes the development of trawler hull forms based on statistical methods of analysis of the National Physical Laboratory resistance and propulsion data. The resistance qualities of these forms have been expressed in equational terms, dependent on certain non-dimensional parameters of their hull shape and dimensions. By minimizing this equation, new combinations of parameters, and hence new hull shapes have been derived which give superior performance relative to all previous results.*

It is now possible for Ship Division, N.P.L. to predict the resistance and propulsive qualities of trawlers from the lines plan, propeller and stern arrangement drawings to an accuracy comparable with that which follows from the usual model experiments in most cases, using computer programmes developed for this purpose. A design procedure is also suggested, by which means any new trawler form covering the range of prismatic coefficient from 0·60 to 0·65 can be derived, having the favourable performance characteristics which have been obtained.

In cases where other design requirements impose restrictions on the hydrodynamic performance, the penalties incurred can be estimated in the early design stages.

1. *Introduction*

SINCE early 1959, further experience of the design of trawler forms and the estimation of their resistance-speed characteristics has been gained, using the statistical methods developed at the National Physical Laboratory and described in Refs. 1 and 2.

It is now standard practice to calculate the effective horse-power of all commercial trawler forms prior to tank-testing, using the appropriate regression equation developed for this purpose. Where significant improvements to these original designs are suggested by this method, they can in most cases be incorporated in the final design of the ship. Several trawlers now in service and influenced by the statistical approach to ship design are showing good performance relative to vessels designed by conventional methods.

As part of the Ship Division's research programme for trawlers, it was decided to minimize the regression equation and design new forms having the parameters indicated, since preliminary calculations given in Ref. 3 had shown the possibility of quite important reductions in resistance relative to best design practice at the time. These new forms have therefore been designed and tested in No. 1 Tank, Ship Division, and their results are included here.

A design procedure is also suggested by which means any new trawler form covering the range of prismatic coefficient from 0·60 to 0·650 can be derived, having the favourable performance characteristics which have been obtained.

The optimized trawler forms derived from the statistical method have also been tested for propulsion in calm water, to determine their propulsive efficiency relative to existing designs. To assist in the evaluation of propulsive efficiency for these vessels, the results of a statistical analysis of propulsion data are included.

2. *The Regression Equation for Conventional Trawler Forms*

The original regression equation for trawlers given in Ref. 1 is an overall presentation of resistance data for all trawler forms tested in No. 1 Tank, Ship Division, N.P.L. up to 1958, and includes several results for unconventional forms such as those having bulbous bows and transom sterns. Although these data for the unconventional forms have the merit of increasing the ranges of the form parameters in some cases, it can be seen that the specific effects of these features cannot be fully explained by the existing regression equation, apart from perhaps the modifying influence of the bulbous bow by the half-angle of entrance. It was therefore decided to re-calculate the regression equation solely for the conventional forms, with a view to a further analysis at a later stage when more data for the unconventional trawlers become available. Opportunity was also taken to include in this re-analysis several new results for conventional forms tested since 1958.

The basic resistance data for the conventional forms at four speed-length ratios given by $V/\sqrt{L} = 0{\cdot}80, 0{\cdot}90, 1{\cdot}0$ and $1{\cdot}10$ are shown in Figs. 1-4. At the top speed ($F_n = 0{\cdot}329$) it can be seen that variations in C_{R200}, and hence in resistance per ton of displacement, of up to 60 per cent or more have occurred at fixed values of displacement. (Δ_{200}).

The scatter of the experiment data decreases as the Froude number decreases, although the variation from minimum to maximum even at a Froude number of $0{\cdot}239$ is still large and is as much as 50 per cent in a few cases.

The best relationship in 1958 between C_{R200} and the displacement of a vessel 200ft. *BP* is indicated by the line shown in each diagram.

These large increases in resistance above the 1958 line for discrete values of displacement, largely reflect the random association of form parameters chosen for these vessels which have obviously not led to the best performance in many cases. These non-optimum conditions arise because of design limitations imposed by other considerations, and/or lack of evidence at the time of the experiments that worthwhile changes in performance were possible by modifying the form parameters and hence the shape of the lines plan.

The statistical analysis of these data was therefore performed as previously described in Ref. 1, the regression equation, dependent on the six form parameters [L/B, B/d, C_m, C_p, $LCB\%$, $\frac{1}{2}\alpha_e{}^{\circ}$] being as follows:—(see discussion p. D121).

$$
\begin{aligned}
C_{R200} = {} & a_o + a_1(B/d) + a_2(B/d)^2 + a_3(LCB) + a_4(LCB)^2 + a_5(C_p) + a_6(C_p)^2 \\
& + a_7(L/B) + a_8(L/B)^2 + a_9(C_m) + a_{10}(\tfrac{1}{2}\alpha_e{}^{2}) + a_{11}(\tfrac{1}{2}\alpha_e{}^{\circ})^2 + a_{12}(C_p)(LCB) \\
& + a_{13}(C_p)(LCB)^2 + a_{14}(C_p)^2(LCB) + a_{15}(C_p)^2(LCB)^2 + a_{16}(C_p)(\tfrac{1}{2}\alpha_e{}^{\circ}) \\
& + a_{17}(C_p)(\tfrac{1}{2}\alpha_e{}^{\circ})^2 + a_{18}(C_p)^2(\tfrac{1}{2}\alpha_e{}^{\circ}) + a_{19}(C_p)^2(\tfrac{1}{2}\alpha_e{}^{\circ})^2 + a_{20}(C_p)(L/B) \\
& + a_{21}(C_p)(L/B)^2 + a_{22}(C_p)^2(L/B) + a_{23}(C_p)^2(L/B)^2 + a_{24}(L/B)(\tfrac{1}{2}\alpha_e{}^{\circ}) \\
& + a_{25}(L/B)(\tfrac{1}{2}\alpha_e{}^{\circ})^2 + a_{26}(L/B)^2(\tfrac{1}{2}\alpha_e{}^{\circ}) + a_{27}(L/B)^2(\tfrac{1}{2}\alpha_e{}^{\circ})^2 \\
& + a_{28}(B/d)(C_p) + a_{29}(B/d)^2(C_p) + a_{30}(B/d)(C_p)^2 + a_{31}(B/d)(C_p)^2
\end{aligned}
$$

..........equation(1

In this equation, C_p has been cross-coupled with all the remaining parameters except C_m which is of small importance, whilst in addition the cross-coupling of L/B and $\frac{1}{2}\alpha_e{}^{\circ}$ allows their respective optimum values to vary with each other in a similar manner, to that described in Ref. 1. Two additional terms, $(B/d)C_p$

and $(B/d)^2C_p^2$ have been added to include further cross-coupling between these important parameters. The transformations from the basic form parameters to the standardized variables which range from -1 to $+1$ are as follows:—

$$x_1 \Rightarrow L/B - 5{\cdot}0 \qquad x_2 \Rightarrow \frac{100}{64}(B/d - 2{\cdot}5) \qquad x_3 \Rightarrow 10(C_m - 0{\cdot}875)$$

$$x_4 \Rightarrow 16(C_p - 0{\cdot}64) \qquad x_5 \Rightarrow \tfrac{1}{4}(LCB - 2{\cdot}0) \qquad x_6 \Rightarrow \frac{10}{128}(\tfrac{1}{2}\alpha_e{}^\circ - 20{\cdot}0)$$

$$\text{and } y \Rightarrow \frac{1}{10}(C_{R200} - 16{\cdot}0) \qquad \text{........equation (2)}$$

The regression coefficients $a_o\ a_1\ a_2\ a_3\ \ldots\ a_{31}$ in equation (1) were derived using the method of least squares, by differentiating the sums of squares of discrepancies between the observed and calculated values of C_R with respect to each coefficient, equating to zero, and solving the series of simultaneous equations generated. With the inclusion of additional data for these vessels which are continually being obtained at N.P.L., it is desirable that the regression coefficients be re-calculated periodically to include these hitherto unexplored regions. Values of these coefficients will be published when it is considered that the complete range of variations of all the relevant parameters has been fully explored.

The residual error in C_{R200} at each speed-length ratio for the current analysis, is rather better than previously obtained and the expectation of ship speed according to the regression equation, relative to that which would be obtained from the model experiments, is within $\pm$ 1/10 knot for 95 per cent of the data at all speeds.

To assist in the evaluation of C_{R200} for specific combinations of the six form parameters and the assessment of independent effects of each parameter on resistance, C_{R200} has been sub-divided into the component functions $F_1\ F_2\ F'_3$ and F_6 as before:—

namely:—$F_1 = f_1(C_p, B/d) + K \quad (K = \text{constant})$

$F_2 = f_2(C_p, LCB)$

$F'_3 = f_3(C_p, \tfrac{1}{2}\alpha_e{}^\circ, L/B)$

and $F_6 = f_6(C_m)$

we have therefore

$$C_{R200} = F_1 + F_2 + F'_3 + F_6 \qquad \text{................equation (3)}$$

The linear function F_6 is given by:—

$$F_6 = 100\,a_9(C_m - 0{\cdot}875) \qquad \text{................equation (4)}$$

in which a_9 has the following values at each speed-length ratio.

TABLE 1

$\frac{V}{\sqrt{L}}$	0·80	0·90	1·00	1·10
a_9	−0·045	−0·053	−0·031	−0·035

Values of the resistance functions $F_1\,F_2$ and F'_3 are given in Tables 2-5 at the four speed-length ratios 0·80, 0·90, 1·0 and 1·10.

3. *Minimization Process*

A detailed calculation showing the derivation of form parameters by minimizing equation (1) has already been given in Ref. 3, but for completeness the outline of the method is now described.

Equation (1) is first expressed in general terms, i.e.

$$C_R = \frac{R.L.}{\Delta V^2} = \phi\,[L/B,\ B/d,\ C_m,\ C_p,\ LCB,\ \tfrac{1}{2}\alpha_e{}^\circ] \quad \text{.......equation (5)}$$

If the expressions for C_m and C_p are introduced in terms of the maximum section area A_m, we have:—

$$C_R = \frac{R.L.}{\Delta V^2} = \phi \left[L/B,\ B/d,\ \frac{A_m}{Bd},\ \frac{35\Delta}{L.A_m},\ LCB,\ \tfrac{1}{2}\alpha_e{}^\circ \right] \quad \text{....equation (6)}$$

where ϕ is the known function having the coefficients given by the least squares solution. It can be seen therefore that the effects on resistance R of changes in displacement, proportions, maximum area, LCB position and half-angle of entrance can all be directly estimated by substitution in equation (6). In specific cases it is usual for an owner or shipbuilder to require the best form, consistent with his other requirements, having a fixed displacement and ship speed. By considering several cases where LBP is constant, we can therefore deduce the best form parameters as follows.

Suppose we consider the case where $LBP = 200$ft. for convenience, a design speed of $V/\sqrt{L} = 1 \cdot 10$ and a fixed displacement Δ. (This method is equally applicable to other ship lengths by applying the appropriate frictional corrections).

We first consider specific combinations of $[L/B,\ B/d,\ C_m,\ C_p]$

$$\text{Since } C_m = \frac{A_m}{Bd} \text{ and } C_p = \frac{35\Delta}{200A_m}$$

$$\therefore \quad C_p = \frac{35\Delta}{200C_m.Bd} \quad \text{..............................equation (7)}$$

Now it is known from the regression equation for C_{R200} that the effects on resistance of changes in C_m are of the second order compared with the effects of the remaining five parameters, so that we will take a representative design value of $C_m = \bar{C}_m$.

$$\text{Hence } C_p = \frac{35\Delta}{200\bar{C}_m.Bd} \quad \text{..............................equation (8)}$$

The combinations of $[L/B,\ B/d,\ C_m,\ C_p]$ therefore depend only on "B" and "d" and we can make independent changes in each, subject to the conditions that C_p, L/B and B/d lie within the practical ranges covered by the basic data, namely:—

$$\left.\begin{aligned} C_p &= 0 \cdot 60 - 0 \cdot 68 \\ L/B &= 4 \cdot 4 \ \ - 5 \cdot 8 \\ B/d &= 2 \cdot 0 \ \ - 2 \cdot 6 \end{aligned}\right\}$$

A typical diagram showing the variations in beam and draught for a vessel 200ft. BP length which also gives the practical area within which a designer can make an exploratory survey to yield the optimized form for a specified speed and displacement, is given in Fig. 30. It will be seen that the shaded area ABCDEFGHIJ is bounded by the limiting lines for $C_p = 0 \cdot 60$ and $C_p = 0 \cdot 68$ given by EF and AJ respectively, the limiting line for $L/B = 4 \cdot 40$ given by ABCDE, and the limiting line FGHIJ given by $B/d = 2 \cdot 0$. Within this shaded area all the required practical conditions are satisfied, and it is therefore possible to calculate the C_{R200} values for any point in this region to determine the optimum form. For example, at the point A $[L/B = 4 \cdot 40,\ B/d = 2 \cdot 30,\ C_m = 0 \cdot 905,\ C_p = 0 \cdot 68]$, and by referring to Table 5 we can see that the function F_2 has a minimum value of $-0 \cdot 69$ when the LCB position is 6 per cent aft of amidships. Similarly for $L/B = 4 \cdot 40$ and $C_p = 0 \cdot 68$, the minimum value of $F'_3 = -1 \cdot 97$ when $\tfrac{1}{2}\alpha_e{}^\circ = 23 \cdot 5^\circ$. The minimum C_{R200} value for the point A is therefore given by:—

$C_{R200} = F_1 + F_2 + F'_3 + F_6 = 17 \cdot 12 - 0 \cdot 69 - 1 \cdot 97 - 0 \cdot 105 = \mathit{14 \cdot 355}$ noting that $F_1 = 17 \cdot 12$ (from Table 5) and $F_6 = -3 \cdot 5\ (0 \cdot 905 - 0 \cdot 875)$ from equation (4).

The best form parameters of the point A are therefore [$L/B = 4 \cdot 40$, $B/d = 2 \cdot 30$, $C_m = 0 \cdot 905$, $C_p = 0 \cdot 68$, $LCB = +6\%$, $\frac{1}{2}\alpha_e^{\circ} = 23 \cdot 5$]. This process is then repeated for all points in Fig. 30 such as B, C, D, E, etc., and the values of C_{R200} obtained reveal the most favourable combination of parameters. Frequently, it will be found that within the region of the survey there is a unique sub-region which exhibits the same values of resistance per ton of displacement, so that there is some latitude in fixing the proportions and form characteristics to suit other special design requirements, without penalty. The N.P.L. computer programmé developed for this purpose can be used to yield the best combination of all five parameters with little effort, and for a typical solution with $\Delta_{200} =$ 1900 tons the reader is referred to Ref. 3. It should be noted that due to the exclusion of the bulbous bow forms the range of $\frac{1}{2}\alpha_e^{\circ}$ of the basic data is now from 10°-30°, the *LCB* position range remaining from 0-6 per cent aft of amidships.

4. *Optimized Trawler Forms*

Using the process described in 3 above, four forms were designed and tested in No. 1 Tank, Ship Division. The models were made in wax in the usual manner and studs ⅛in. diameter, 1/10in. projection and 1in. spacing were fitted near the bow profile to stimulate turbulent flow. The offsets of the lines are given in Tables 6, 7, 8 and 9, whilst the body plans and waterline endings are shown in Figs. 5, 6, 7 and 8.

It will be noted that the *LCB* position has not been moved aft to the fullest extent (6 per cent *L*) in every case, since in these hitherto unexplored regions it was decided to keep some margin against possible after-body flow separation. More recent work at N.P.L. suggests that this reasoning was rather over-cautious, and if required further small but nevertheless significant improvements suggested from the analysis by moving the *LCB* position to 6 per cent aft of amidships appear to be quite feasible. Opportunity was also taken to make small changes in some of the design parameters in this scarcely populated region of the data and these additional modifications were incorporated in the optimized forms and tested as before. The results of these experiments have been added to Figs. 1-4, from which the advantages relative to the best practice in 1958 can be readily seen. It will be noted that apart from the improvements in performance at the designed trial speed given by $V/\sqrt{L} = 1 \cdot 10$, these improvements are generally maintained over the full speed range down to $V/\sqrt{L} = 0 \cdot 80$. The order of improvement varies with displacement, increasing from about 4 per cent at $\Delta_{200} = 1600$ tons up to 25 per cent at $\Delta_{200} = 3200$ tons, for $V/\sqrt{L} = 1 \cdot 10$. Comparisons of performance with the corresponding C_{R200} values derived from equation (1) are shown in Figs. 9, 10, 11 and 12 which show that the resistances of these optimized forms conform very well with the statistical expectations of resistance over the speed range given by $F_n = 0 \cdot 239$ to $F_n = 0 \cdot 329$.

5. *Proposed Design Method*

(a) Having minimized the regression equation for C_R in a particular case according to the method described in 3 and Ref. 3, the best dimensions, maximum area, *LCB* position and $\frac{1}{2}\alpha_e^{\circ}$ are known for a specified displacement. Some method of transforming this information into a ship's lines plan is therefore required. The method used at the present time at N.P.L. is first to derive from vessels of known good full-scale performance a series of offsets defining the transverse sections along the length. By referring to Figs. 1-4 it is possible to identify these best performers available in 1958 and hence to plot their body offsets as percentages of the moulded beam for a series of waterlines, expressed as percentages of the moulded draught amidships. These non-dimensional offsets for about ten of the best forms were plotted to a base of prismatic coefficient at the various stations, and faired lines drawn through the points obtained. A type of axometric plotting was used for fairing purposes, covering the range of C_p from $0 \cdot 60$ to $0 \cdot 65$.

(b) Interpolation for deriving the transverse section character of any trawler form within this range of prismatic coefficient can therefore be made, using the non-dimensional offsets given in Figs. 13, 14, 15 and 16. An explanatory drawing showing the graphical derivation of the form required at a fixed value of C_p is given in Fig. 17.

(c) Since the optimization process yields the required value of C_p, the corresponding non-dimensional offsets can be derived according to (b) above.

(d) For the ship length in question we now evaluate the corresponding beam and draught from the known values of L/B and B/d. The non-dimensional offsets can now be converted to actual ship dimensions and the basic body plan drawn to scale. At this stage it is usual to draw on the body plan the various trimmed waterlines corresponding to the standard designed trim of $1/30$ *LBP* by the stern, and thus derive the basic curve of areas and the trimmed waterline offsets.

(e) The maximum section area should now be compared with the value initally assumed in the optimization process. Any small deviation from the required value can usually be adjusted by slight modification of the "rise of floor", without materially affecting the transverse sections in the region of the maximum section.

(f) Comparisons can also be made of the $\frac{1}{2}\alpha_e^\circ$ value of the trimmed waterline and the *LCB* position derived from the curve of areas, with those required by the optimization process. The $\frac{1}{2}\alpha_e^\circ$ value will generally be within $\pm 1^\circ$ of that required so that only minor adjustment of the designed waterline is involved. The *LCB* position of the basic form, however, will usually be further forward from the best value of 6 per cent aft of amidships *BP* and adjustment to the curve of areas is necessary.

(g) Adjustments to the curve of areas of the derived basic form have been made using similar methods to those described by Lackenby[4]. In general, since the vessels under consideration have no parallel middle body and the same prismatic coefficient as the basic form, a longitudinal shift of sections δx can be taken, defined as:—

$$\delta x = cx\,(1 - x)^n \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{equation (9)}$$

where "c" and "n" are coefficients affecting the magnitude of the modification.

If we now differentiate equation (9) with respect to "x" and equate to zero, we find that the maximum shift of sections occurs at

$$x = \frac{1}{1 + n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\text{equation (10)}$$

where $x = 0$ at the maximum section and $x = +1$ at the ends of the vessel. Variation in the choice of "n" therefore governs the position in both fore and after-bodies where area is reduced or added to the maximum extent. If $n = 1$ (as considered by Lackenby), the maximum shift of sections occurs approximately at the $\frac{1}{4}$ points along the length of the vessel in this case, as the maximum section is not generally amidships. If, therefore, we consider a required shift of *LCB* position aft, giving a consequent reduction $\delta\,(C_p)_f$ in the fore-body prismatic coefficient, we have in general;

$$\delta\,(C_p)_f = \int_0^1 \delta x \,.\, dy = \int_0^1 cx(1 - x)^n dy$$

and hence

$$\delta(C_p)_f = c\int_0^1 x\left[1 - nx + \frac{x^2}{2!}(n)\,(n-1) - \frac{x^3}{3!}(n)\,(n-1)\,(n-2) + \right.$$

$$\left. + \frac{x^{r-1}}{(r-1)!}(-1)^{r-1}\,(n)\,(n-1)\ldots\ldots(n-r+2)\right]dy.$$

$$\ldots\ldots\ldots\ldots\text{equation (11)}$$

The moment of the portion of the area curve $\delta(C_p)_f$ about the maximum section is given by:—

$$\left[\delta(C_p)_f \cdot h_f\right] = \int_0^1 \delta x \left(x + \frac{\delta x}{2}\right) dy = \int_0^1 x\, \delta x\, dy + \tfrac{1}{2}\int_0^1 (\delta x)^2\, dy$$

.................equation (12)

Depending therefore on the required position of the *LCB* and the type of area curve required in the optimized form, values of "c" and h_f can be determined from equations (11) and (12). In the case where $n = 2$ for example, equation (11) reduces to

$$\delta(C_p)_f = c \int_0^1 x(1 - 2x + x^2)\, dy$$

and $\therefore$ $c = \dfrac{\delta(C_p)_f}{(C_p)_f\,[1 - 4\bar{x}_f + 3\bar{k}_f]}$

and on substituting in equation (9) we have:—

$$\delta x_f = \frac{\delta(C_p)_f \cdot x(1 - x)^2}{(C_p)_f\,[1 - 4\bar{x}_f + 3\bar{k}_f]} \qquad \text{.................... equation (13)}$$

whilst equation (12) reduces to:—

$$h_p \cdot \delta(C_f)_f = \frac{\delta(C_p)_f}{(C_p)_f\,[1 - 4\bar{x}_f + 3\bar{k}_f]} \int_0^1 x^2\,(1 - x)^2\, dy$$

$$+ \tfrac{1}{2} \cdot \frac{\delta(C_p)^2_f}{(C_p)^2_f\,[1 - 4\bar{x}_f + 3\bar{k}_f]^2} \cdot \int_0^1 x^2\,(1 - x)^4\, dy$$

which when $\delta(C_p)_f$ is small in relation to $(C_p)_f$ gives:—

$$h_f = \left[\frac{2\bar{x}_f - 6\bar{k}_f^2 + 4\bar{r}_f^3}{1 - 4\bar{x}_f + 3\bar{k}_f^2}\right] \qquad \text{....................equation (14)}$$

where:—$\bar{x}_f$ is the lever of the first moment of the basic fore-body area curve about the maximum section.

$\bar{k}_f$ is the lever of the second moment of the basic fore-body area curve about the maximum section.

$\bar{r}_f$ is the lever of the third moment of the basic fore-body area curve about the maximum section.

Similar expressions also apply to determine "c" and "h_a" in the after-body.

For trawlers a value of "n" $= 2$ is usually found to give the best type of modification to the basic area curve since the maximum shift of transverse sections then occurs at $x = \frac{1}{3}$ (see equation (10)), which involves more easing of the forward shoulder than for, say, $n = 1$ where a more general fining of the fore-body occurs. Values of "n" > 2 are not generally preferred except in special cases, since the after-body sectional area curve is then often made too steep immediately aft of the maximum section, with possible harmful influences on the after-body flow.

(h) Having thus calculated the required shift of sections in both fore- and after-bodies to give the desired *LCB* position, the new lines plan can be derived. An example of the method for a trawler of 0·619 prismatic coefficient is shown in Appendix 1.

The following firms kindly gave their permission to incorporate in this paper the results of model experiments conducted to their account, and this co-operation is gratefully acknowledged:

Brooke Marine Ltd., Lowestoft; Cochrane and Sons Ltd., Selby, Yorks; Cook, Welton and Gemmell Ltd., Beverley, Yorks; Richard Dunston Ltd., Thorne, nr. Doncaster; Goole Shipbuilding and Repairing Co. Ltd., Goole, Yorks; Hall Russell and Co. Ltd., Aberdeen; Herd and Mackenzie, Buckie, Banff, Scotland; John Lewis and Sons Ltd., Aberdeen; Philip and Son Ltd., Dartmouth, Devon; Henry Robb Ltd., West Pier, Leith; Smith's Dock Co. Ltd., Middlesborough; Vosper Ltd., Portsmouth.

