(昭和 38 年 11 月造船協会秋季講演会において講演)

The Design of Preliminary Ship-Lines from the Standard Series by a Digital Computer

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Summary

The purpose of the paper is to propose a design procedure for preliminary ship-lines using a high speed digital computer, which derives prismatic curve, offsets and hydrostatic data with which given characteristics are satisfied, from the standard series having block coefficient within the range from 0.65 to 0.85.

The method is outlined as follows :-

The data of the prismatic curves and lines' offsets of the standard series, which are provided beforehand as basic data, are loaded in the high speed digital computer (I.B.M. 7090 is used in this case) with the object program for the calculation.

By these data and object program, the computer calculates and prints out the prismatic curve, offsets and hydrostatic data having given characteristics such as principal dimensions, prismatic coefficient, midship section coefficient, longitudinal centre of buoyancy, sharpness of shoulder of prismatic curve, shape of section of body and sheer.

In the first part of the paper, the principles of the method are described. In the second part, the standard series of prismatic curves and lines are illustrated in detail. Finally an outline of the procedure of the calculations of prismatic curve, lines etc. is given, using I.B.M. 7090, and an example is also presented.

Abbreviations

L_{pp} : Length between perpendiculars
B : Breadth, moulded
D : Depth, moulded
d : Draft, moulded
AM : Area of midship section
C_B : Block coefficient
C_P : Prismatic coefficient
C_M : Midship section coefficient
C_W : Designed load waterline coefficient
l_{CB} : Longitudinal center of buoyancy
WL : Water line
LWL : Load water line
s : Sharpness of shoulder of prismatic curve, +1 sharp～−1 round
f : Degree of shape of section, +1U shape～−1 V shape

Suffixes F and A show forebody and afterbody respectively.

1 Introduction

When a merchant ship is initially designed, it recently becomes very important that preliminary lines having a good