The author wishes to acknowledge the assistance of Mathematics Division, N.P.L., in computing the results and Mr. D. Fraser, Ship Division, who conducted the model experiments and assisted in their analysis.

REFERENCES

1. DOUST, D. J. and O'BRIEN, T. P., " Resistance and Propulsion of Trawlers," *N.E.C. Inst.*, **75**, 1959, p. 355.

2. DOUST, D. J., "Statistical Analysis of Resistance Data for Trawlers," Fishing Boats of the World 2. (Fishing News Books Ltd.), 1959, p. 370.

3. DOUST, D. J., " Trawler Design at N.P.L." IV Sesja Naukowa Okretowcow, Szczecin, 1961.

4. LACKENBY, H., " On the Systematic Geometrical Variation of Ship Forms," *R.I.N.A.*, **92**, July, 1950.

APPENDIX I

1. We have considered the case when $C_p = 0{\cdot}619$, and derived the non-dimensional offsets for the basic form using Figs. 13-16. In this instance $LBP = 200$ft. and the appropriate beam and draught are given by $B = 39{\cdot}25$ft. and $d = 17{\cdot}833$ft. The offsets can therefore be determined to scale.

2. For the standard design trim of 1/30 *LBP*, the designed waterline can now be drawn and the curve of sectional areas determined by planimeter.

3. Table 1 (Appendix I) shows the fractional areas expressed in terms of the maximum area at 4½ station for appropriate sections along the length of both fore-and after-bodies. $x = 0$ is the maximum section, and $x = \pm 1$ are the *FP* and *AP* respectively.

4. We now calculate the functions of volume, first, second and third moments about the maximum section, using Simpson's rule for both fore-and after-bodies. (See Table 1, Appendix I).

5. The levers h_f and h_a (equation 14) are therefore calculable as follows:—

$$h_f = \left[\frac{2\bar{x}_f - 6\bar{k}_f^2 + 4\bar{r}_f^3}{1 - 4\bar{x}_f + 3\bar{k}_f^2}\right] = \frac{2(0{\cdot}3358) - 6(0{\cdot}1632) + 4(0{\cdot}0946)}{1 - 4(0{\cdot}3358) + 3(0{\cdot}1632)} = +0{\cdot}4836$$

Similarly

$$h_a = \frac{2(0{\cdot}3776) - 6(0{\cdot}2042) + 4(0{\cdot}1304)}{1 - 4(0{\cdot}3776) + 3(0{\cdot}2042)} = +0{\cdot}5049$$

6. The *LCB* position of the basic form is given by:—

$$\bar{z} = \frac{(C_p)_f (L_e)^2 (\bar{x}_f) - (C_p)_a (L_r)^2 (\bar{x}_a)}{(C_p) \,.\, L}$$

where L_e = length of entrance $= 0{\cdot}575L$
and L_r = length of run $= 0{\cdot}425L$

Hence $\bar{z}$ (forward of maximum section)

$$= [0{\cdot}586(0{\cdot}575)^2\,(0{\cdot}3358) - 0{\cdot}663\,(0{\cdot}425)^2\,(0{\cdot}3776)]\ \frac{L}{0{\cdot}619}$$

$$\therefore \quad \bar{z} = \frac{0{\cdot}01984L}{0{\cdot}619} = 0{\cdot}03205L\ (3{\cdot}205\%L)$$

Since the maximum section is $7\frac{1}{2}$ per cent aft of amidships, the *LCB* is $4{\cdot}295\%L$ aft of amidships (excluding cruiser stern).

7. We now require to move the *LCB* position of the basic form to $5{\cdot}6$ per cent aft of amidships (excluding cruiser stern), giving the optimum value of $6{\cdot}0$ per cent aft of amidships for the complete ship. The shift of *LCB* is therefore $5{\cdot}6 - 4{\cdot}295 = 1{\cdot}305\%L$ aft which we will denote by $+\,\delta\bar{z}$.

Now it can be shown that

$$(C_p)\,(L)\,(\delta\bar{z}) = \delta(C_p)_f\,(L_e)^2 h_f + \delta(C_p)_a\,(L_r)^2 h_a$$

Hence in this case

$$\delta(C_p)_f = \delta(C_p)_a = \frac{0{\cdot}619 \times 0{\cdot}01305}{(0{\cdot}575)^2\,(0{\cdot}4836) + (0{\cdot}425)^2\,(0{\cdot}5049)}$$

$$\therefore \quad \delta(C_p)_f = \delta(C_p)_a = \frac{0{\cdot}008078}{0{\cdot}2511} = 0{\cdot}03217$$

8. The required shifts of sections to give the correct *LCB* position are therefore given by equation (13), namely:—

$$\delta x_f = \frac{\delta(C_p)_f\,x\,(1-x)^2}{(C_p)_f\,[1 - 4\bar{x}_f + 3\bar{k}_f{}^2]} = \frac{0{\cdot}03217x\,(1-x)^2}{0{\cdot}586(0{\cdot}1464)} = 0{\cdot}375x\,(1-x)^2$$

$$\text{and } \delta x_a = \frac{\delta(C_p)_a\,.\,x\,.\,(1-x)^2}{(C_p)_a[1 - 4\bar{x}_a + 3\bar{k}_a{}^2]} = \frac{0{\cdot}03217\,.\,x\,.\,(1-x)^2}{0{\cdot}663(0{\cdot}1022)} = 0{\cdot}4748x\,(1-x)^2$$

and the shifts at $x = 0$, $0{\cdot}2$, $0{\cdot}4$, $0{\cdot}6$, $0{\cdot}80$ and $1{\cdot}0$ in the respective bodies are as follows:— (see also Figs. 18, 19).

x	*Fore-body*	*After-body*	*Fore-body*	*After-body*
0	$0{\cdot}0L_e$	$0{\cdot}0L_r$	$0{\cdot}0L$	$0{\cdot}0L$
$0{\cdot}2$	$0{\cdot}048L_e$	$0{\cdot}0608L_r$	$0{\cdot}0276L$	$0{\cdot}0258L$
$0{\cdot}4$	$0{\cdot}054L_e$	$0{\cdot}0684L_r$	$0{\cdot}0311L$	$0{\cdot}0291L$
$0{\cdot}6$	$0{\cdot}036L_e$	$0{\cdot}0456L_r$	$0{\cdot}0207L$	$0{\cdot}0194L$
$0{\cdot}8$	$0{\cdot}012L_e$	$0{\cdot}0152L_r$	$0{\cdot}0069L$	$0{\cdot}0065L$
$1{\cdot}0$	$0{\cdot}0L_e$	$0{\cdot}0L_r$	$0{\cdot}0L$	$0{\cdot}0L$

9. We can now modify the curve of areas of the basic form and lift off the new area ordinates at the correct stations. Fig. 20 shows the original body plan and the amended body plan having the required *LCB* position.

6. *Propulsion Data for Trawlers Tested at N.P.L.*

Fig. 21 shows the overall summary of propulsion data for modern trawlers tested at N.P.L. The q.p.c. values have been evaluated at a loading given by Froude e.h.p. plus 10 per cent, and are shown plotted to a base of advance coefficient, $J = V/Dn$, based on the ship speed.

It can be seen that there is a general increase in the level of quasi-propulsive coefficient (q.p.c.) with increase in advance coefficient and that for constant values of advance coefficient there is quite a marked variation in propulsive efficiency of the various forms. As there is little or no information available to explain these variations in propulsive efficiency, it was decided to attempt a statistical analysis of these data.

In the first instance the regression equation used to interpret the results was expressed in linear form and dependent on the following parameters known or considered to be of importance in determining the propulsive efficiency of these vessels, namely:—

b.a.r. = Blade area ratio of propeller

$J = V/Dn$ = Advance coefficient

$\frac{P_m}{D}$ = Mean face pitch ratio of propeller

t/D = Thickness ratio of propeller at 0·2 radius section

$\frac{t'}{l}$ = Maximum rudder thickness ratio per cent

$a/D\%$ = Clearance between trailing edge of propeller and fin or rudder nose, as percentage of diameter

$b/D\%$ = Clearance from top of aperture to screw tips, as percentage of diameter

$c/D\%$ = Clearance of propeller at tips to forward side of aperture, at top, as percentage of diameter

$\frac{1}{2}\alpha°_{rs}$ = Maximum angle of run at $\frac{1}{2}$ station of the underwater form

$\alpha°_{Bs}$ = Maximum slope of buttock line at quarter beam, of the underwater form.

Since it is considered that the accuracy of repeatability of propulsive efficiency in No. 1 Tank, Ship Division is generally within ±2 per cent, these limits were kept in mind when assessing the results derived from the analysis. The coefficients of the linear regression equation were derived as follows (using a DEUCE computer programme developed for this purpose):—

$$\begin{aligned} \text{q.p.c.} = {} & 0{\cdot}645 - 0{\cdot}147\,(\text{b.a.r.}) + 0{\cdot}023\,(P_m/D) - 2{\cdot}623\,(t/D) + 0{\cdot}2327\,(V/Dn) \\ & + 0{\cdot}00274\,(t'/l) + 0{\cdot}0016\,(a/D)\% - 0{\cdot}00145\,(b/D)\% + 0{\cdot}00044(c/D)\% \\ & - 0{\cdot}00155\,(\tfrac{1}{2}\alpha°_{rs}) - 0{\cdot}00079\,(\alpha°_{Bs}). \qquad \ldots\ldots\ldots\ldots\ldots\ldots\text{equation (15)} \end{aligned}$$

Using equation (15) and comparing the calculated results with those measured in the model experiments we obtain a standard error of ±1·45 per cent in q.p.c., which appears to satisfy the expected accuracy of measurement. In view of this reasonably close agreement with the measured data, it was decided to abandon any further refinements of the regression equation which might otherwise be made, and to use this equation as a standard measure of attainment until further results become available.

Some interesting conclusions immediately become apparent by considering equation (15). In the first place by paying due regard to the signs prefixed to the various parameters it can be seen that for maximum propulsive efficiency the following parameters should be increased as far as possible within the usual practical ranges, namely:—

1) P_m/D 2) $(V/Dn$ 3) t'/l 4) $a/D\%$ 5) $c/D\%$

The following parameters should be reduced wherever possible:—

1) b.a.r. 2) t/D 3) $b/D\%$ 4) $\frac{1}{2}\alpha^\circ_{rs}$ 5) α°_{Bs}.

The magnitudes of the maximum changes in q.p.c. over the full practical ranges of each of the ten parameters are shown in Table 10.

From Table 10 the three most important parameters are seen to be the thickness ratio of the propeller, the advance coefficient and the rudder thickness ratio, since within the practical ranges these produce the maximum changes in propulsive efficiency. Three typical examples showing their calculated and measured q.p.c. values, and the anticipated effects of changes in individual parameters are given in Appendix II.

7. *Propulsion Data for Optimized Trawler Forms*

The optimized trawler forms of 0·606, 0·625 and 0·649 prismatic coefficient were tested for propulsion in No. Tank to determine their propulsive efficiency relative to good modern practice as represented by the data given in Fig. 21. As these forms are also to be subsequently compared for rough water performance with existing vessels, the model sizes were chosen to accommodate the respective propellers of three vessels of 180ft., 134·1ft. and 112ft. *BP*. Table 11 shows the model scales and corresponding diameters of the ship propellers used, together with the main ship dimensions of the forms tested. The sterns arrangements and corresponding propeller drawings are given in Figs. 22-27. It can be seen by referring back to Fig. 21 that the q.p.c. values of the optimized forms are above average and therefore there is no adverse effect on q.p.c. offsetting the favourable resistance performances obtained, The hull efficiency elements at the various speeds covered by these experiments for each of the three models tested are given in Figs. 28-29 and are self explanatory.

Conclusions

1. Using the regression equation derived for conventional trawler forms it it is possible to obtain estimates resistance performance to within practical requirements of accuracy.

2. Minimization of the regression equation indicates regions of the data where new combinations of form parameters give expectation of favourable resistance characteristics.

3. Models designed having these optimized form parameters show significant advantages in resistance per ton of displacement compared with contemporary vessels.

4. The advantages in resistan performance have been obtained without loss of propulsive efficiency.

5. Estimates of propulsive efficiency using a regression equation based on existing propulsion data for trawler forms, give comparable accuracy with the model experiment results.

6. The statistical analysis of propulsion data suggests that the main factors governing the q.p.c. are the thickness ratio of the propeller, the advance coefficient and the rudder thickness ratio.

Acknowledgments

The work described above has been carried out as part of the research programme of the National Physical Laboratory, and this paper is published by permission of the Director of the Laboratory.

The following firms kindly gave their permission to incorporate in this paper the results of model experiments conducted to their account, and this co-operation is gratefully acknowledged:

Brooke Marine Ltd., Lowestoft; Cochrane and Sons Ltd., Selby, Yorks; Cook, Welton and Gemmell Ltd., Beverley, Yorks; Richard Dunston Ltd., Thorne, nr. Doncaster; Goole Shipbuilding and Repairing Co. Ltd., Goole, Yorks; Hall Russell and Co. Ltd., Aberdeen; Herd and Mackenzie, Buckie, Banff, Scotland; John Lewis and Sons Ltd., Aberdeen; Philip and Son Ltd., Dartmouth, Devon; Henry Robb Ltd., West Pier, Leith; Smith's Dock Co. Ltd., Middlesborough; Vosper Ltd., Portsmouth.

The author wishes to acknowledge the assistance of Mathematics Division, N.P.L., in computing the results and Mr. D. Fraser, Ship Division, who conducted the model experiments and assisted in their analysis.

REFERENCES

1. Doust, D. J. and O'Brien, T. P., "Resistance and Propulsion of Trawlers," *N.E.C. Inst.*, 75, 1959, p. 355.

2. Doust, D. J., "Statistical Analysis of Resistance Data for Trawlers," Fishing Boats of the World 2. (Fishing News Books Ltd.), 1959, p. 370.

3. Doust, D. J., "Trawler Design at N.P.L." IV Sesja Naukowa Okretowcow, Szczecin, 1961.

4. Lackenby, H., "On the Systematic Geometrical Variation of Ship Forms," *R.I.N.A.*, 92, July, 1950.

APPENDIX I

1. We have considered the case when $C_p = 0{\cdot}619$, and derived the non-dimensional offsets for the basic form using Figs. 13-16. In this instance LBP = 200ft. and the appropriate beam and draught are given by $B = 39{\cdot}25$ft. and $d = 17{\cdot}833$ft. The offsets can therefore be determined to scale.

2. For the standard design trim of 1/30 LBP, the designed waterline can now be drawn and the curve of sectional areas determined by planimeter.

3. Table 1 (Appendix I) shows the fractional areas expressed in terms of the maximum area at 4½ station for appropriate sections along the length of both fore-and after-bodies. $x = 0$ is the maximum section, and $x = \pm 1$ are the FP and AP respectively.

4. We now calculate the functions of volume, first, second and third moments about the maximum section, using Simpson's rule for both fore-and after-bodies. (See Table 1, Appendix I).

5. The levers h_f and h_a (equation 14) are therefore calculable as follows:—

$$h_f = \left[\frac{2\bar{x}_f - 6\bar{k}_f{}^2 + 4\bar{r}_f{}^3}{1 - 4\bar{x}_f + 3\bar{k}_f{}^2}\right] = \frac{2(0{\cdot}3358) - 6(0{\cdot}1632) + 4(0{\cdot}0946)}{1 - 4(0{\cdot}3358) + 3(0{\cdot}1632)} = +0{\cdot}4836$$

Similarly

$$h_a = \frac{2(0{\cdot}3776) - 6(0{\cdot}2042) + 4(0{\cdot}1304)}{1 - 4(0{\cdot}3776) + 3(0{\cdot}2042)} = +0{\cdot}5049$$

6. The LCB position of the basic form is given by:—

$$\bar{z} = \frac{(C_p)_f\,(L_e)^2\,(\bar{x}_f) - (C_p)_a\,(L_r)^2\,(\bar{x}_a)}{(C_p)\,.\,L}$$

where L_e = length of entrance = $0{\cdot}575L$
and L_r = length of run = $0{\cdot}425L$

Hence $\bar{z}$ (forward of maximum section)

$$= [0{\cdot}586(0{\cdot}575)^2\,(0{\cdot}3358) - 0{\cdot}663\,(0{\cdot}425)^2\,(0{\cdot}3776)]\ \frac{L}{0{\cdot}619}$$

$$\therefore \quad \bar{z} = \frac{0{\cdot}01984L}{0{\cdot}619} = 0{\cdot}03205L\ (3{\cdot}205\%L)$$

Since the maximum section is $7\frac{1}{2}$ per cent aft of amidships, the *LCB* is $4{\cdot}295\%L$ aft of amidships (excluding cruiser stern).

7. We now require to move the *LCB* position of the basic form to 5·6 per cent aft of amidships (excluding cruiser stern), giving the optimum value of 6·0 per cent aft of amidships for the complete ship. The shift of *LCB* is therefore 5·6 - 4·295 = $1{\cdot}305\%L$ aft which we will denote by $+\,\delta\bar{z}$.

Now it can be shown that

$$(C_p)\,(L)\,(\delta\bar{z}) = \delta(C_p)_f\,(L_e)^2 h_f + \delta(C_p)_a\,(L_r)^2 h_a$$

Hence in this case

$$\delta(C_p)_f = \delta(C_p)_a = \frac{0{\cdot}619 \times 0{\cdot}01305}{(0{\cdot}575)^2\,(0{\cdot}4836) + (0{\cdot}425)^2\,(0{\cdot}5049)}$$

$$\therefore \quad \delta(C_p)_f = \delta(C_p)_a = \frac{0{\cdot}008078}{0{\cdot}2511} = 0{\cdot}03217$$

8. The required shifts of sections to give the correct *LCB* position are therefore given by equation (13), namely:—

$$\delta x_f = \frac{\delta(C_p)_f\,x\,(1-x)^2}{(C_p)_f\,[1 - 4\bar{x}_f + 3\bar{k}_f^{\,2}]} = \frac{0{\cdot}03217x\,(1-x)^2}{0{\cdot}586(0{\cdot}1464)} = 0{\cdot}375x\,(1-x)^2$$

$$\text{and } \delta x_a = \frac{\delta(C_p)_a\,.\,x\,.\,(1-x)^2}{(C_p)_a[1 - 4\bar{x}_a + 3\bar{k}_a^{\,2}]} = \frac{0{\cdot}03217\,.\,x\,.\,(1-x)^2}{0{\cdot}663(0{\cdot}1022)} = 0{\cdot}4748x\,(1-x)^2$$

and the shifts at x = 0, 0·2, 0·4, 0·6, 0·80 and 1·0 in the respective bodies are as follows:— (see also Figs. 18, 19).

x	*Fore-body*	*After-body*	*Fore-body*	*After-body*
0	$0{\cdot}0L_e$	$0{\cdot}0L_r$	$0{\cdot}0L$	$0{\cdot}0L$
0·2	$0{\cdot}048L_e$	$0{\cdot}0608L_r$	$0{\cdot}0276L$	$0{\cdot}0258L$
0·4	$0{\cdot}054L_e$	$0{\cdot}0684L_r$	$0{\cdot}0311L$	$0{\cdot}0291L$
0·6	$0{\cdot}036L_e$	$0{\cdot}0456L_r$	$0{\cdot}0207L$	$0{\cdot}0194L$
0·8	$0{\cdot}012L_e$	$0{\cdot}0152L_r$	$0{\cdot}0069L$	$0{\cdot}0065L$
1·0	$0{\cdot}0L_e$	$0{\cdot}0L_r$	$0{\cdot}0L$	$0{\cdot}0L$

9. We can now modify the curve of areas of the basic form and lift off the new area ordinates at the correct stations. Fig. 20 shows the original body plan and the amended body plan having the required *LCB* position.

[illegible]

Case 3

				q.p.c.	
B.A.R.	= 0·530	$a/D\%$	= 10·8%	+ ve terms	− ve terms
				0·645	0·076
P_m/D	= 0·851	$b/D\%$	= 12·6%	0·020	0·111
				0·200	0·018
t/D	= 0·0422	$c/D\%$	= 21·9%	0·045	0·043
				0·017	0·014
V/Dn	= 0·860	$\frac{1}{2}\alpha^\circ_{rs}$	= 27·5°	0·010	
					0·026
t'/l	= 16·4%	α°_{Bs}	= 18·00°	0·937	

q.p.c. = 0·675

measured q.p.c. = 0·678

Effect of changes in V/Dn

V/Dn	0·60	0·70	0·80	1·00
q.p.c.	0·615	0·638	0·661	0·708

NOMENCLATURE

L = Length between perpendicular (ft.) = distance between the intersections of the trimmed waterline with the stem profile and the after side of the stern post.

⊠ = Amidships = section 50%L from after perpendicular.

B = Breadth moulded (ft.), measured on the waterline at ⊠.

d = Mean moulded draught at ⊠.

C_m = Maximum area coefficient evaluated to the trimmed waterline.

C_p = Prismatic coefficient based on the maximum section area and the moulded displacement including stern (35 ft³/ton).

LCB = Position of the longitudinal centre of buoyancy of the underwater form, including stern, measured from ⊠ and expressed as a percentage of L (+ *ve* aft).

$\frac{1}{2}\alpha e^\circ$ = The half angle of entrance measured on the trimmed waterline forward.

R = Ship resistance in pounds.

V = Ship speed in knots.

Δ = Extreme displacement, evaluated to the trimmed waterline, including stern. (35 ft³/ton).

C_R = $\dfrac{R.L.}{\Delta V^2}$

C_{R200} = C_R for vessel 200ft. BP length.

L/B = Length-breadth ratio.

APPENDIX II

Case 1

				q.p.c. +ve terms	q.p.c. −ve terms
b.a.r.	= 0·55	$a/D\%$	= 17·9%	0·645	0·081
P_m/D	= 0·750	$b/D\%$	= 18·2%	0·017	0·118
				0·176	0·026
t/D	= 0·045	$c/D\%$	= 33·3%	0·046	0·032
				0·029	0·011
V/Dn	= 0·757	$\frac{1}{2}\alpha^\circ_{rs}$	= 20·5°	0·015	
					0·268
t'/l	= 16·7%	α°_{Bs}	= 14·0°	0·928	

q.p.c. = 0·660

measured q.p.c. = 0·656

Effect of changes in blade area ratio

b.a.r.	0·45	0·65	0·70
q.p.c.	0·675	0·645	0·638

Case 2

				q.p.c. +ve terms	q.p.c. −ve terms
b.a.r.	= 0·600	$a/D\%$	= 13·9%	0·645	0·088
P_m/D	= 0·591	$b/D\%$	= 32·9%	0·014	0·096
				0·126	0·048
t/D	= 0·0366	$c/D\%$	= 41·9%	0·032	0·044
				0·022	0·018
V/Dn	= 0·541	$\frac{1}{2}\alpha^\circ_{rs}$	= 28·5°	0·018	
					0·294
t'/l	= 11·8%	α°_{Bs}	= 22·5°	0·857	

q.p.c. = 0·563

measured q.p.c. = 0·554

Effect of changes in t/D

t/D	0·030	0·040	0·050	0·060
q.p.c.	0·580	0·554	0·528	0·502

APPENDIX I

TABLE 1—*Calculation of Shift of Sections of Basic Form to give required LCB Position*

After-body	Multipliers	f(area)	f(volume)	fractional lever	1st moment	2nd moment	3rd moment	Fore-body	SM's	f(area)	f(volume)	fractional lever	1st moment	2nd moment	3rd moment
0	1	1.000	1.000	0	0.000	0.000	0.000	0.0	1	1.000	1.000	0	0.000	0.000	0.000
0.20	4	0.958	3.832	0.20	0.766	0.153	0.031	0.20	4	0.950	3.800	0.20	0.760	0.152	0.031
0.40	$1\frac{1}{2}$	0.826	1.239	0.40	0.496	0.198	0.079	0.40	$1\frac{1}{2}$	0.780	1.170	0.40	0.468	0.187	0.075
0.50	2	0.730	1.460	0.50	0.730	0.365	0.183	0.50	2	0.646	1.292	0.50	0.646	0.323	0.162
0.60	1	0.614	0.614	0.60	0.368	0.221	0.133	0.60	1	0.496	0.496	0.60	0.298	0.179	0.107
0.70	2	0.490	0.980	0.70	0.686	0.480	0.336	0.70	2	0.335	0.670	0.70	0.469	0.328	0.230
0.80	$\frac{3}{4}$	0.355	0.266	0.80	0.213	0.170	0.136	0.80	$\frac{3}{4}$	0.195	0.146	0.80	0.117	0.094	0.075
0.85	1	0.285	0.285	0.85	0.242	0.206	0.175	0.85	1	0.135	0.135	0.85	0.115	0.098	0.083
0.90	$\frac{1}{2}$	0.210	0.105	0.90	0.095	0.085	0.077	0.90	$\frac{1}{2}$	0.085	0.043	0.90	0.039	0.035	0.032
0.95	1	0.140	0.140	0.95	0.133	0.126	0.120	0.95	1	0.043	0.043	0.95	0.041	0.039	0.037
1.00	$\frac{1}{4}$	0.109	0.027	1.00	0.027	0.027	0.027	1.00	$\frac{1}{4}$	0	0	1.00	0	0	0
	$\boxed{15}$		$\boxed{9.948}$		$\boxed{3.756}$	$\boxed{2.031}$	$\boxed{1.297}$		$\boxed{15}$		$\boxed{8.795}$		$\boxed{2.953}$	$\boxed{1.\ 35}$	$\boxed{0.832}$

Afterbody

Afterbody prismatic coefficient $\left(C_p\right)_a = \frac{9.948}{15} = 0.663$

Lever of 1st moment about maximum section $= \frac{3.756}{9.948} = 0.3776 = \bar{x}_a$

Lever of 2nd moment about maximum section $= \frac{2.031}{9.948} = 0.2042 = \bar{k}_a{}^2$

Lever of 3rd moment about maximum section $= \frac{1.297}{9.948} = 0.1304 = \bar{r}_a{}^3$

$$CI = \frac{1}{5} L_r$$

$$\therefore CI = \frac{1}{5} (42.5\%L)$$

$$\therefore CI = 8.5\%L$$

Forebody

Forebody prismatic coefficient $\left(C_p\right)_f = \frac{8.795}{15} = 0.586$

Lever of 1st moment about maximum section $= \frac{2.953}{8.795} = 0.3358 = \bar{x}_f$

Lever of 2nd moment about maximum section $= \frac{1.435}{8.795} = 0.1632 = \bar{k}_f{}^2$

Lever of 3rd moment about maximum section $= \frac{0.832}{8.795} = 0.0946 = \bar{r}_f{}^3$

$$CI = \frac{1}{5} L_e$$

$$\therefore CI = \frac{1}{5} (57.5\%L)$$

$$\therefore CI = 11.5\%L$$

B/d = Breadth-draught ratio.

$(C_p)_f$ = Prismatic coefficient of fore-body.

$(C_p)_a$ = Prismatic coefficient of after-body.

L_e = Length of entrance.

L_r = Length of run.

h_f = Lever about maximum section of portion under area curve represented by $\delta(C_p)_f$.

h_a = Lever about maximum section of portion under area curve represented by $\delta(C_p)_a$.

$\bar{x}_f$ = Lever of the first moment of the basic fore-body area curve about maximum section.

$\bar{x}_a$ = Lever of the first moment of the basic after-body area curve about maximum section.

$\bar{k}_f$ = Lever of the second moment of the basic fore-body area curve about maximum section.

$\bar{k}_a$ = Lever of the second moment of the basic after-body area curve about maximum section.

$\bar{r}_f$ = Lever of the third moment of the basic fore-body area curve about maximum section.

$\bar{r}_a$ = Lever of the third moment of the basic after-body area curve about maximum section.

$\delta\bar{z}$ = Required shift of *LCB* position (+*ve* aft) expressed as percentage of *L*.

D = Propeller diameter.

P_m = Mean face pitch ratio of propeller.

t = Thickness of propeller at 0·2 radius section.

t' = Thickness of rudder at maximum section.

l = Mean length of rudder.

a = Clearance between trailing edge of propeller and fin or rudder nose.

b = Clearance from top aperture to propeller tips.

c = Clearance from propeller at tips to forward side of aperture at top.

$\frac{1}{2}\alpha^\circ_{rs}$ = Maximum angle of run at $\frac{1}{2}$ station of the underwater form.

α°_{Bs} = Maximum slope of buttock at $(B/4)$ of the underwater form.

n = Propeller revolutions per second.

TABLE 3—C_R — *Function Tables* *

$V/\sqrt{L} = 0.90$

* Underlined Figures are negative

Function F_1

[illegible]	C_p 0.60	0.62	0.64	0.66	0.68
2.0	8.75	9.66	9.80	9.16	7.73
2.1	9.22	9.82	9.83	9.25	8.09
2.2	9.63	9.98	9.92	9.44	8.55
2.3	10.00	10.17	10.08	9.73	9.12
2.4	10.32	10.37	10.30	10.11	9.80
2.5	10.59	10.59	10.59	10.59	10.59
2.6	10.81	10.83	10.94	11.17	11.49

Function F_2

L.C.B% aft	C_p 0.60	0.62	0.64	0.66	0.68
0	0.72	$\underline{0.01}$	$\underline{0.10}$	0.45	1.65
1	0.66	$\underline{0.02}$	$\underline{0.01}$	0.57	1.76
2	0.60	$\underline{0.01}$	0.00	0.62	1.86
3	0.52	$\underline{0.10}$	$\underline{0.06}$	0.63	1.97
4	0.42	$\underline{0.24}$	$\underline{0.19}$	0.58	2.07
5	0.31	$\underline{0.45}$	$\underline{0.39}$	0.48	2.17
6	0.19	$\underline{0.71}$	$\underline{0.66}$	0.33	2.27

Function F'_3

$C_p = 0.60$

[illegible]	$\frac{1}{2}\alpha_e{}^\circ$ [illegible]	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
[illegible]						$\underline{1.98}$	$\underline{1.21}$	$\underline{0.42}$	0.39	1.23	2.09
[illegible]	[illegible]PLORED REGION					$\underline{1.68}$	$\underline{0.87}$	0.04	1.06	2.19	3.43
[illegible]						$\underline{1.30}$	$\underline{0.47}$	0.53	1.72	3.07	4.61
[illegible]						$\underline{0.85}$	0.00	1.07	2.37	3.89	5.63
[illegible]	[illegible]	$\underline{1.30}$	$\underline{1.43}$	$\underline{1.31}$	$\underline{0.95}$	$\underline{0.33}$	0.54	1.65	3.01	4.63	6.49
[illegible]	[illegible]	$\underline{0.70}$	$\underline{0.84}$	$\underline{0.73}$	$\underline{0.36}$	0.26	1.14	2.27	3.65	5.29	
[illegible]	[illegible]	$\underline{0.22}$	$\underline{0.30}$	$\underline{0.13}$	0.28	0.92	1.80	2.92			
[illegible]	[illegible]	0.14	0.22	0.49	0.97	1.65	2.53	3.62			

$C_p = 0.62$

L/B	$\frac{1}{2}\alpha_e{}^\circ$ 5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
4.4						$\underline{1.22}$	$\underline{0.81}$	$\underline{0.41}$	$\underline{0.01}$	0.37	0.74
4.6	UNEXPLORED REGION					$\underline{1.04}$	$\underline{0.60}$	$\underline{0.08}$	0.52	1.20	1.95
4.8						$\underline{0.80}$	$\underline{0.33}$	0.29	1.05	1.95	3.00
5.0						$\underline{0.49}$	0.00	0.68	1.56	2.62	3.87
5.2	0.58	0.01	$\underline{0.35}$	$\underline{0.49}$	$\underline{0.41}$	$\underline{0.12}$	0.39	1.11	2.05	3.21	4.58
5.4	1.03	0.45	0.08	$\underline{0.06}$	0.01	0.31	0.83	1.57	2.54	3.72	
5.6	1.27	0.77	0.47	0.38	0.49	0.81	1.34	2.07			
5.8	1.28	0.96	0.81	0.83	1.01	1.37	1.90	2.60			

$C_p = 0.64$

[illegible]						$\underline{1.07}$	$\underline{0.85}$	$\underline{0.68}$	$\underline{0.54}$	$\underline{0.44}$	$\underline{0.38}$
[illegible]	[illegible]PLORED REGION					$\underline{0.84}$	$\underline{0.59}$	$\underline{0.29}$	0.05	0.45	0.89
[illegible]						$\underline{0.58}$	$\underline{0.31}$	0.08	0.59	1.21	1.95
[illegible]						$\underline{0.30}$	0.00	0.46	1.08	1.86	2.81
[illegible]	[illegible]	0.66	0.22	$\underline{0.04}$	$\underline{0.11}$	0.02	0.33	0.83	1.52	2.39	3.46
[illegible]	[illegible]	1.30	0.55	0.29	0.23	0.35	0.68	1.19	1.90	2.81	
[illegible]	[illegible]	1.19	0.81	0.60	0.57	0.72	1.05	1.56			
[illegible]	[illegible]	1.22	0.98	0.88	0.92	1.11	1.44	1.91			

$C_p = 0.66$

4.4						$\underline{1.53}$	$\underline{1.36}$	$\underline{1.24}$	$\underline{1.18}$	$\underline{1.18}$	$\underline{1.25}$
4.6	UNEXPLORED REGION					$\underline{1.07}$	$\underline{0.86}$	$\underline{0.62}$	$\underline{0.36}$	$\underline{0.07}$	$\underline{0.25}$
4.8						$\underline{0.64}$	$\underline{0.41}$	$\underline{0.08}$	$\underline{0.35}$	$\underline{0.87}$	1.48
5.0						$\underline{0.26}$	0.00	$\underline{0.40}$	0.94	1.62	2.44
5.2	1.22	0.66	0.27	0.04	$\underline{0.02}$	0.09	0.36	0.80	1.41	2.18	3.12
5.4	1.55	0.97	0.57	0.34	0.28	0.39	0.67	1.13	1.76	2.56	
5.6	1.54	1.05	0.72	0.54	0.52	0.65	0.94	1.39			
5.8	1.22	0.91	0.72	0.65	0.70	0.87	1.16	1.57			

$C_p = 0.68$

L/B	$\frac{1}{2}\alpha_e{}^\circ$ 5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
4.4						$\underline{2.61}$	$\underline{2.31}$	$\underline{2.09}$	$\underline{1.94}$	$\underline{1.87}$	$\underline{1.88}$
4.6	UNEXPLORED REGION					$\underline{1.73}$	$\underline{1.40}$	$\underline{1.05}$	$\underline{0.70}$	$\underline{0.34}$	0.04
4.8						$\underline{0.98}$	$\underline{0.63}$	$\underline{0.19}$	0.32	0.91	1.58
5.0						$\underline{0.38}$	0.00	0.50	1.13	1.88	2.76
5.2	0.37	0.01	$\underline{0.20}$	$\underline{0.25}$	$\underline{0.16}$	0.09	0.48	1.03	1.72	2.57	3.57
5.4	0.72	0.34	0.13	0.07	0.16	0.41	0.82	1.38	2.10	2.97	
5.6	0.64	0.35	0.20	0.20	0.33	0.60	1.01	1.57			
5.8	0.14	0.04	0.03	0.13	0.34	0.65	1.06	1.58			

TABLE 2—C_R—*Function Tables* *

$V/\sqrt{L} = 0.80$

* Underlined Figures are negative

Function F_1

[illegible]	C_p 0.60	0.62	0.64	0.66	0.68
[illegible]	7.78	8.80	8.91	8.13	6.45
[illegible]	8.24	8.89	8.89	8.23	6.91
[illegible]	8.64	9.02	8.94	8.41	7.44
[illegible]	8.99	9.16	9.06	8.69	8.05
[illegible]	9.28	9.32	9.25	9.06	8.74
[illegible]	9.51	9.51	9.51	9.51	9.51
[illegible]	9.68	9.72	9.84	10.05	10.35

Function F_2

L.C.B% aft	C_p 0.60	0.62	0.64	0.66	0.68
0	0.83	0.03	$\underline{0.32}$	$\underline{0.22}$	0.34
1	0.82	0.09	$\underline{0.14}$	0.13	0.89
2	0.83	0.14	0.00	0.41	1.38
3	0.86	0.17	0.10	0.64	1.81
4	0.91	0.18	0.15	0.82	2.19
5	0.98	0.17	0.16	0.93	2.50
6	1.08	0.15	0.12	0.99	2.77

Function F'_3

$C_p = 0.60$

[illegible]	$\frac{1}{2}\alpha_e°$ [illegible]	[illegible]	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
[illegible]						$\underline{1.84}$	$\underline{1.23}$	$\underline{0.64}$	$\underline{0.05}$	0.54	1.12
[illegible]	[illegible] REGION					$\underline{1.50}$	$\underline{0.89}$	$\underline{0.25}$	0.42	1.13	1.86
[illegible]						$\underline{1.11}$	$\underline{0.48}$	0.22	0.97	1.80	2.68
[illegible]						$\underline{0.66}$	0.00	0.76	1.60	2.54	3.57
[illegible]	[illegible]	[illegible]	$\underline{1.59}$	$\underline{1.23}$	$\underline{0.75}$	$\underline{0.16}$	0.55	1.37	2.31	3.37	4.54
[illegible]	[illegible]	[illegible]	$\underline{1.10}$	$\underline{0.74}$	$\underline{0.24}$	0.39	1.16	2.06	3.10	4.27	
[illegible]	[illegible]	[illegible]	$\underline{0.62}$	$\underline{0.23}$	0.32	1.01	1.84	2.83			
[illegible]	[illegible]	[illegible]	$\underline{0.15}$	0.30	0.91	1.67	2.59	3.67			

$C_p = 0.62$

L/B	$\frac{1}{2}\alpha_e°$ 5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
4.4						$\underline{1.21}$	$\underline{0.90}$	$\underline{0.62}$	$\underline{0.39}$	$\underline{0.20}$	$\underline{0.06}$
4.6	UNEXPLORED REGION					$\underline{0.96}$	$\underline{0.64}$	$\underline{0.33}$	$\underline{0.01}$	0.30	0.60
4.8						$\underline{0.68}$	$\underline{0.34}$	0.03	0.42	0.85	1.31
5.0						$\underline{0.37}$	0.00	0.43	0.92	1.46	2.06
5.2	$\underline{0.89}$	$\underline{0.88}$	$\underline{0.79}$	$\underline{0.62}$	$\underline{0.36}$	$\underline{0.03}$	0.39	0.89	1.47	2.13	2.87
5.4	$\underline{0.52}$	$\underline{0.55}$	$\underline{0.48}$	$\underline{0.30}$	$\underline{0.03}$	0.35	0.82	1.40	2.07	2.85	
5.6	$\underline{0.26}$	$\underline{0.29}$	$\underline{0.20}$	0.00	0.32	0.75	1.30	1.96			
5.8	$\underline{0.11}$	$\underline{0.09}$	0.04	0.30	0.69	1.19	1.82	2.58			

$C_p = 0.64$

[illegible]						$\underline{1.15}$	$\underline{0.97}$	$\underline{0.87}$	$\underline{0.84}$	$\underline{0.87}$	$\underline{0.98}$
[illegible]	[illegible] REGION					$\underline{0.84}$	$\underline{0.65}$	$\underline{0.51}$	$\underline{0.39}$	$\underline{0.31}$	$\underline{0.26}$
[illegible]						$\underline{0.53}$	$\underline{0.33}$	$\underline{0.13}$	0.07	0.27	0.47
[illegible]						$\underline{0.23}$	0.00	0.26	0.55	0.87	1.22
[illegible]	[illegible]	[illegible]	$\underline{0.48}$	$\underline{0.35}$	$\underline{0.17}$	0.06	0.34	0.67	1.05	1.48	1.97
[illegible]	[illegible]	[illegible]	$\underline{0.26}$	$\underline{0.13}$	0.07	0.34	0.68	1.09	1.56	2.11	
[illegible]	[illegible]	[illegible]	$\underline{0.11}$	0.05	0.29	0.61	1.02	1.52			
[illegible]	[illegible]	[illegible]	$\underline{0.04}$	0.18	0.48	0.88	1.38	1.96			

$C_p = 0.66$

4.4						$\underline{1.67}$	$\underline{1.47}$	$\underline{1.37}$	$\underline{1.37}$	$\underline{1.47}$	$\underline{1.67}$
4.6	UNEXPLORED REGION					$\underline{1.13}$	$\underline{0.93}$	$\underline{0.79}$	$\underline{0.71}$	$\underline{0.68}$	$\underline{0.72}$
4.8						$\underline{0.66}$	$\underline{0.44}$	$\underline{0.25}$	$\underline{0.08}$	0.06	0.18
5.0						$\underline{0.25}$	0.00	0.25	0.51	0.77	1.03
5.2	$\underline{1.02}$	$\underline{0.85}$	$\underline{0.65}$	$\underline{0.43}$	$\underline{0.18}$	0.09	0.39	0.71	1.06	1.44	1.83
5.4	$\underline{0.75}$	$\underline{0.62}$	$\underline{0.44}$	$\underline{0.21}$	0.06	0.37	0.73	1.13	1.57	2.06	
5.6	$\underline{0.68}$	$\underline{0.54}$	$\underline{0.35}$	$\underline{0.09}$	0.22	0.59	1.02	1.50			
5.8	$\underline{0.81}$	$\underline{0.63}$	$\underline{0.39}$	$\underline{0.08}$	0.30	0.74	1.25	1.83			

$C_p = 0.68$

L/B	$\frac{1}{2}\alpha_e°$ 5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
4.4						$\underline{2.75}$	$\underline{2.38}$	$\underline{2.13}$	$\underline{2.00}$	$\underline{1.99}$	2.10
4.6	UNEXPLORED REGION					$\underline{1.84}$	$\underline{1.47}$	$\underline{1.17}$	$\underline{0.96}$	$\underline{0.83}$	$\underline{0.78}$
4.8						$\underline{1.07}$	$\underline{0.67}$	$\underline{0.33}$	$\underline{0.03}$	0.22	0.42
5.0						$\underline{0.43}$	0.00	0.41	0.79	1.16	1.51
5.2	$\underline{2.24}$	$\underline{1.78}$	$\underline{1.32}$	$\underline{0.86}$	$\underline{0.39}$	0.08	0.55	1.02	1.50	1.98	2.47
5.4	$\underline{1.88}$	$\underline{1.46}$	$\underline{1.02}$	$\underline{0.55}$	$\underline{0.07}$	0.44	0.97	1.53	2.10	2.70	
5.6	$\underline{1.80}$	$\underline{1.37}$	$\underline{0.92}$	$\underline{0.42}$	0.11	0.67	1.27	1.91			
5.8	$\underline{1.98}$	$\underline{1.52}$	$\underline{1.02}$	$\underline{0.47}$	0.13	0.77	1.45	2.18			

TABLE 5—C_R — *Function Tables* *

$V/\sqrt{L} = 1.10$

* Underlined Figures are negative

Function F_1

[illegible]	C_p				
	0.60	0.62	0.64	0.66	0.68
[illegible]	16.77	16.47	16.56	17.05	17.93
[illegible]	17.08	16.84	16.79	16.94	17.28
[illegible]	17.41	17.23	17.10	17.03	17.01
[illegible]	17.75	17.63	17.48	17.31	17.12
[illegible]	18.11	18.05	17.95	17.80	17.61
[illegible]	18.49	18.49	18.49	18.49	18.49
[illegible]	18.88	18.94	19.10	19.37	19.74

Function F_2

L.C.B.% aft	C_p				
	0.60	0.62	0.64	0.66	0.68
0	$\underline{1.35}$	0.63	1.50	1.27	$\underline{0.08}$
1	$\underline{2.01}$	$\underline{0.42}$	0.75	1.50	1.82
2	$\underline{2.61}$	$\underline{1.34}$	0.00	1.42	2.92
3	$\underline{3.16}$	$\underline{2.15}$	$\underline{0.74}$	1.04	3.21
4	$\underline{3.67}$	$\underline{2.83}$	$\underline{1.48}$	0.36	2.71
5	$\underline{4.14}$	$\underline{3.39}$	$\underline{2.22}$	$\underline{0.62}$	1.41
6	$\underline{4.55}$	$\underline{3.83}$	$\underline{2.94}$	$\underline{1.90}$	$\underline{0.69}$

Function F'_3

$C_p = 0.60$

[illegible]	$\frac{1}{2}\alpha_e°$										
	[illegible]	[illegible]	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
[illegible]	[illegible] REGION					$\underline{2.44}$	$\underline{1.50}$	$\underline{0.84}$	$\underline{0.46}$	$\underline{0.34}$	$\underline{0.50}$
[illegible]						$\underline{1.97}$	$\underline{1.00}$	$\underline{0.09}$	0.75	1.53	2.24
[illegible]						$\underline{1.51}$	$\underline{0.50}$	0.63	1.87	3.23	4.70
[illegible]						$\underline{1.07}$	0.00	1.33	2.92	4.76	6.86
[illegible]	[illegible]	[illegible]	$\underline{1.87}$	$\underline{1.83}$	$\underline{1.43}$	$\underline{0.65}$	0.49	2.00	3.88	6.12	8.74
[illegible]	[illegible]	[illegible]	$\underline{1.25}$	$\underline{1.36}$	$\underline{1.03}$	$\underline{0.25}$	0.98	2.65	4.76	7.32	
[illegible]	[illegible]	[illegible]	$\underline{0.68}$	$\underline{1.03}$	$\underline{0.69}$	0.14	1.46	3.26			
[illegible]	[illegible]	[illegible]	$\underline{0.76}$	$\underline{0.83}$	$\underline{0.41}$	0.51	1.93	3.86			

$C_p = 0.62$

L/B	$\frac{1}{2}\alpha_e°$										
	5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
4.4	UNEXPLORED REGION					$\underline{2.44}$	$\underline{1.53}$	$\underline{0.79}$	$\underline{0.21}$	0.21	0.46
4.6						$\underline{1.97}$	$\underline{1.03}$	$\underline{0.05}$	0.99	2.07	3.20
4.8						$\underline{1.51}$	$\underline{0.52}$	0.69	2.12	3.78	5.67
5.0						$\underline{1.04}$	0.00	1.41	3.19	5.34	7.86
5.2	1.03	$\underline{0.25}$	$\underline{1.05}$	$\underline{1.37}$	$\underline{1.22}$	$\underline{0.58}$	0.53	2.13	4.20	6.75	9.78
5.4	2.25	0.66	$\underline{0.37}$	$\underline{0.84}$	$\underline{0.76}$	$\underline{0.12}$	1.08	2.83	5.14	8.00	
5.6	2.90	1.19	0.08	$\underline{0.43}$	$\underline{0.34}$	0.35	1.64	3.53			
5.8	3.00	1.34	0.29	$\underline{0.15}$	0.03	0.81	2.20	4.21			

$C_p = 0.64$

[illegible]	[illegible] REGION					$\underline{2.33}$	$\underline{1.61}$	$\underline{0.96}$	$\underline{0.38}$	0.13	0.58
[illegible]						$\underline{1.84}$	$\underline{1.08}$	$\underline{0.19}$	0.85	2.02	3.34
[illegible]						$\underline{1.35}$	$\underline{0.55}$	0.57	2.01	3.76	5.83
[illegible]						$\underline{0.86}$	0.00	1.32	3.10	5.34	8.05
[illegible]	[illegible]	[illegible]	0.28	$\underline{0.51}$	$\underline{0.73}$	$\underline{0.37}$	0.56	2.06	4.13	6.77	9.99
[illegible]	[illegible]	[illegible]	0.98	0.05	$\underline{0.24}$	0.12	1.13	2.78	5.09	8.05	
[illegible]	[illegible]	[illegible]	1.45	0.48	0.19	0.60	1.71	3.50			
[illegible]	[illegible]	[illegible]	1.69	0.78	0.58	1.09	2.29	4.21			

$C_p = 0.66$

4.4	UNEXPLORED REGION					$\underline{2.11}$	$\underline{1.73}$	$\underline{1.35}$	$\underline{0.96}$	$\underline{0.56}$	$\underline{0.16}$
4.6						$\underline{1.56}$	$\underline{1.15}$	$\underline{0.52}$	0.32	1.38	2.66
4.8						$\underline{1.03}$	$\underline{0.57}$	0.28	1.52	3.16	5.19
5.0						$\underline{0.51}$	0.00	1.05	2.64	4.76	7.43
5.2	6.77	4.11	2.11	0.75	0.04	$\underline{0.02}$	0.56	1.79	3.67	6.20	9.37
5.4	7.99	5.03	2.80	1.29	0.51	0.45	1.12	2.51	4.62	7.46	
5.6	8.64	5.56	3.24	1.69	0.92	0.91	1.66	3.19			
5.8	8.71	5.68	3.42	1.95	1.26	1.34	2.21	3.85			

$C_p = 0.68$

L/B	$\frac{1}{2}\alpha_e°$										
	5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
4.4	UNEXPLORED REGION					$\underline{1.77}$	$\underline{1.89}$	$\underline{1.96}$	$\underline{1.95}$	$\underline{1.89}$	$\underline{1.76}$
4.6						$\underline{1.13}$	$\underline{1.22}$	$\underline{1.04}$	$\underline{0.58}$	0.15	1.15
4.8						$\underline{0.54}$	$\underline{0.59}$	$\underline{0.18}$	0.67	1.98	3.74
5.0						$\underline{0.01}$	0.00	0.61	1.81	3.61	6.00
5.2	10.62	7.18	4.45	2.41	1.09	0.46	0.55	1.33	2.83	5.03	7.93
5.4	11.80	8.05	5.09	2.91	1.51	0.89	1.05	2.00	3.73	6.24	
5.6	12.36	8.49	5.44	3.22	1.83	1.26	1.52	2.60			
5.8	12.31	8.49	5.51	3.36	2.05	1.57	1.94	3.14			

TABLE 4—C_R — *Function Tables* *

$V/\sqrt{L} = 1.00$

* Underlined Figures are negative

Function F_1

B/H	C_p				
	0.60	0.62	[illegible]	0.66	0.68
2.0	12.87	13.74	14.02	13.71	12.80
2.1	13.40	13.92	13.95	13.51	12.59
2.2	13.89	14.14	14.02	13.54	12.70
2.3	14.33	14.40	14.23	13.81	13.16
2.4	14.73	14.71	14.58	14.32	13.95
2.5	15.07	15.07	15.07	15.07	15.07
2.6	15.36	15.47	15.70	16.06	16.53

Function F_2

L.C.B% aft	C_p				
	0.60	0.62	0.64	0.66	0.68
0	$\underline{0.32}$	$\underline{0.20}$	0.80	2.69	5.45
1	$\underline{0.85}$	$\underline{0.56}$	0.45	2.19	4.66
2	$\underline{1.37}$	$\underline{1.02}$	0.00	1.68	4.02
3	$\underline{1.88}$	$\underline{1.56}$	$\underline{0.55}$	1.14	3.51
4	$\underline{2.38}$	$\underline{2.18}$	$\underline{1.19}$	0.59	3.15
5	$\underline{2.86}$	$\underline{2.89}$	$\underline{1.93}$	0.01	2.94
6	$\underline{3.34}$	$\underline{3.69}$	$\underline{2.77}$	$\underline{0.59}$	2.87

Function F'_3

$C_p = 0.60$

[illegible]	$\frac{1}{2}\alpha_e{}^\circ$										
	[illegible]	[illegible]	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
[illegible]	UNEXPLORED REGION					$\underline{2.09}$	$\underline{1.21}$	$\underline{0.18}$	0.99	2.32	3.79
[illegible]						$\underline{1.92}$	$\underline{0.88}$	0.48	2.17	4.19	6.52
[illegible]						$\underline{1.62}$	$\underline{0.48}$	1.10	3.12	5.58	8.49
[illegible]						$\underline{1.17}$	0.00	1.67	3.84	6.52	9.69
[illegible]	[illegible]	[illegible]	$\underline{0.96}$	$\underline{1.34}$	$\underline{1.21}$	$\underline{0.58}$	0.55	2.19	4.34	6.98	10.13
[illegible]	[illegible]	[illegible]	$\underline{0.26}$	$\underline{0.58}$	$\underline{0.44}$	0.15	1.18	2.67	4.60	6.98	
[illegible]	[illegible]	[illegible]	0.43	0.29	0.48	1.02	1.89	3.09			
[illegible]	[illegible]	[illegible]	1.11	1.25	1.56	2.03	2.67	3.47			

$C_p = 0.62$

L/B	$\frac{1}{2}\alpha_e{}^\circ$										
	5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
4.4	UNEXPLORED REGION					$\underline{1.48}$	$\underline{1.06}$	$\underline{0.55}$	0.06	0.75	1.54
4.6						$\underline{1.33}$	$\underline{0.75}$	0.10	1.22	2.60	4.25
4.8						$\underline{1.08}$	$\underline{0.40}$	0.67	2.12	3.95	6.17
5.0						$\underline{0.71}$	0.00	1.16	2.76	4.80	7.29
5.2	3.07	1.51	0.41	$\underline{0.26}$	$\underline{0.47}$	$\underline{0.24}$	0.44	1.56	3.13	5.15	7.61
5.4	3.32	1.94	0.96	0.36	0.15	0.34	0.92	1.89	3.25	5.00	
5.6	3.15	2.17	1.46	1.04	0.89	1.03	1.44	2.13			
5.8	2.55	2.19	1.93	1.79	1.75	1.82	2.00	2.29			

$C_p = 0.64$

[illegible]	UNEXPLORED REGION					$\underline{1.47}$	$\underline{1.33}$	$\underline{1.16}$	$\underline{0.95}$	$\underline{0.71}$	$\underline{0.44}$
[illegible]						$\underline{1.17}$	$\underline{0.86}$	$\underline{0.35}$	0.37	1.29	2.42
[illegible]						$\underline{0.82}$	$\underline{0.42}$	0.31	1.36	2.73	4.43
[illegible]						$\underline{0.43}$	0.00	0.82	2.02	3.61	5.58
[illegible]	[illegible]	2.27	1.12	0.36	$\underline{0.01}$	0.00	0.40	1.18	2.35	3.91	5.86
[illegible]	[illegible]	2.60	1.57	0.87	0.50	0.47	0.77	1.40	2.36	3.65	
[illegible]	[illegible]	2.65	1.90	1.37	1.07	0.98	1.11	1.47			
[illegible]	[illegible]	2.42	2.13	1.88	1.68	1.53	1.44	1.39			

$C_p = 0.66$

4.4	UNEXPLORED REGION					$\underline{2.07}$	$\underline{2.03}$	$\underline{2.02}$	$\underline{2.04}$	$\underline{2.08}$	$\underline{2.16}$
4.6						$\underline{1.43}$	$\underline{1.23}$	$\underline{0.88}$	$\underline{0.38}$	0.26	1.04
4.8						$\underline{0.85}$	$\underline{0.55}$	0.01	0.84	1.93	3.28
5.0						$\underline{0.33}$	0.00	0.65	1.63	2.93	4.56
5.2	3.53	2.20	1.19	0.51	0.16	0.13	0.43	1.05	2.00	3.27	4.87
5.4	3.61	2.45	1.57	0.95	0.61	0.53	0.73	1.20	1.94	2.95	
5.6	3.10	2.34	1.73	1.29	1.01	0.88	0.91	1.10			
5.8	1.99	1.85	1.69	1.53	1.35	1.16	0.96	0.75			

$C_p = 0.68$

L/B	$\frac{1}{2}\alpha_e{}^\circ$										
	5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°
4.4						$\underline{3.27}$	$\underline{3.15}$	$\underline{3.13}$	$\underline{3.19}$	$\underline{3.35}$	$\underline{3.61}$
4.6						$\underline{2.12}$	$\underline{1.84}$	$\underline{1.48}$	$\underline{1.03}$	$\underline{0.51}$	0.10
4.8						$\underline{1.17}$	$\underline{0.79}$	$\underline{0.22}$	0.56	1.54	2.72
5.0						$\underline{0.41}$	0.00	0.67	1.60	2.79	4.24
5.2	2.23	1.29	0.61	0.20	0.05	0.16	0.53	1.17	2.07	3.23	4.66
5.4	2.28	1.52	0.96	0.61	0.47	0.54	0.81	1.29	1.98	2.88	
5.6	1.61	1.24	0.97	0.79	0.71	0.72	0.83	1.03			
5.8	0.20	0.45	0.63	0.73	0.76	0.71	0.59	0.39			

TABLE 7—*Non-dimensional Offsets of Optimized Trawler Form,* $C_p = 0{\cdot}606$

Waterlines % mean mld. draught												Bulwark Offsets	
5%	10%	20%	40%	60%	80%	100%	120%	140%	160%	180%	200%	Height % draught	width % beam
-	-	-	-	-	-	23.8	50.3	71.9	87.5	95.6	-	183.2	96.4
-	-	-	-	-	0.6	33.9	57.9	76.9	90.7	97.7	-	180.7	97.7
1.5	2.2	3.4	4.9	8.1	18.8	42.8	65.0	81.5	93.2	-	-	178.1	98.4
2.8	4.3	6.7	10.8	17.0	29.2	51.3	71.0	86.4	95.3	-	-	175.4	98.5
4.3	7.1	10.9	17.4	26.0	39.5	59.1	76.3	88.8	96.6	-	-	172.8	98.9
8.8	13.5	20.2	31.6	43.6	56.9	71.7	84.9	93.5	98.4	-	-	167.8	99.4
13.1	20.6	31.3	46.2	59.4	71.5	82.1	90.5	96.3	99.4	-	-	163.2	99.6
18.0	28.7	42.7	60.1	72.6	82.4	89.8	95.1	98.3	-	-	-	159.2	99.9
21.8	36.3	53.7	72.2	83.2	90.6	95.2	97.9	99.3	-	-	-	155.6	100.0
24.9	46.9	70.5	88.8	96.1	99.0	100.0	100.0	100.0	-	-	-	151.4	100.0
24.9	49.3	74.2	91.3	97.7	99.6	100.0	100.0	100.0	-	-	-	151.5	100.0
24.9	45.4	66.2	82.3	89.3	92.9	95.4	97.3	98.9	-	-	-	154.6	99.9
22.9	36.3	50.0	63.1	70.1	75.4	80.5	85.7	91.2	97.5	-	-	161.5	98.3
19.2	28.6	39.7	51.1	57.9	63.5	69.6	76.4	84.1	93.1	-	-	166.9	96.9
14.0	20.9	29.4	38.8	44.8	50.4	57.0	64.9	74.3	85.4	-	-	173.2	93.9
8.8	14.0	20.1	26.9	31.3	36.3	43.0	51.5	61.9	74.4	88.6	-	180.2	89.2
4.6	7.9	12.1	16.2	18.8	22.4	28.4	36.8	47.2	60.0	74.6	-	187.3	80.7
3.2	5.3	8.6	11.6	13.5	16.1	21.1	28.7	38.8	51.5	65.9	-	191.0	74.9
2.0	3.3	5.2	7.3	8.7	10.8	14.5	20.8	30.0	42.1	56.1	-	194.8	67.9
0.8	1.2	2.0	3.3	4.4	5.8	8.2	12.8	20.6	31.7	44.8	-	198.9	59.3
-	-	-	-	-	-	2.5	5.2	11.0	20.2	32.3	46.6	203.0	49.2

TABLE 6—*Non-dimensional Offsets of Optimized Trawler Form.* $C_p = 0{\cdot}582$

Station	5%	10%	20%	40%	60%	80%	100%	120%	140%	160%	180%	200%	Bulwark Offsets	
	Waterlines % mean mld. draught												Height %draught	width % beam
[illegible]	-	-	-	-	-	-	11.0	41.2	61.7	75.5	85.4	-	193.2 21	88.4
[illegible]	2.0	2.0	2.0	2.1	2.8	4.7	23.2	52.0	70.7	82.6	89.8	-	189.7 20	92.1
[illegible]	2.4	2.9	3.7	6.0	9.1	15.3	35.1	60.9	78.3	88.0	93.8	-	186.1 19	94.6
[illegible]	3.1	4.2	6.1	10.4	16.2	26.3	45.5	68.7	83.3	91.3	95.6	-	183.1 18	95.9
[illegible]	3.9	5.8	9.2	16.2	24.1	36.5	55.5	75.1	87.6	93.9	96.9	-	180.1 17	96.8
[illegible]	6.7	10.7	17.0	28.3	39.7	54.2	71.0	84.8	93.4	97.6	-	-	174.4 16	98.8
[illegible]	9.8	16.5	26.9	42.4	54.9	69.2	83.0	91.9	97.0	99.3	-	-	169.6 15	99.7
[illegible]	13.8	23.1	37.0	56.5	69.2	80.8	90.3	96.1	99.0	99.7	-	-	165.1 14	100.0
[illegible]	18.5	30.6	47.6	69.5	81.7	89.7	95.3	98.5	100.0	100.0	-	-	161.3 13	100.0
[illegible]	21.9	41.5	65.9	86.5	95.2	98.9	100.0	100.0	100.0	-	-	-	156.7 12	100.0
[illegible]	21.9	41.5	70.4	90.7	97.5	99.8	100.0	100.0	100.0	-	-	-	155.9 11	100.0
[illegible]	21.9	40.9	59.2	76.4	84.3	88.9	91.9	94.6	97.0	-	-	-	159.3 10	100.0
[illegible]	20.1	29.4	41.6	55.5	63.3	69.2	74.9	81.1	88.2	96.7	-	-	167.4 9	100.0
[illegible]	16.4	23.3	32.7	44.1	51.2	57.2	63.3	70.8	80.0	91.2	-	-	173.4 8	99.1
[illegible]	10.7	16.1	2[illegible].7	33.1	38.8	44.2	50.6	59.1	69.8	82.7	97.0	-	180.3 7	97.0
[illegible]	6.9	10.5	15.7	22.4	26.9	31.6	37.8	46.3	57.3	71.1	85.8	-	189.0 6	91.9
[illegible]	4.2	5.9	8.6	12.7	16.1	20.1	25.2	32.7	42.9	55.5	70.1	-	198.2 5	83.3
[illegible]	2.4	3.6	5.7	8.7	11.2	14.3	19.0	25.7	34.6	46.3	60.5	75.2	203.0 4	77.2
[illegible]	0.9	1.7	3.0	4.8	6.7	9.2	13.1	18.8	26.7	36.8	49.7	64.1	208.0 3	69.2
[illegible]	-	-	0.6	1.8	2.9	4.7	7.5	11.8	18.3	26.9	37.7	50.7	213.3 2	59.4
[illegible]	-	-	-	-	-	0.6	2.3	5.1	9.5	16.1	25.2	35.9	218.3 1	46.6

TABLE 9—*Non-dimensional Offsets of Optimized Trawler Form.* $C_p = 0{\cdot}649$

[illegible]	5%	10%	20%	40%	60%	80%	100%	120%	140%	160%	180%	200%	Bulwark Offsets Height % Draught	Width % Beam
[illegible]	-	-	-	-	-	14.6	41.2	60.4	75.6	87.7	97.8	-	182.5	98.8
[illegible]	-	-	-	-	-	26.3	50.5	67.7	80.8	91.2	-	-	179.7	99.4
[illegible]	0.8	0.9	1.3	3.7	13.3	38.1	58.9	74.3	85.4	93.8	-	-	177.2	99.4
[illegible]	1.1	1.8	3.6	10.2	26.1	49.4	66.9	79.9	89.1	95.7	-	-	174.7	99.5
[illegible]	1.9	3.4	7.0	18.5	39.0	59.1	73.8	84.7	92.1	97.2	-	-	172.3	99.6
[illegible]	4.7	8.8	17.3	38.4	59.2	74.2	84.9	92.2	96.7	99.0	-	-	168.0	99.8
[illegible]	8.8	17.1	32.2	58.0	74.6	85.3	92.1	96.3	98.9	100.0	-	-	163.5	99.9
[illegible]	15.8	29.8	49.6	73.3	85.6	92.5	96.3	98.4	99.5	-	-	-	159.8	100.0
[illegible]	26.5	44.4	65.5	84.3	92.5	96.2	98.1	99.1	99.7	-	-	-	156.6	100.0
[illegible]	33.6	62.2	82.3	94.6	98.7	100.0	100.0	100.0	100.0	-	-	-	152.7	100.0
[illegible]	33.6	64.3	84.3	95.6	99.2	100.0	100.0	100.0	100.0	-	-	-	152.2	100.0
[illegible]	33.6	59.3	75.8	86.8	92.1	95.6	98.0	99.6	100.0	-	-	-	154.9	100.0
[illegible]	32.5	45.7	56.4	67.1	75.1	82.4	88.7	93.7	97.2	99.5	-	-	160.0	99.5
[illegible]	28.1	36.3	45.0	54.9	63.3	71.5	78.8	85.8	91.6	96.9	-	-	164.1	97.7
[illegible]	20.0	26.5	33.4	41.8	49.6	57.8	66.2	75.0	83.1	90.8	-	-	169.2	94.2
[illegible]	11.8	16.8	22.1	28.5	34.9	42.2	51.5	60.9	70.7	80.6	-	-	175.3	87.5
[illegible]	6.3	9.1	12.0	16.1	21.0	27.3	35.6	45.3	55.3	65.9	76.7	-	181.9	78.1
[illegible]	4.0	6.0	8.0	10.5	14.1	19.9	27.9	36.8	46.1	56.2	67.1	-	185.4	70.8
[illegible]	2.3	3.2	4.3	6.1	8.7	13.0	19.6	27.5	36.5	46.1	57.0	-	189.2	62.7
[illegible]	0.8	1.1	1.6	2.3	3.8	6.5	11.2	17.7	25.4	34.7	45.0	-	193.9	52.8
[illegible]	-	-	-	-	-	-	2.9	7.8	14.2	22.5	32.1	-	197.1	41.9

TABLE 8—*Non-dimensional Offsets of Optimized Trawler Form.* $C_p = 0{\cdot}625$ Model 2

[illegible]	5%	10%	20%	40%	60%	80%	100%	120%	140%	160%	180%	200%	Bulwark Offsets	
													Height %Draught	Width % Beam
[illegible]	–	–	–	–	–	–	28.5	50.7	67.1	81.1	94.0	–	185.7	97.9
[illegible]	–	–	–	–	–	7.4	38.6	59.2	74.3	86.4	97.1	–	183.2	98.7
[illegible]	0.9	1.3	1.8	4.1	9.1	23.9	46.9	66.3	80.1	90.2	98.6	–	180.7	98.8
[illegible]	1.7	2.8	5.1	10.4	20.0	35.2	54.6	72.9	84.9	93.1	–	–	178.0	98.9
[illegible]	2.9	4.5	8.8	17.1	29.3	45.1	62.5	77.7	88.3	94.9	–	–	175.4	99.1
[illegible]	6.2	10.2	17.8	32.8	47.5	62.2	75.3	85.6	92.5	97.3	–	–	170.1	99.2
[illegible]	11.4	18.7	30.1	49.2	64.0	75.9	85.4	91.9	95.9	98.8	–	–	165.3	99.4
[illegible]	18.3	29.8	45.1	65.1	77.4	86.2	92.3	96.1	98.1	99.2	–	–	161.1	99.5
[illegible]	26.5	41.3	59.5	77.4	86.9	93.2	96.9	98.9	99.5	–	–	–	157.7	99.7
[illegible]	33.4	59.4	78.8	92.8	97.4	99.2	100.0	100.0	100.0	–	–	–	152.4	100.0
[illegible]	33.4	63.3	83.6	96.4	99.5	100.0	100.0	100.0	100.0	–	–	–	151.3	100.0
[illegible]	33.4	58.0	75.6	88.6	94.0	96.6	98.1	99.3	100.0	–	–	–	154.5	100.0
[illegible]	28.5	41.5	55.7	69.3	77.5	83.2	87.8	92.3	95.8	98.8	–	–	161.0	99.3
[illegible]	22.8	32.4	44.6	57.2	65.2	72.0	78.1	84.4	90.2	95.7	–	–	165.3	97.4
[illegible]	15.6	23.4	32.5	42.6	50.8	57.7	64.9	72.7	80.7	89.2	–	–	170.0	93.5
[illegible]	10.1	15.1	22.0	30.6	35.8	42.2	49.4	57.8	67.7	78.3	– 6	–	175.2	86.9
[illegible]	4.9	8.4	13.2	17.8	21.7	26.8	33.2	41.7	51.9	63.5	75.4	–	180.7	76.5
[illegible]	3.4	5.5	8.7	12.5	15.7	19.7	25.2	32.9	42.8	54.3	66.3	–	183.6	69.4
[illegible]	2.0	3.2	[illegible]	8.1	10.2	12.7	16.9	23.8	32.9	[illegible]	56.0	–	186.7	60.3
[illegible]	0.9	1.7	3.1	4.6	5.1	6.5	9.5	14.8	22.2	31.6	43.3	–	190.0	49.5
[illegible]	–	–	–	–	–	–	2.3	5.3	10.6	18.7	29.3	–	193.1	37.0

Fig. 1—N.P.L. Trawler Data for Conventional Forms $V/\sqrt{L} = 0 \cdot 80$ $(F_n = 0 \cdot 239)$

TABLE 10

Parameter	*Maximum Variation in Parameter*	*Maximum corresponding Change in q.p.c.*
b.a.r.	0·45 – 0·70	−0·037
P_m/D	0·70 —1·10	+0·009
t/D	0·030—0·070	−0·105
V/Dn	0·60 —1·00	+0·091
t'/l	5—25	+0·057
$a/D\%$	5—25	+0·032
$b/D\%$	5—35	−0·044
$c/D\%$	10—35	+0·011
$\frac{1}{2}\alpha^{\circ}_{rs}$	20—45	−0·039
α°_{Bs}	15—27	−0·009

TABLE 11

	LBP(ft.)	*B (ft.)*	*d (ft.)*	*Trim/Stern*	*Displacement mld (ton)*	*Propeller Diameter (ft.)*	*Scale of Model*	*Model BP length (ft.)*
Model No. 1	180·0	34·62	15·74	1/30 LBP	1486·2	8·400	1/12	15·0
Model No. 2	134.4	26·294	11·92	1/30 LBP	682·3	7·287	1/9·25	14·5
Model No. 3	112·0	25·45	11·57	1/30 LBP	554·5	6·900	1/8	14·0

Fig. 3—N.P.L. Trawler Data for Conventional Forms Design Speed (Service) = $V/\sqrt{L} = 1{\cdot}00$ ($F_n = 0{\cdot}299$)

Fig. 2—N.P.L. Trawler Data for Conventional Forms $V/L = 0{\cdot}90$ $(F_n = 0{\cdot}269)$

Fig. 5—Model No. 1

Fig. 6—Model No. 2


+++ RESULTS UP TO 1960
◆◆◆ FORMS DERIVED FROM STATISTICAL ANALYSIS
NOTE :-
ORDINATES ARE DIRECTLY PROPORTIONAL TO ESTIMATED SHIP RESISTANCE AT CONSTANT DISPLACEMENT
BEST MODERN PRACTICE 1958
MINIMUM LINE AT 1960
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400
DISPLACEMENT OF 200 FT BP TRAWLER (TONS)

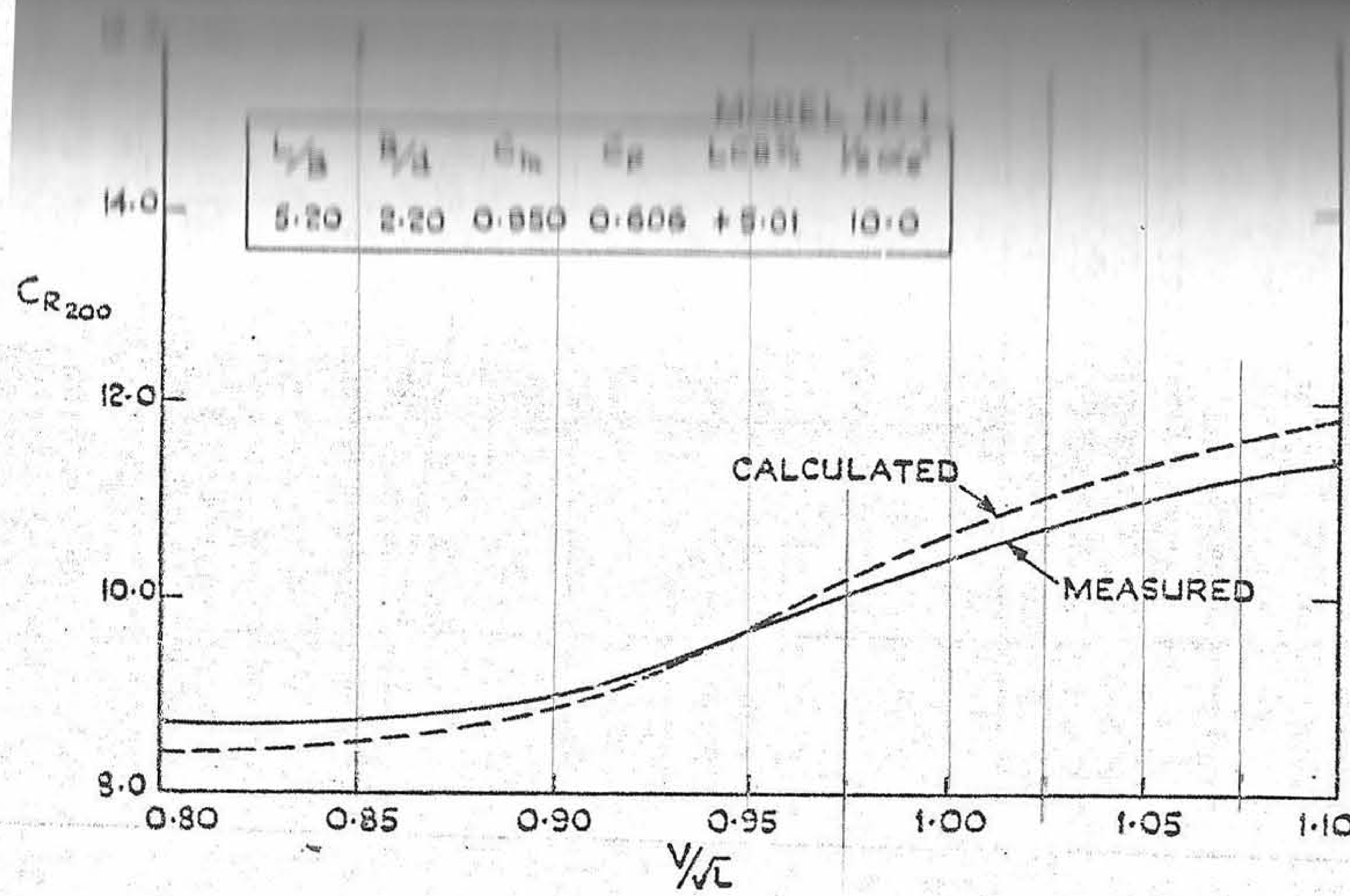


Fig. 9—Comparison of Measured and Calculated Performances of Optimized Forms

$\frac{200 R}{\Delta V^2}$

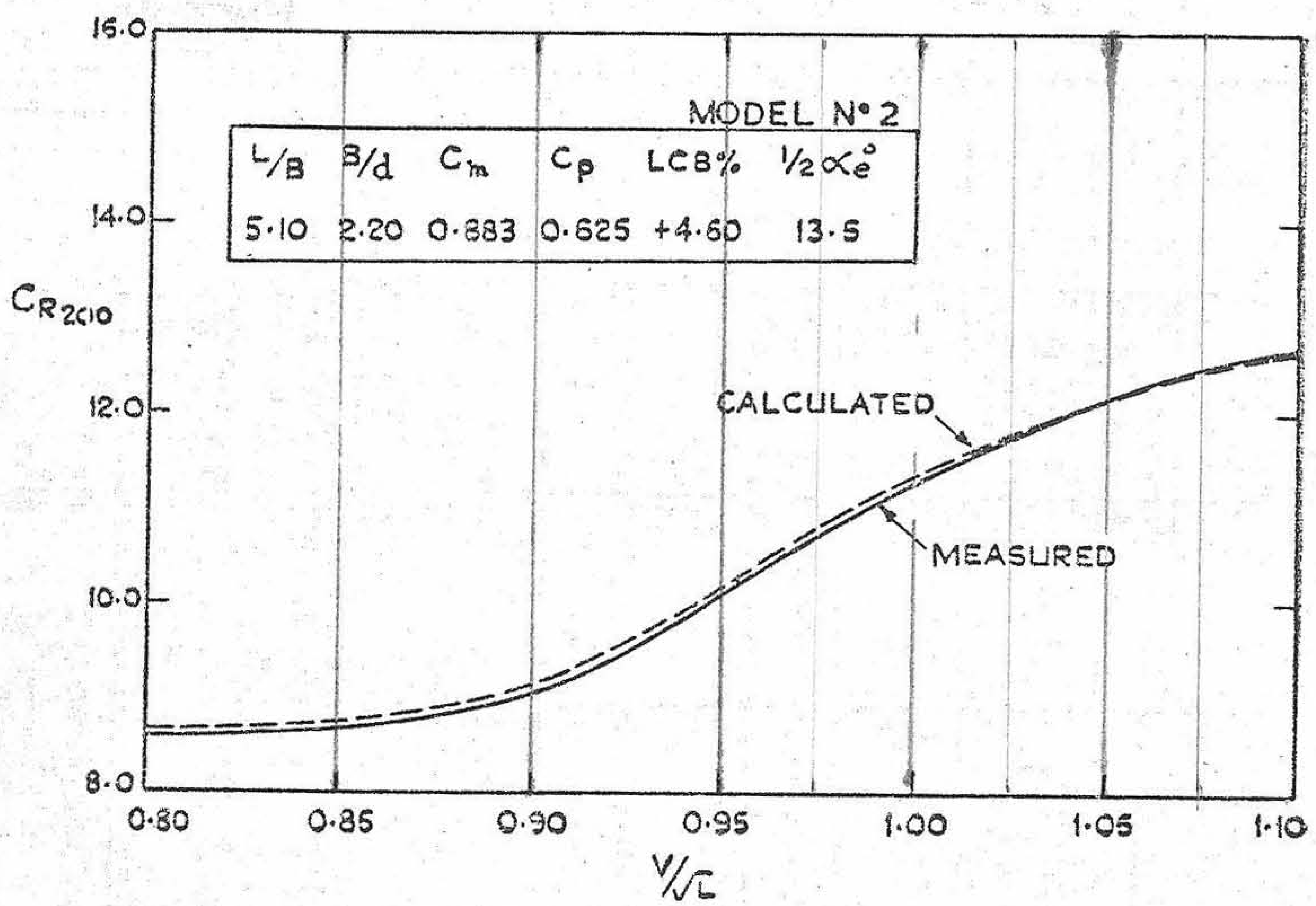
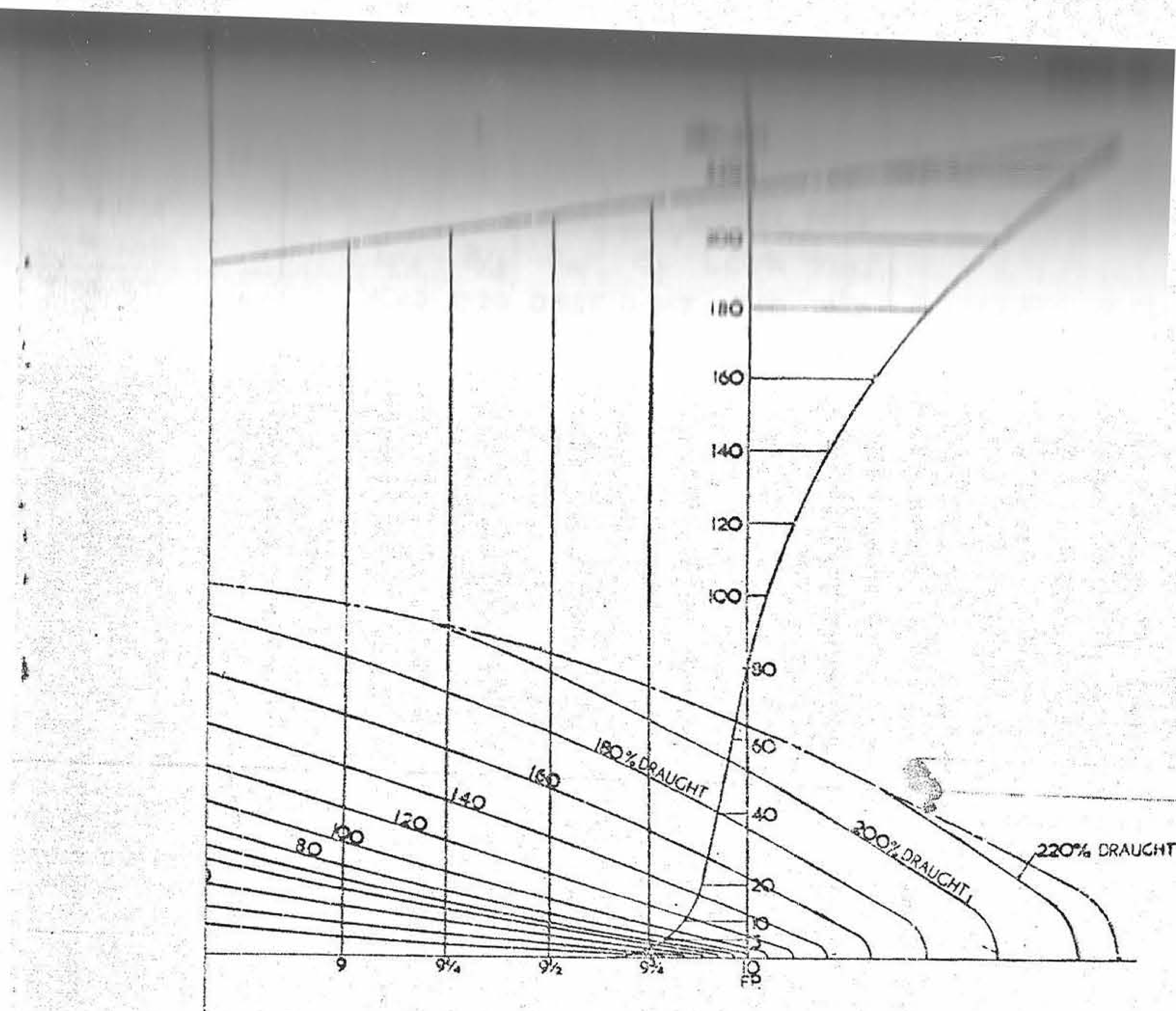


Fig. 10—Comparison of Measured and Calculated Performances of Optimized Forms



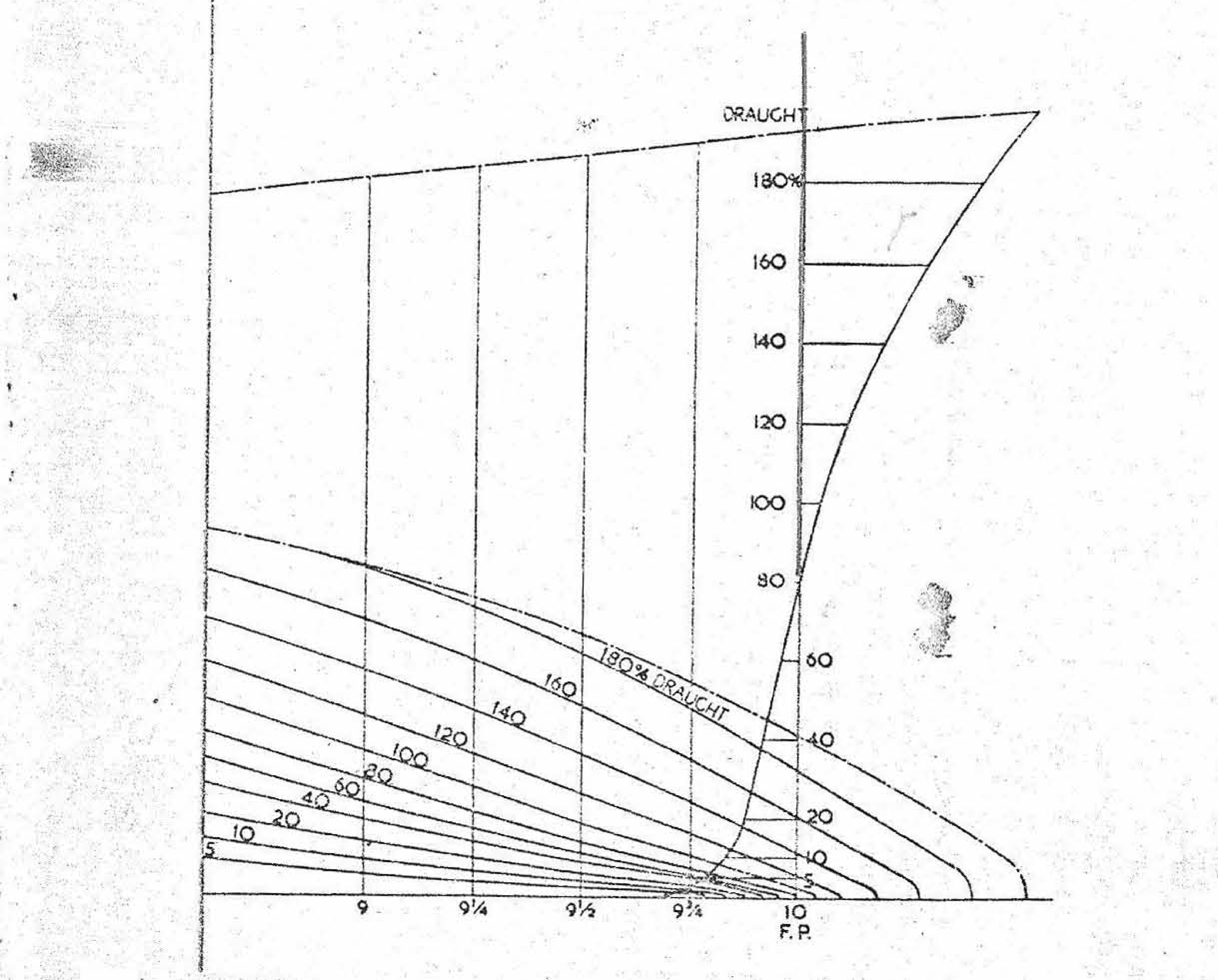


Fig. 7—Model No. 3

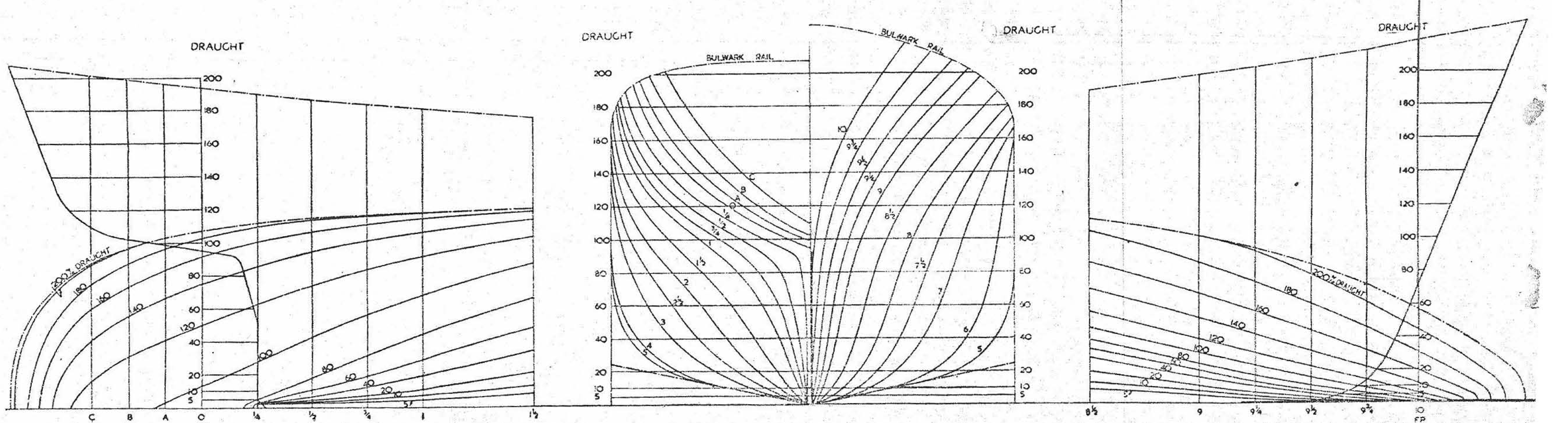


Fig. 8—Model No. 4

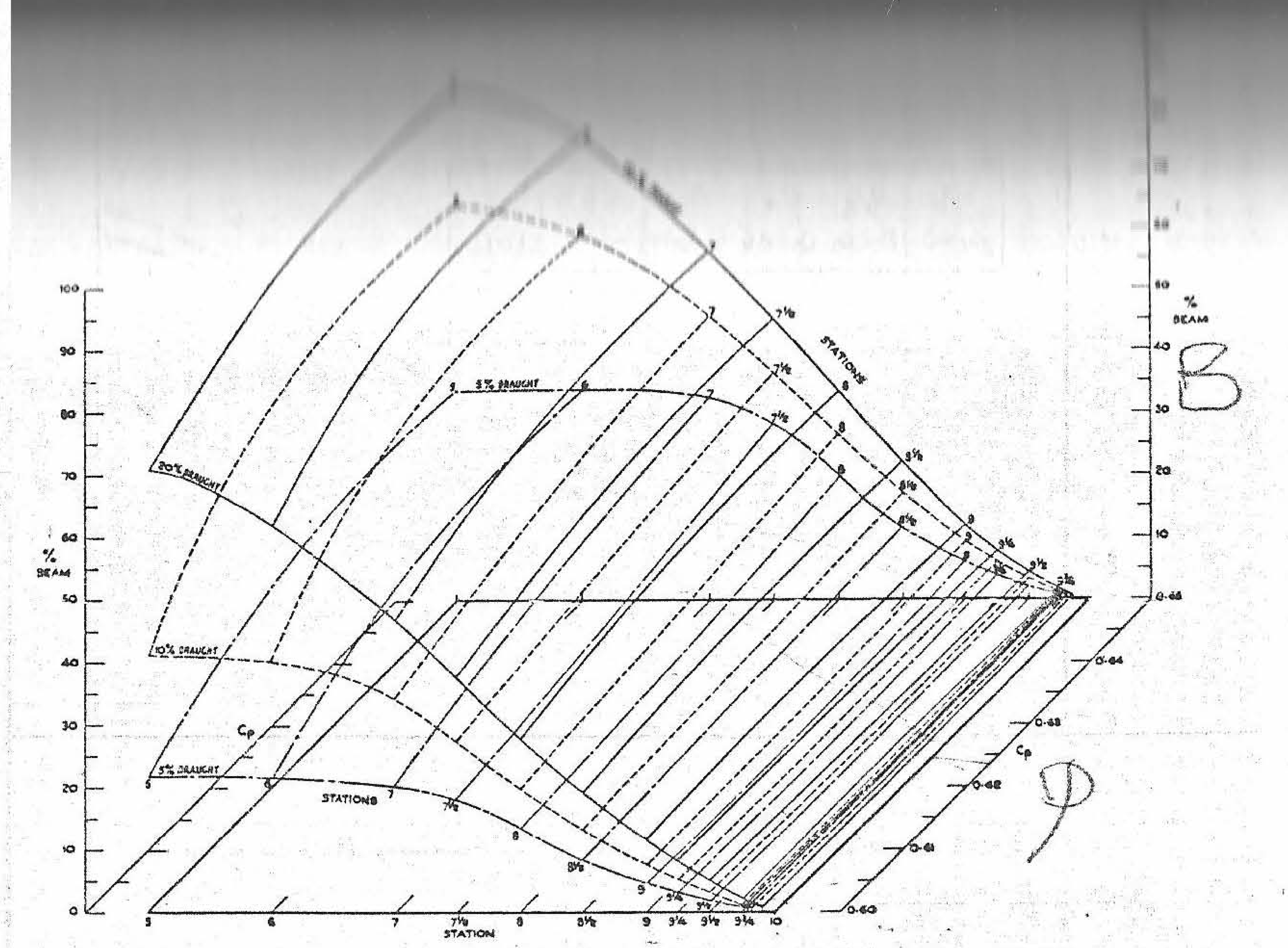


Fig. 13—Non-dimensional Offsets of Optimized Forms (0 – 20% Mean Moulded Draught) — Forebody —

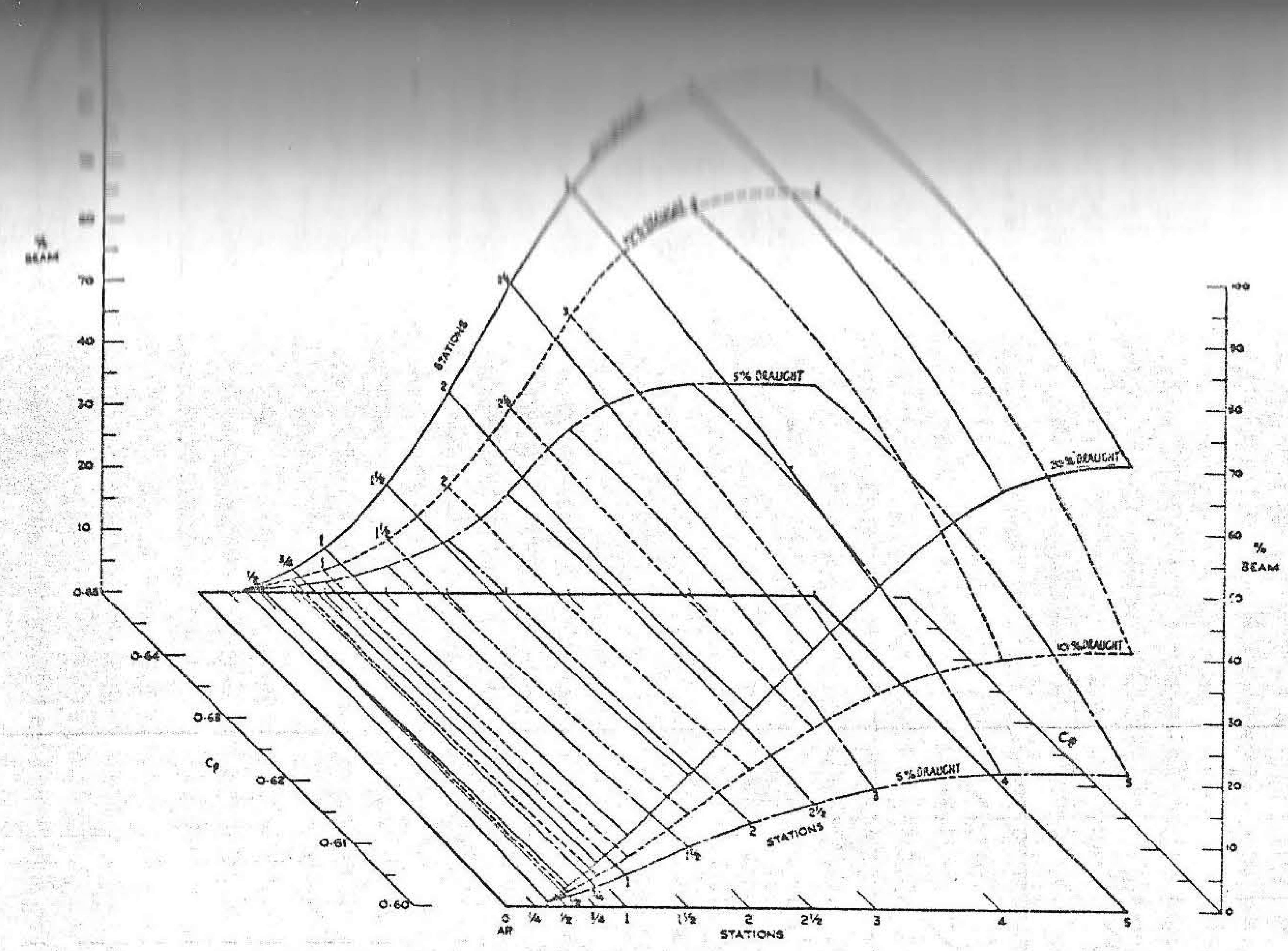


Fig. 15—Non-dimensional Offsets of Optimized Forms (0 – 20% Mean Moulded Draught) — Afterbody —

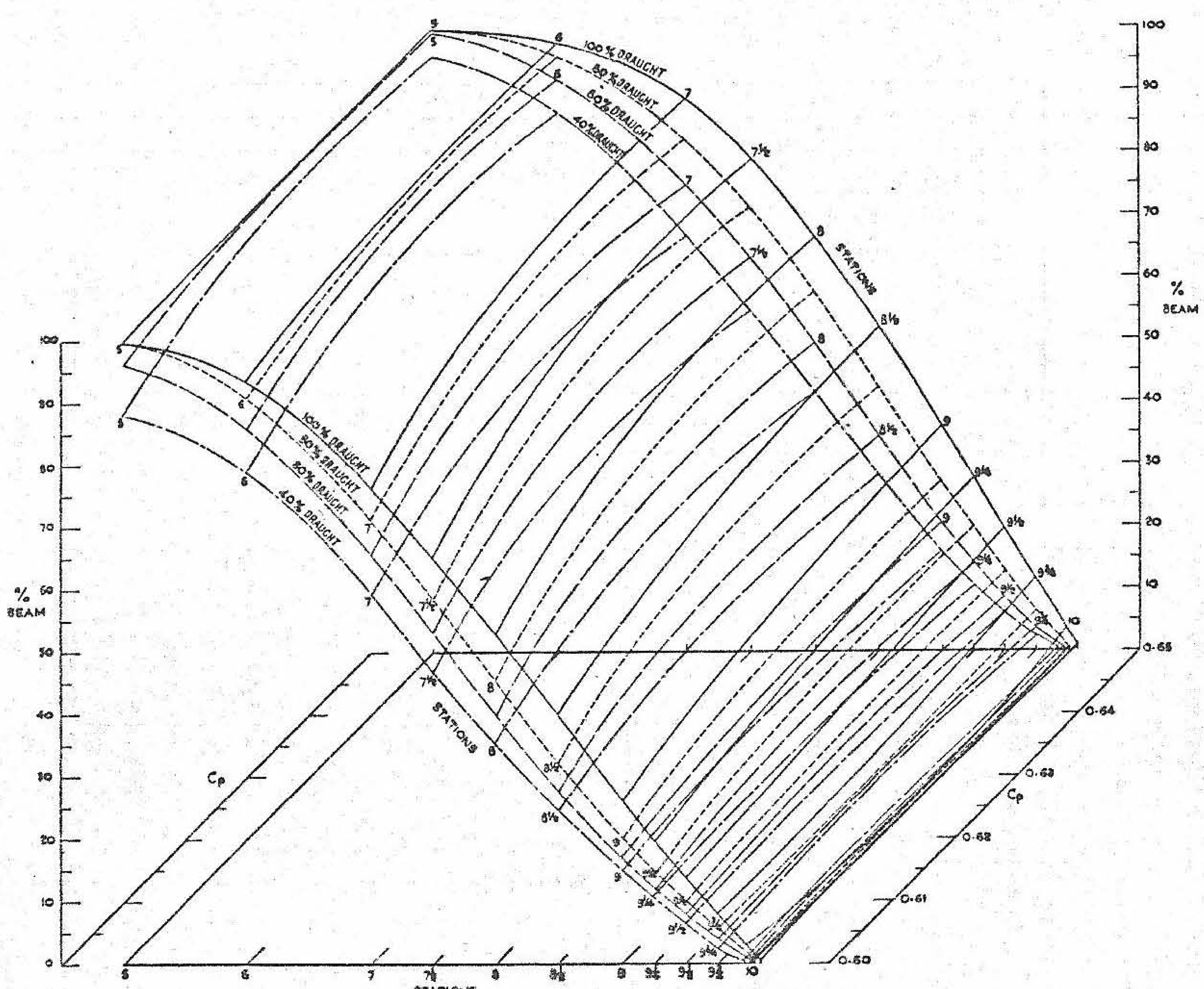


Fig. 14—Non-dimensional Offsets of Optimized Forms (40 – 100% Mean Moulded Draught) — Forebody —

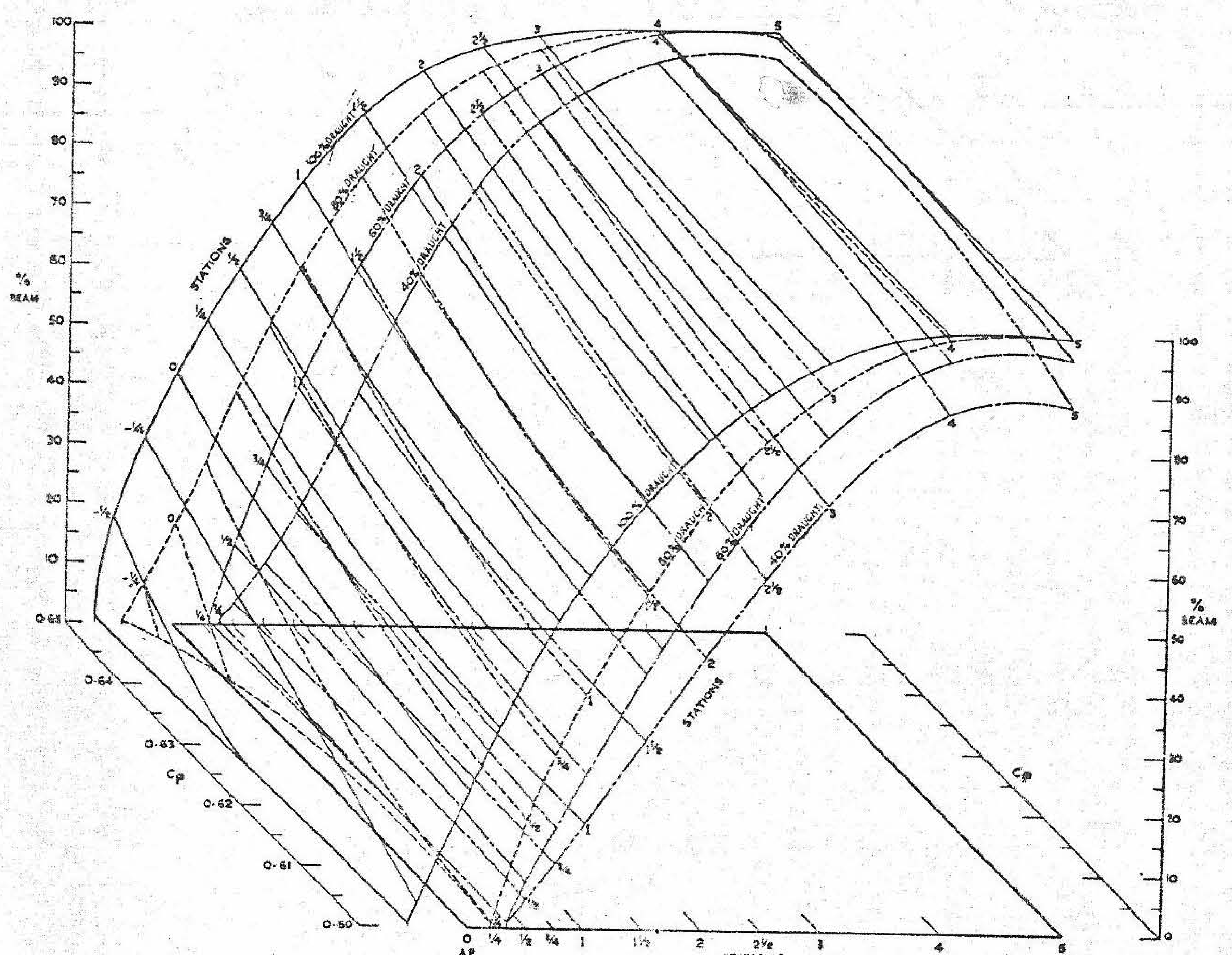


Fig. 16—Non-dimensional Offsets of Optimized Forms (40 – 100% Mean Moulded Draught) — Afterbody —

Lpp	180	134,1	112
Bwl	34,62	26,29	25,45
Twl	15,74	11,75	11,57
Δ	14862	682,3	554,5
Lcb	+5,01	+4,60	+5,60
Cx	0,850	0,883	0,885
Cwp	—	—	—
V	10	13,50	17
Cb	0,515	0,552	0,574

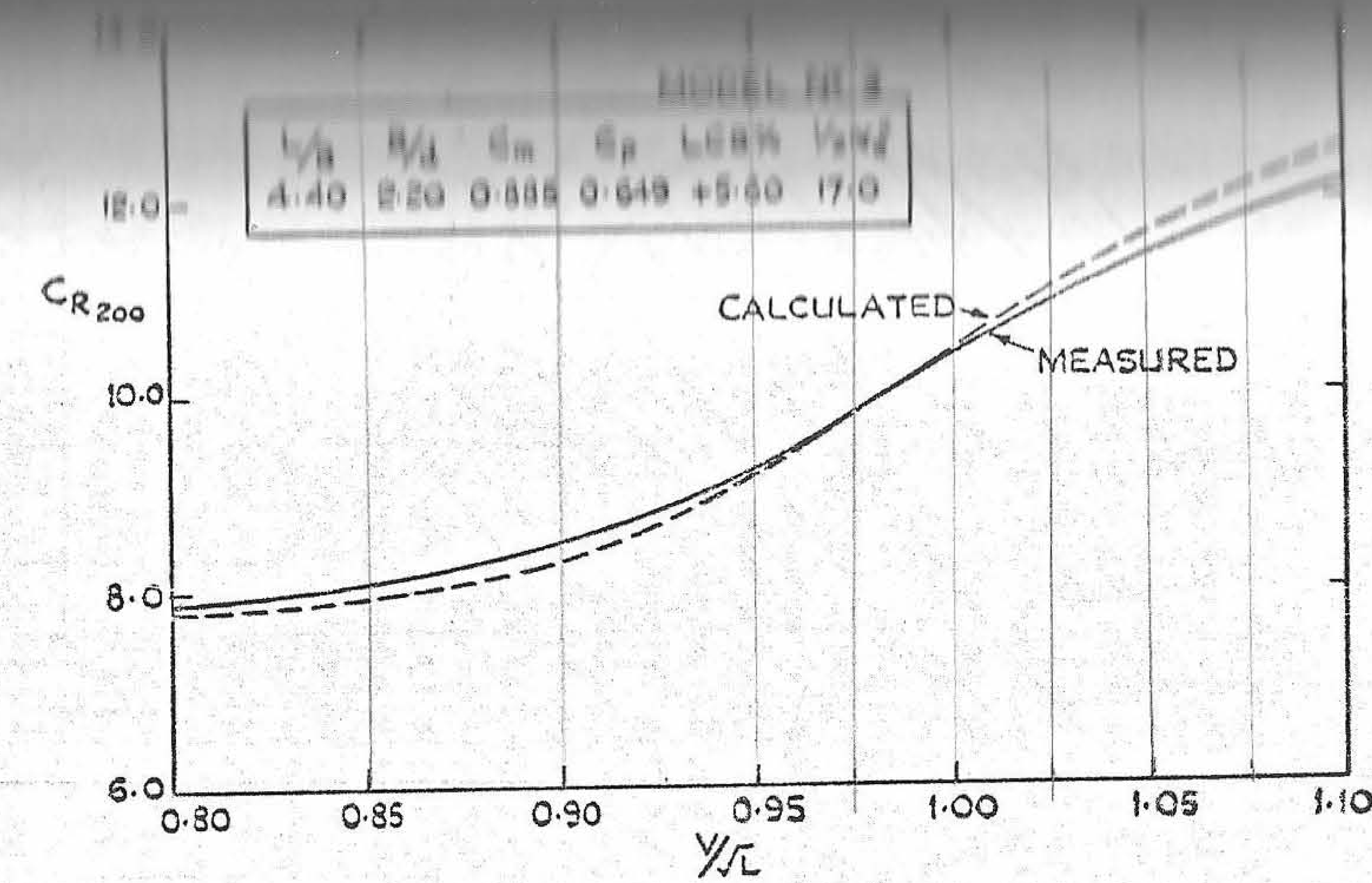


Fig. 11—Comparison of Measured and Calculated Performances of Optimized Forms

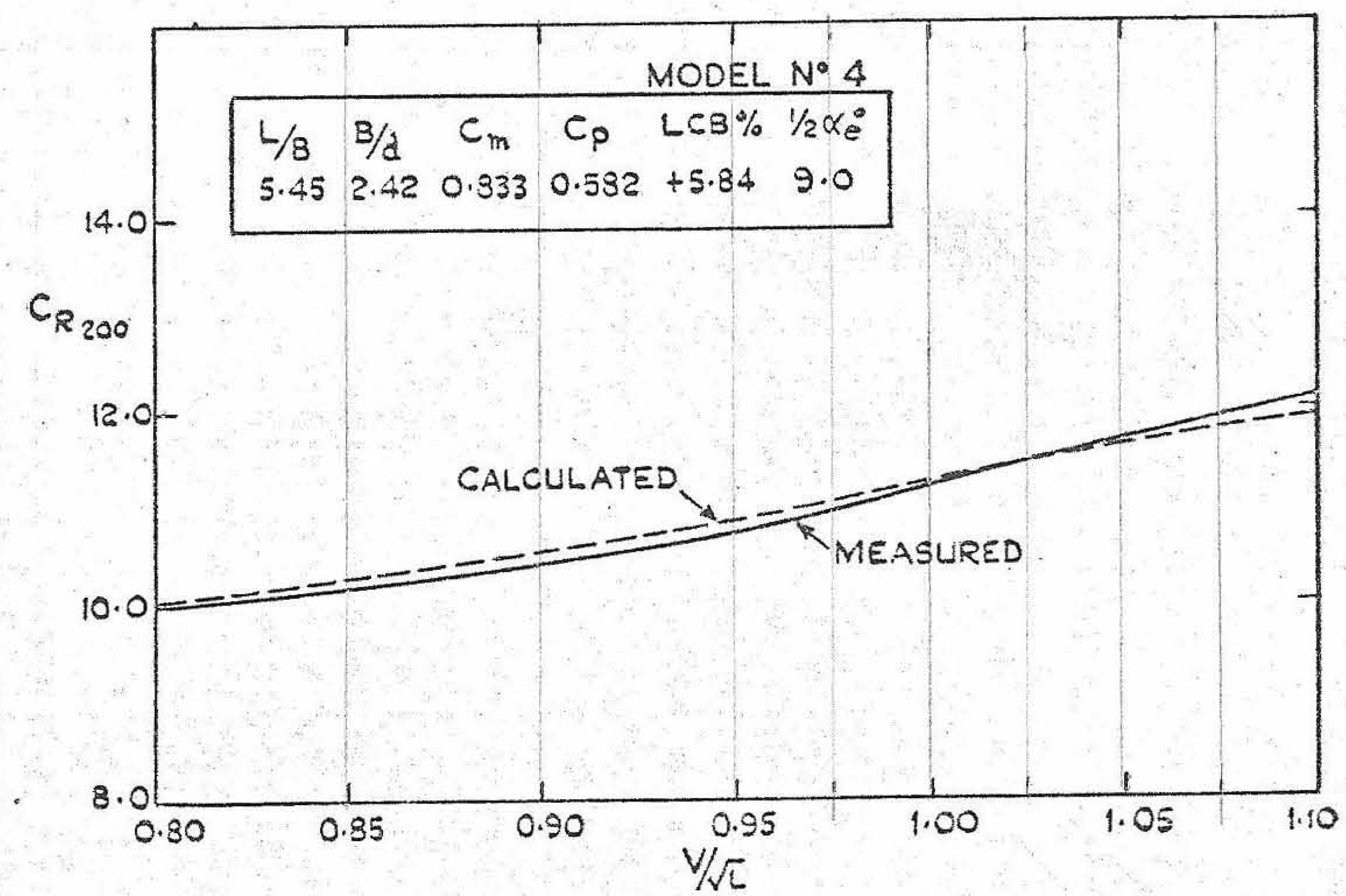


Fig. 12—Comparison of Measured and Calculated Performances of Optimized Forms

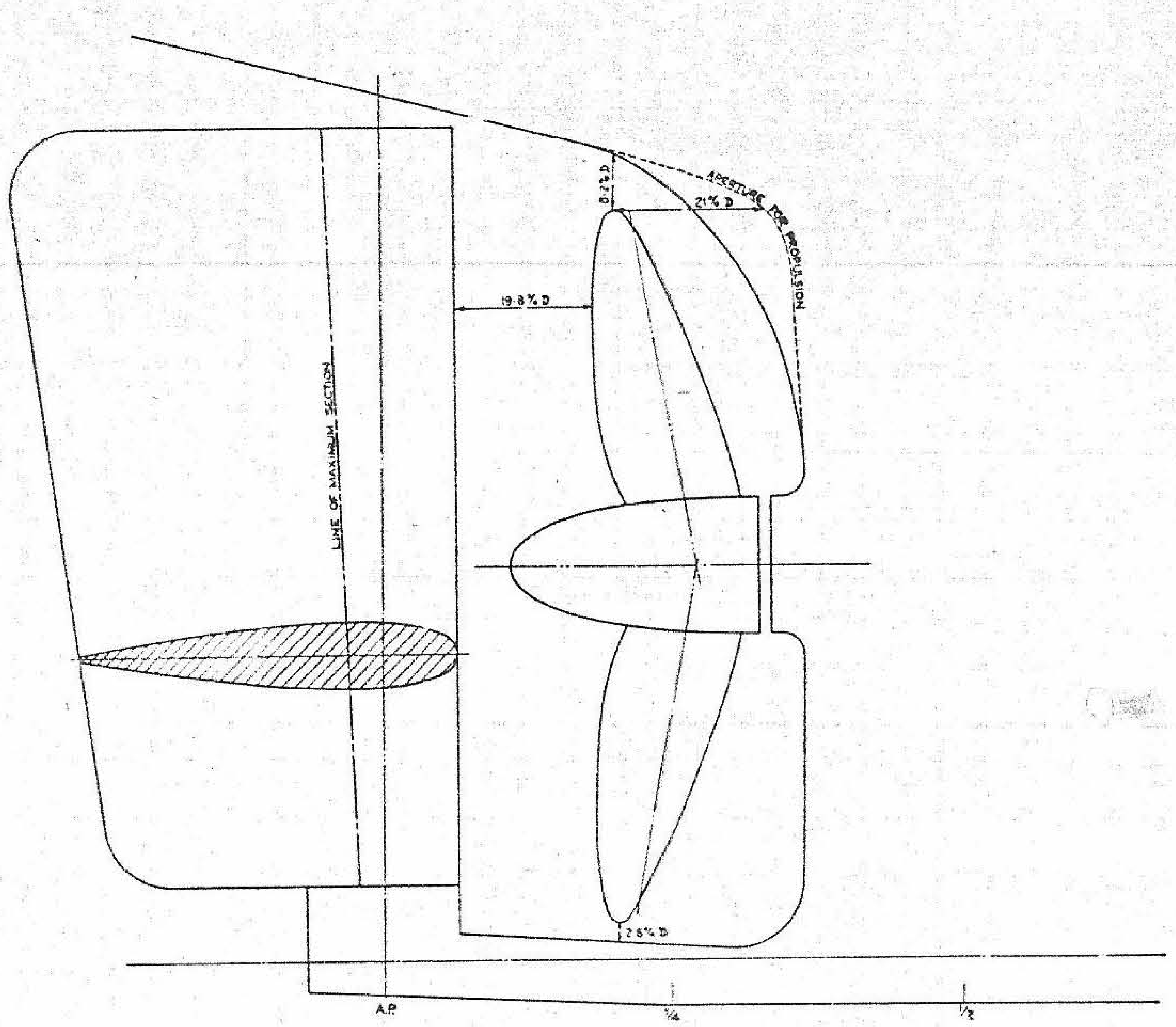


Fig. 24—Model No. 3 ~ Stern Arrangement

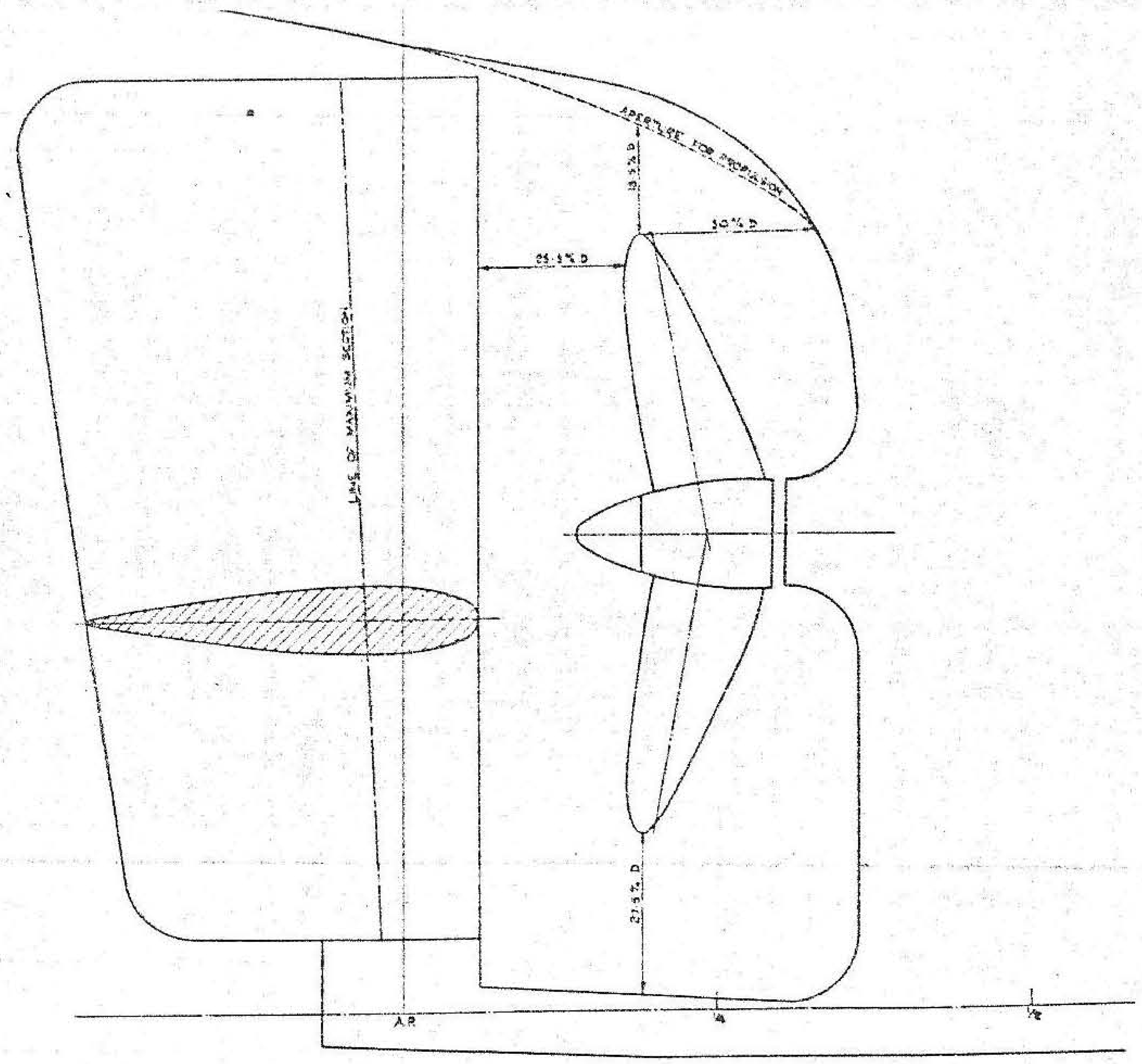


Fig. 22—Model No. 1 ~ Stern Arrangement

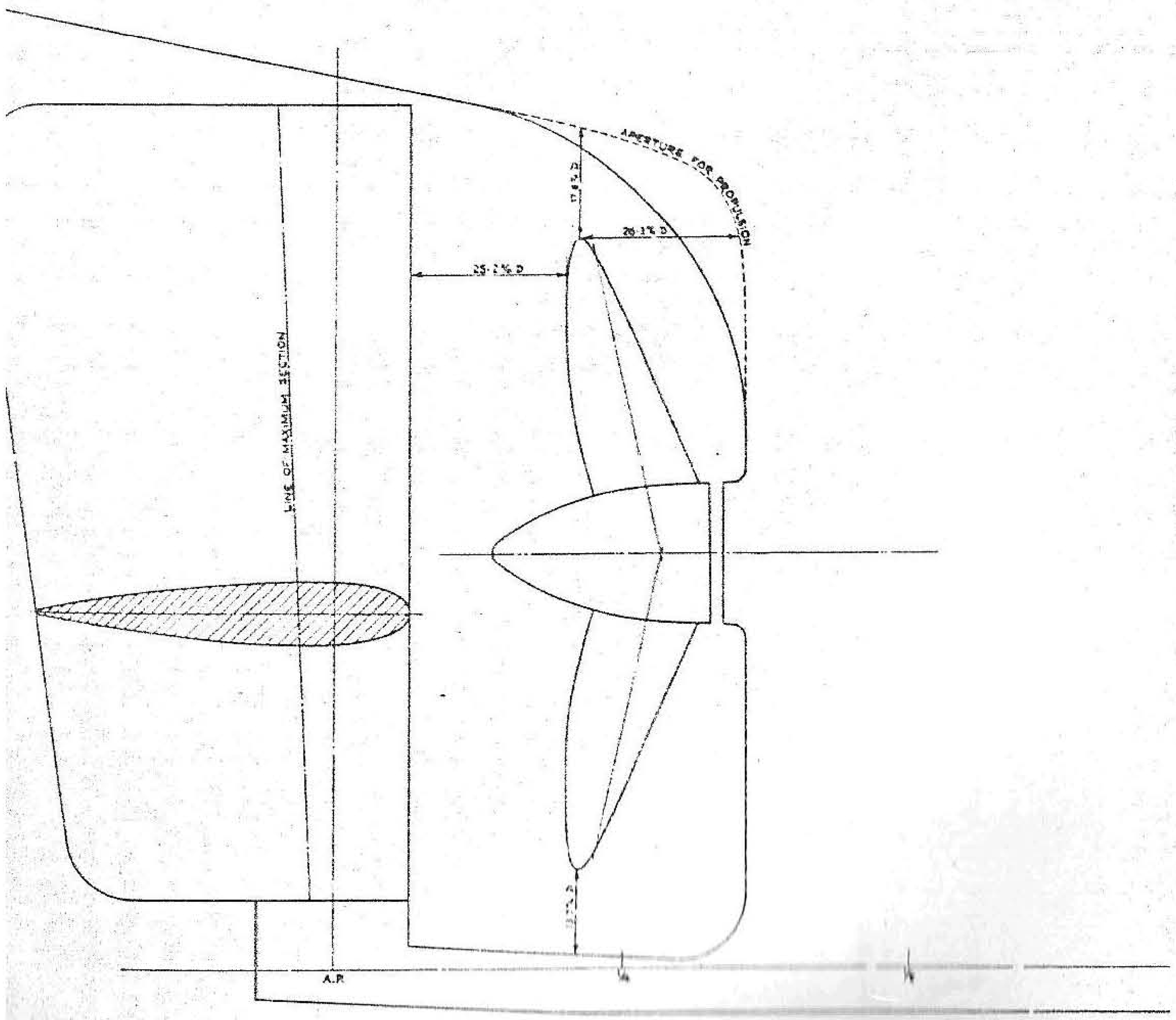


Fig. 23—Model No. 2 ~ Stern Arrangement

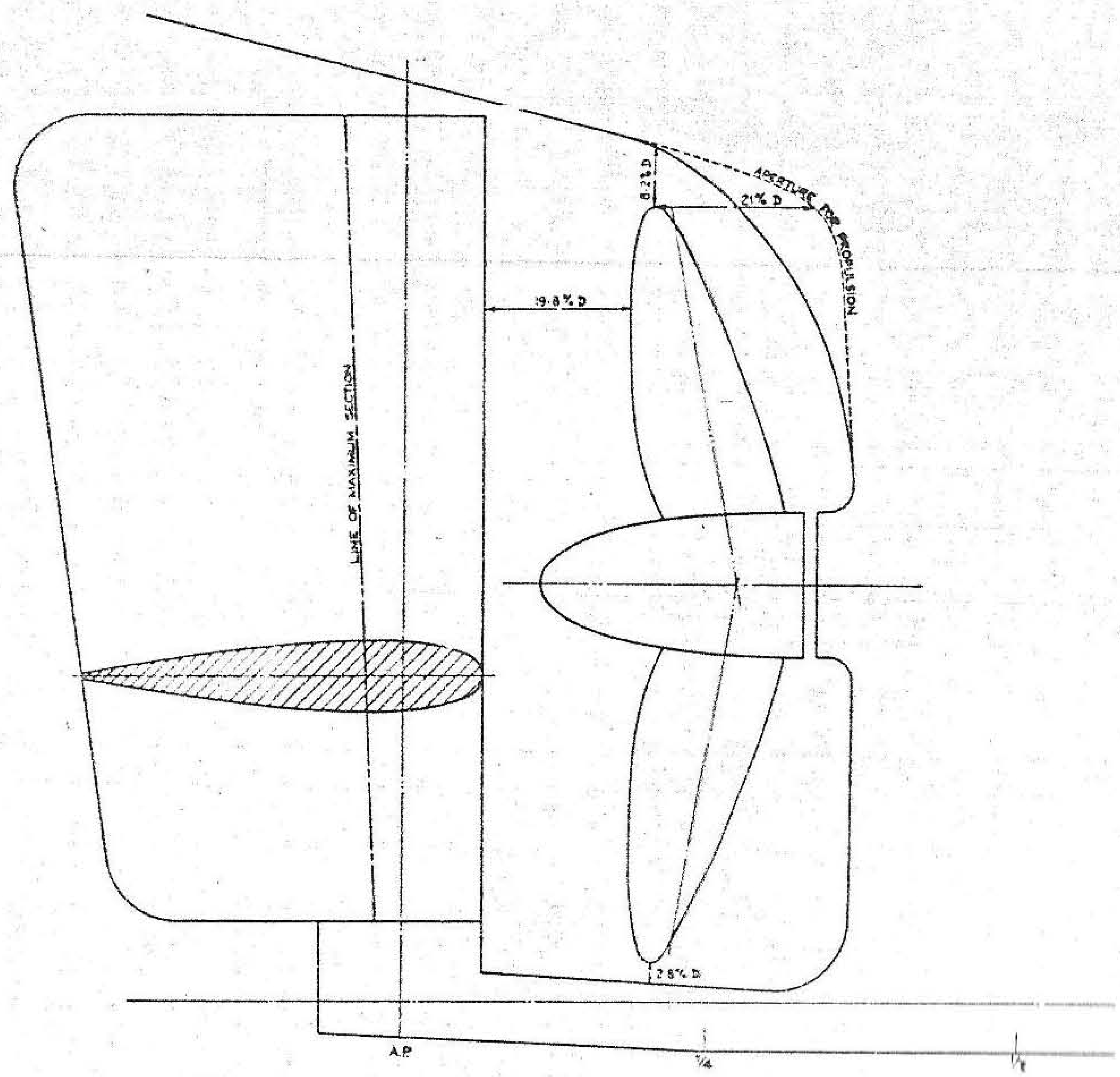


Fig. 24—Model No. 3 ~ Stern Arrangement

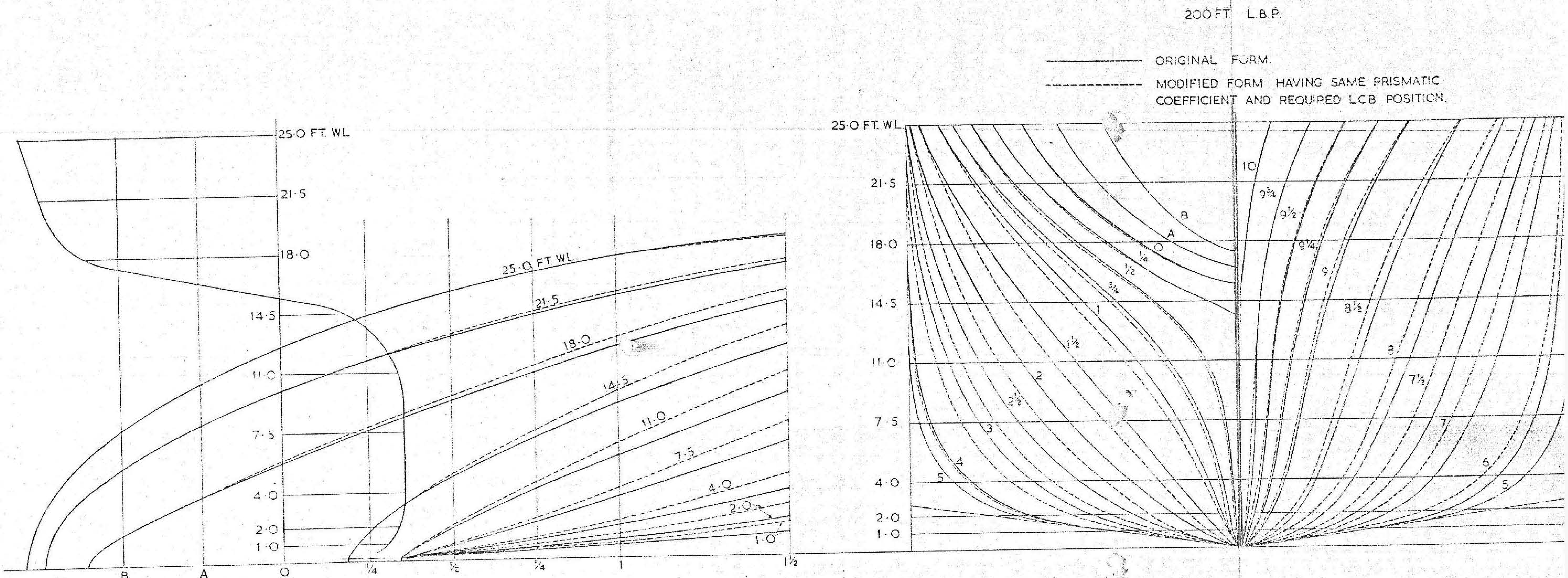
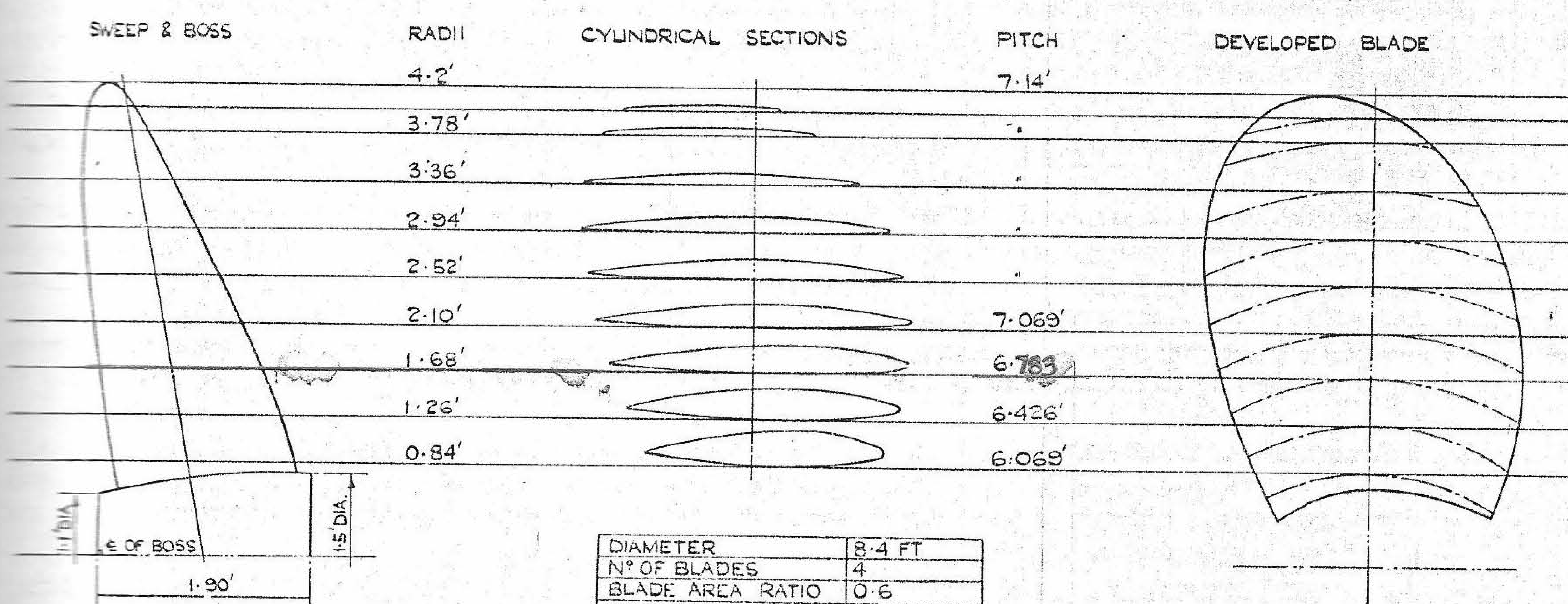


Fig. 20—N.P.L. Trawler Propulsion Data



DIAMETER	8·4 FT
Nº OF BLADES	4
BLADE AREA RATIO	0·6
MEAN FACE PITCH RATIO	0·837

Fig. 25—Propeller Details for Model No. 1

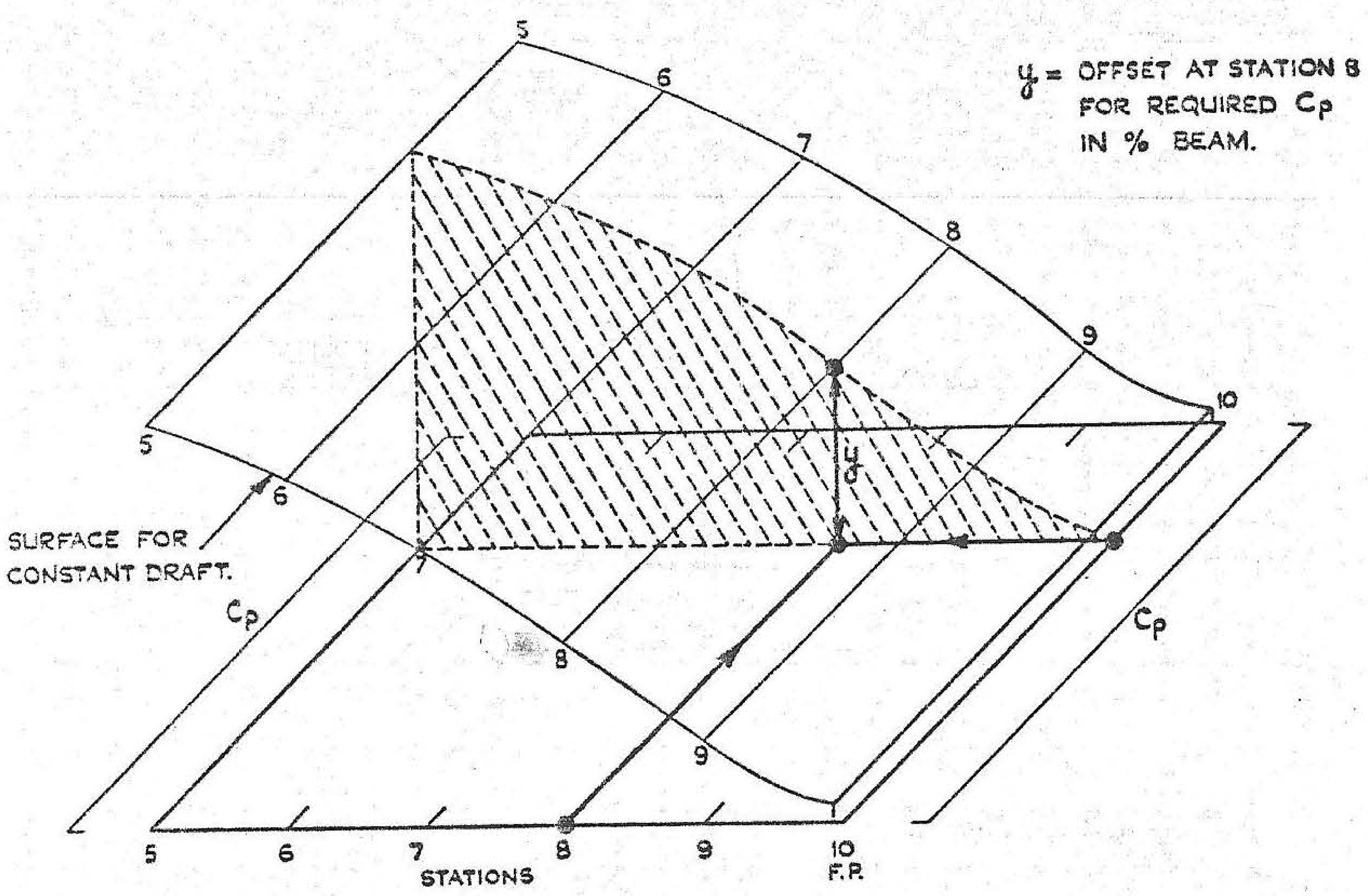


Fig. 17—Typical Graphical Derivation of Non-dimensional Offsets

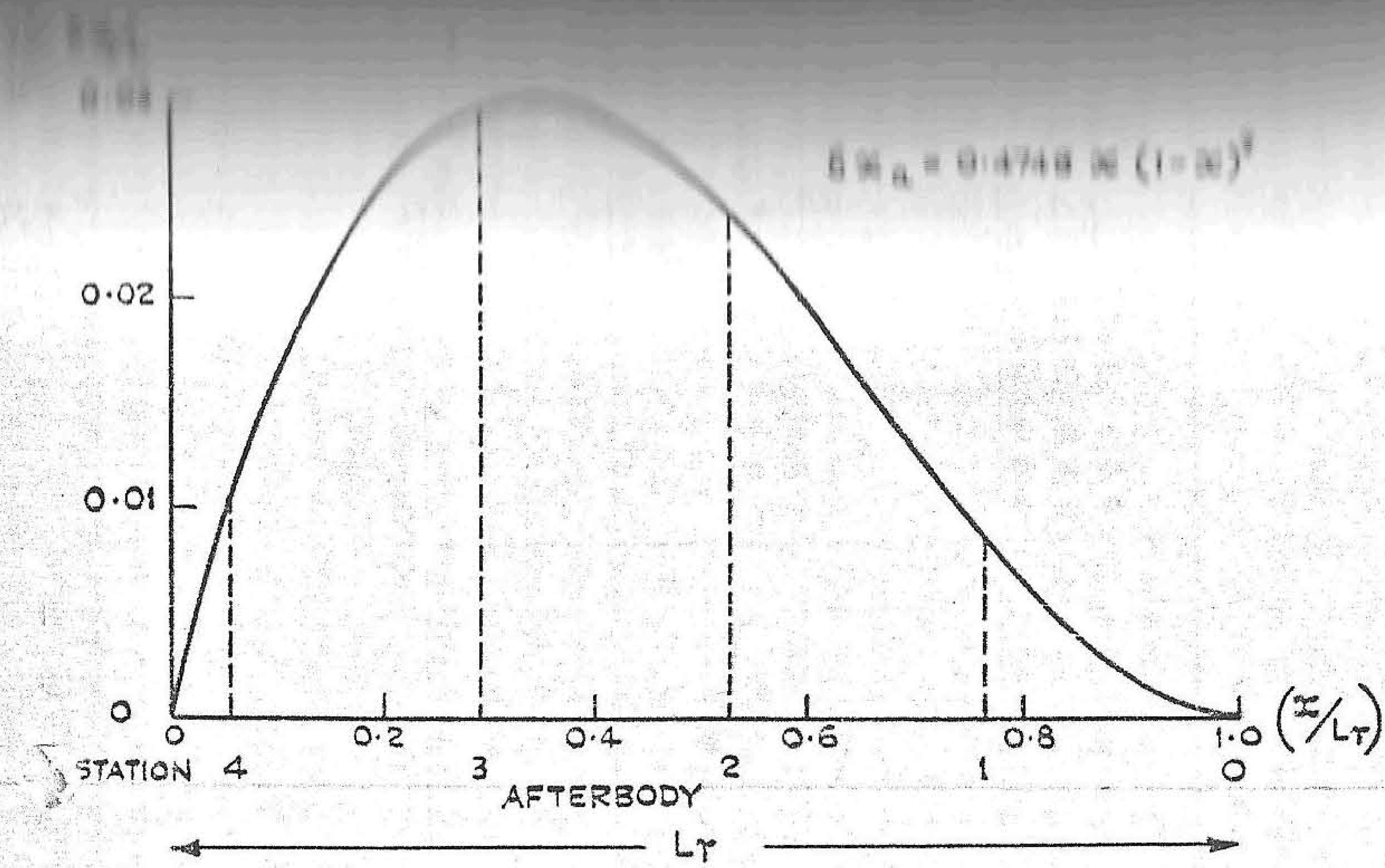


Fig. 18—Calculated Shifts of Section to give required LCB Position

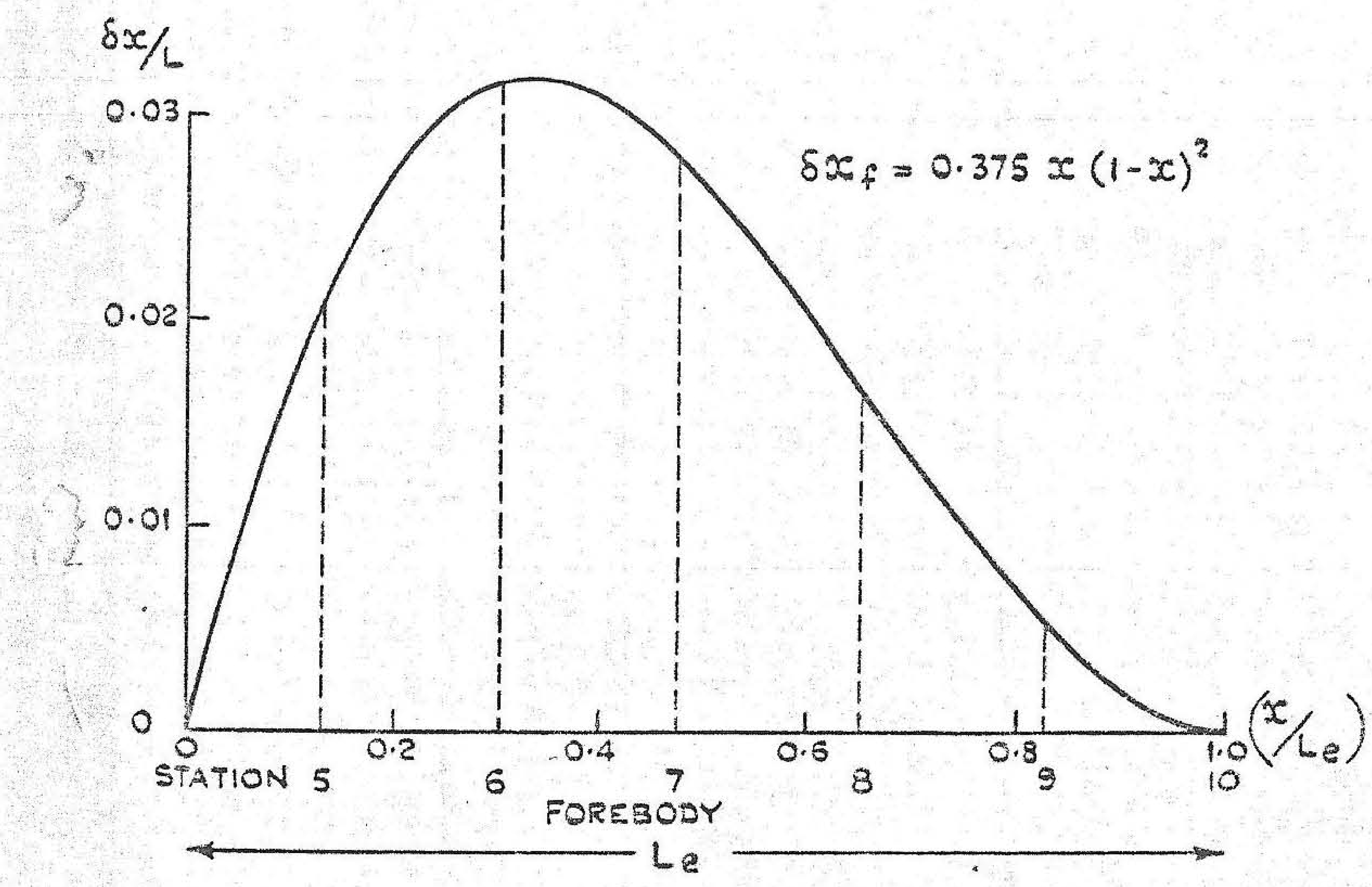
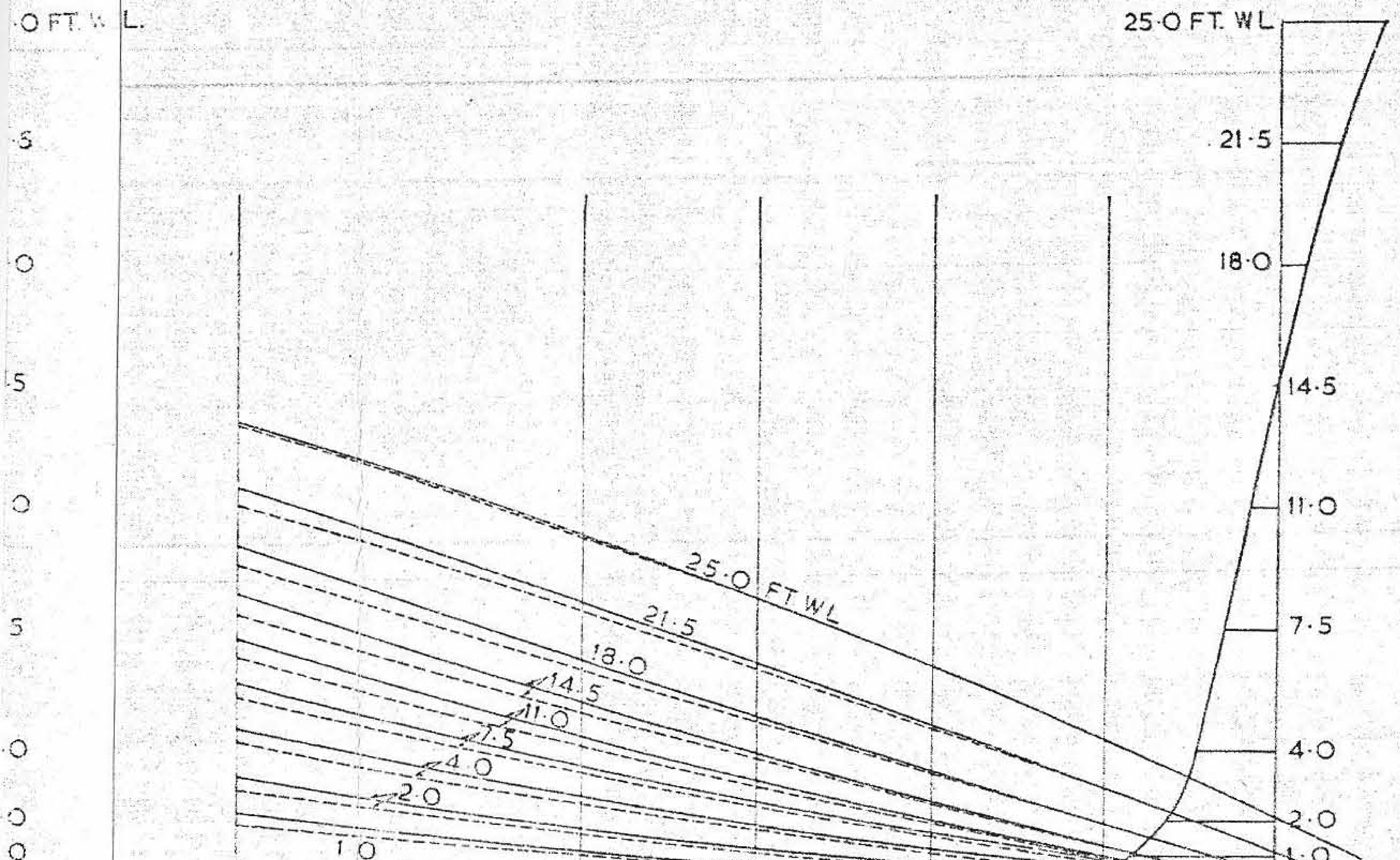


Fig. 19—Calculated Shifts of Sections to give required LCB Position


·O FT. W.L.
·5
·O
·5
·O
5
·O
·O
O
25·O FT. WL
21·5
18·O
14·5
11·O
7·5
4·O
2·O
1·O
25·O FT WL
21·5
18·O
14·5
11·O
7·5
4·O
2·O
1·O
8½
9
9¼
9½
9¾
10
F. P.

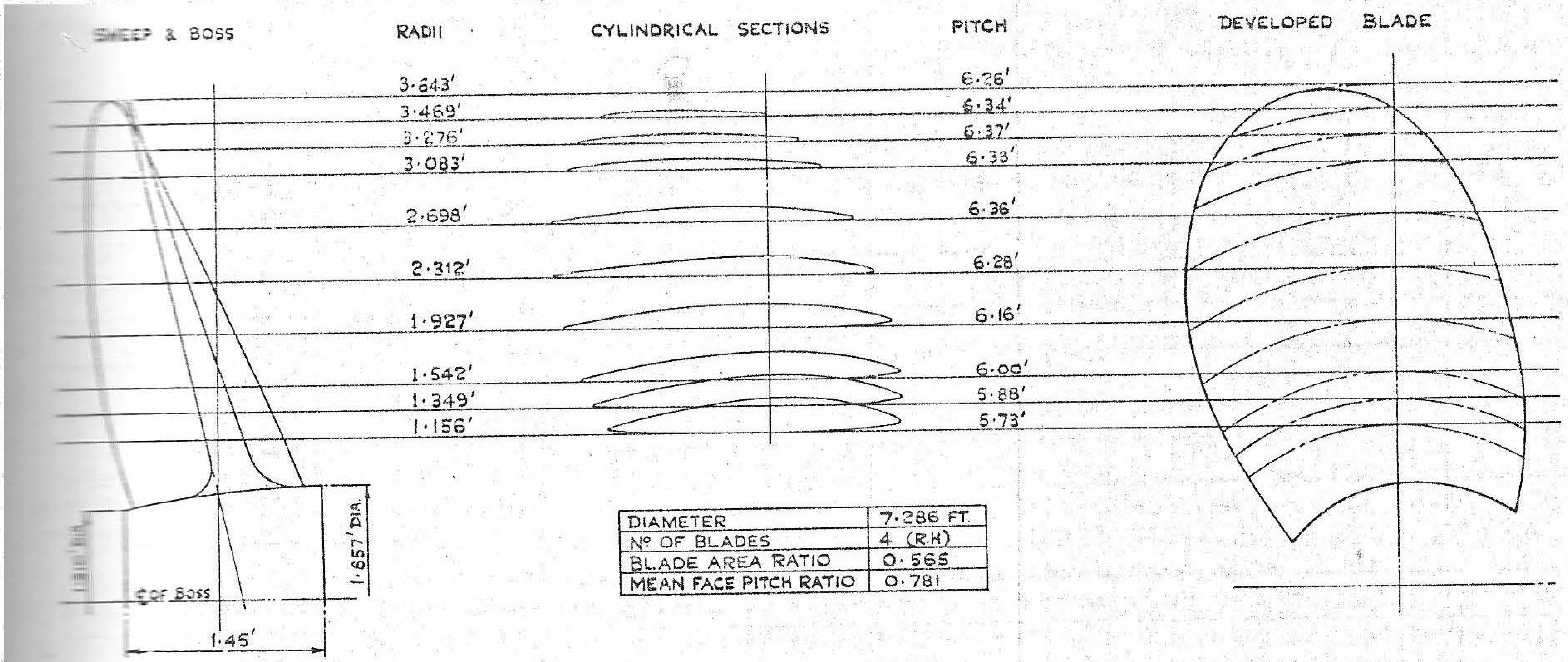


Fig. 26—Propeller Details for Model No. 2

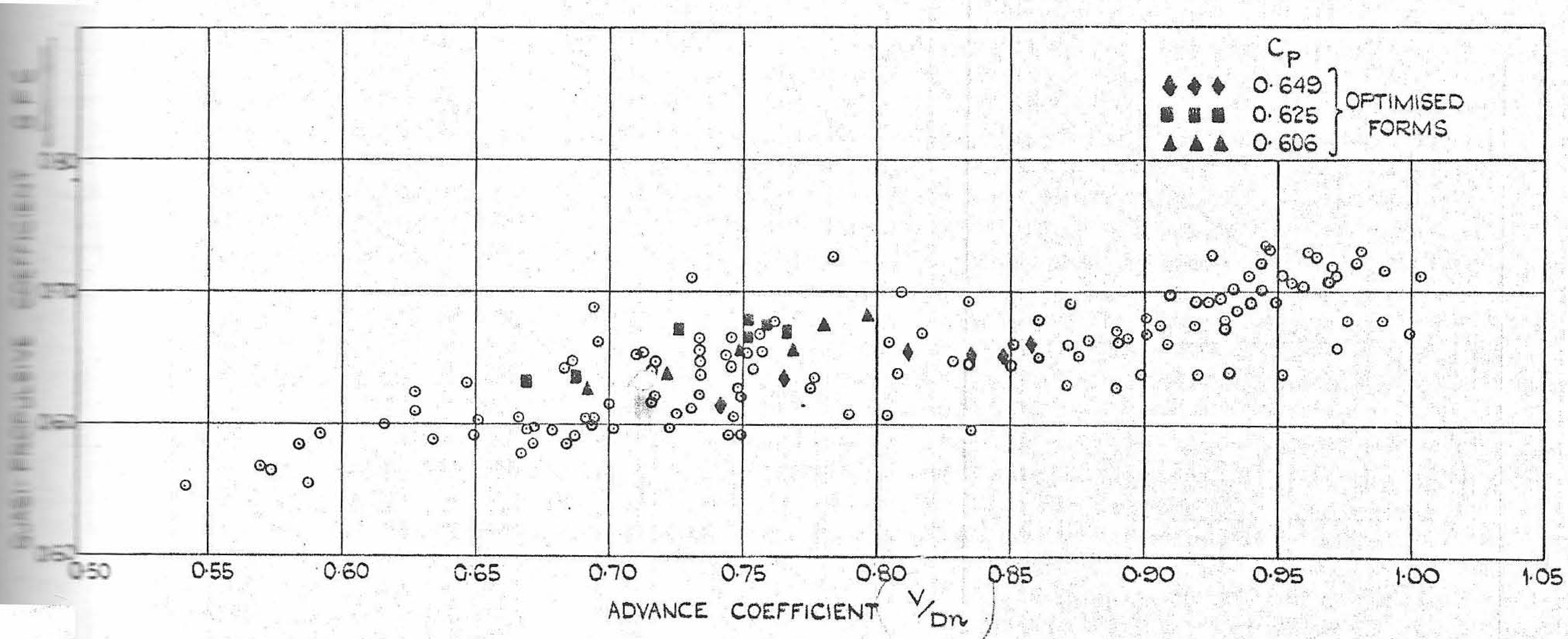


Fig. 21—N.P.L. Trawler Propulsion Data

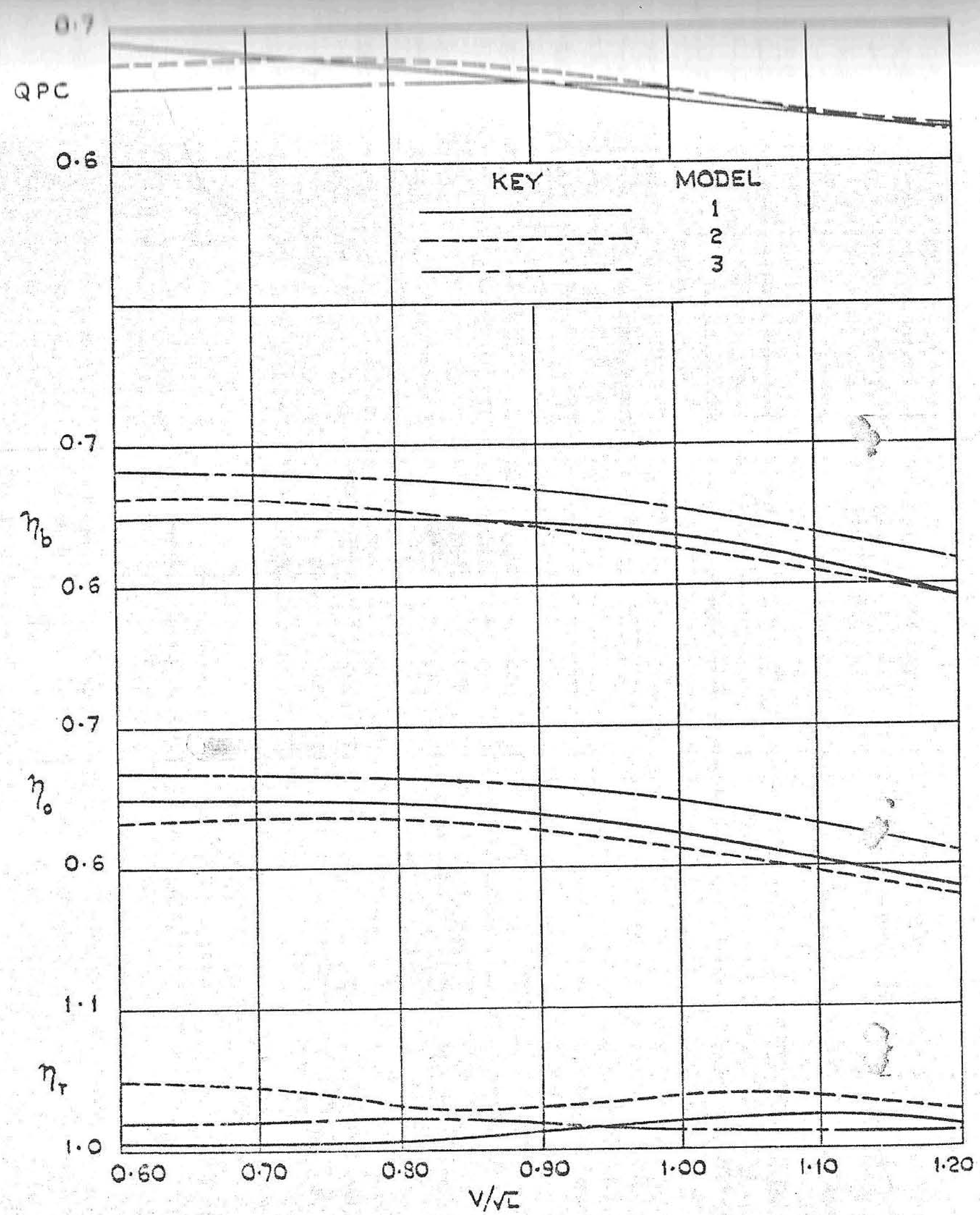


Fig. 28—Propulsive Coefficients

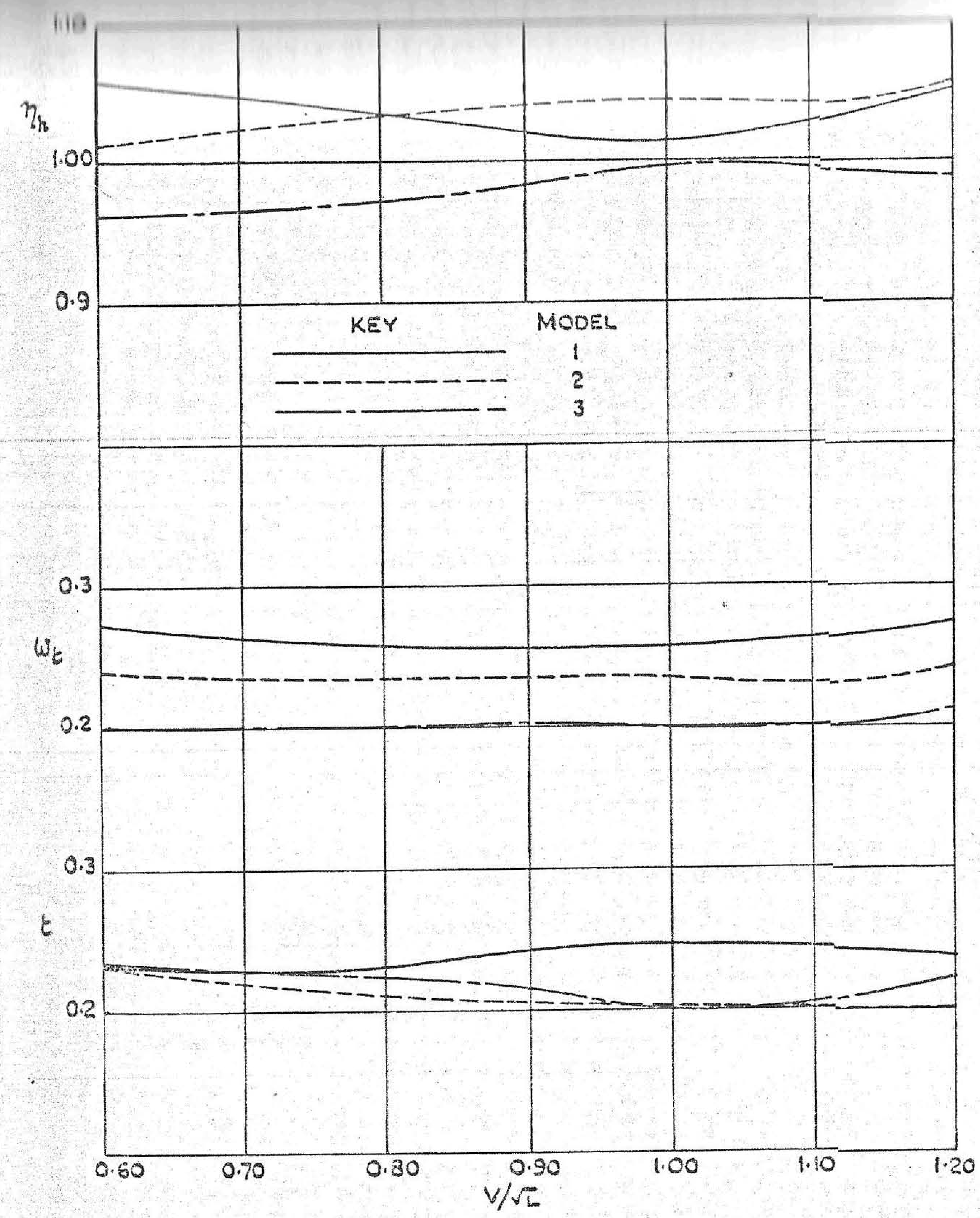


Fig. 29—Hull Factors

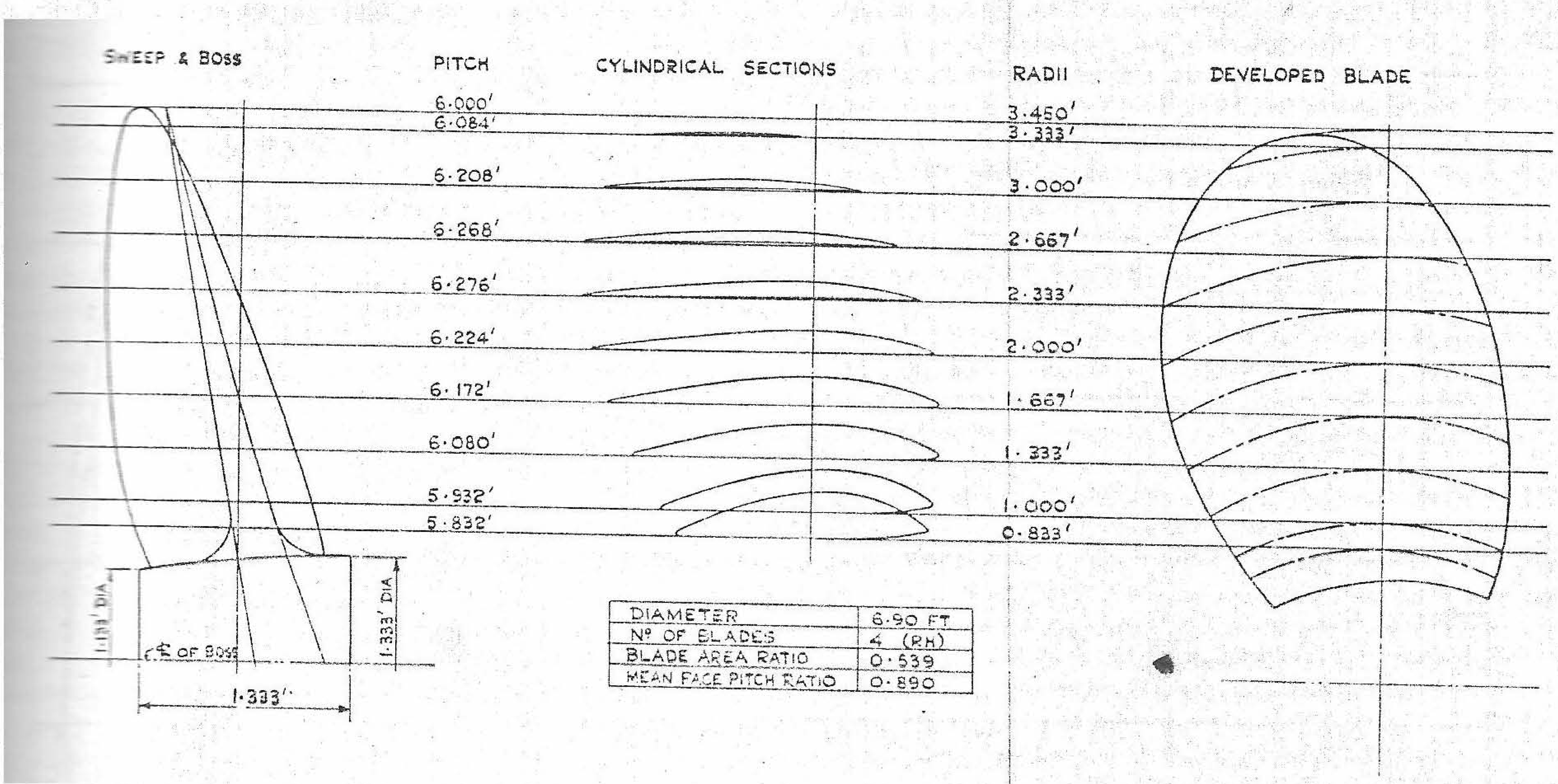


Fig. 27—Propeller Details for Model No. 3

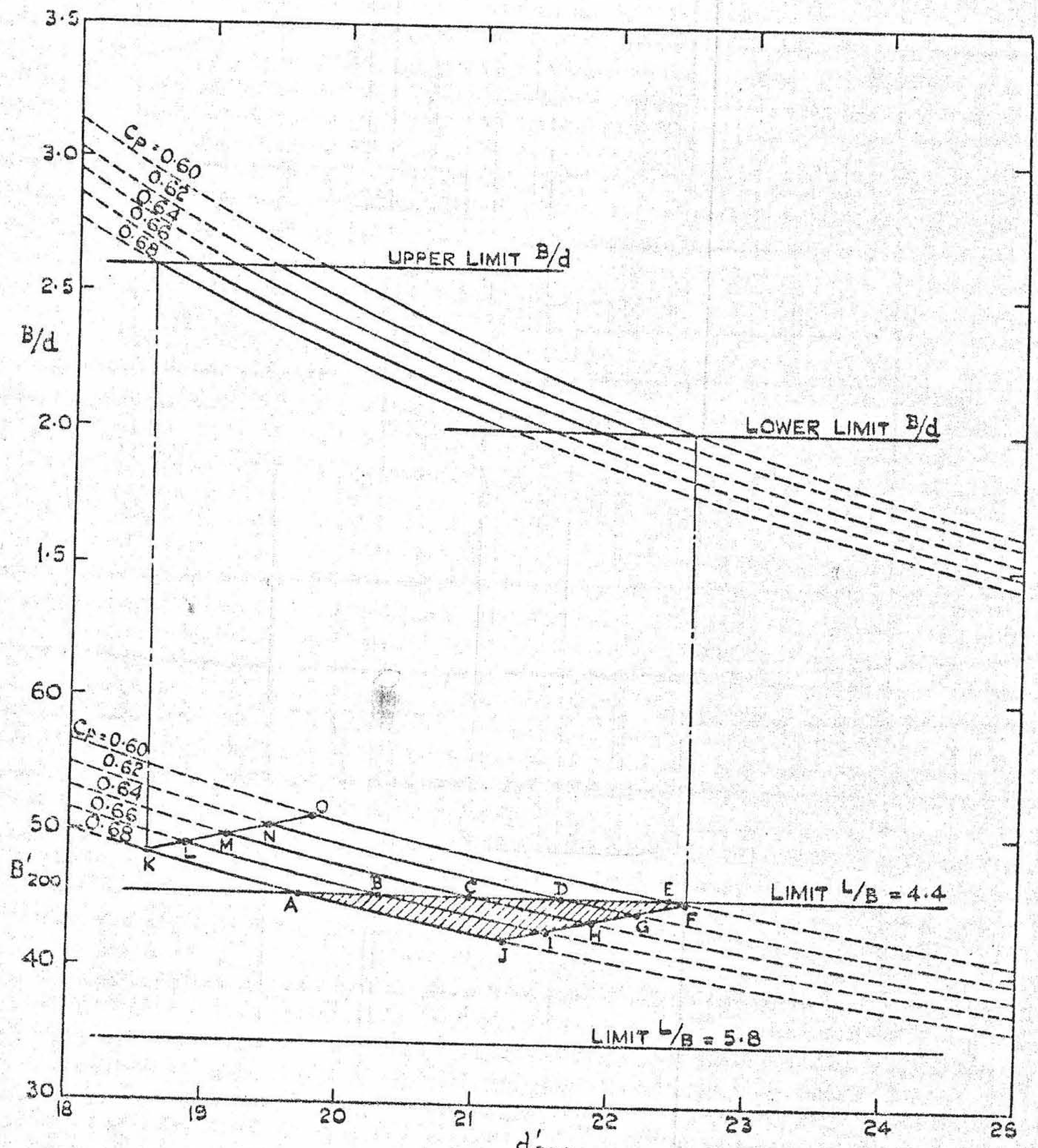


Fig. 30—Typical Diagram of Beam and Draught Variation giving Forms of Specified Displacement within Practical Ranges of Form Parameters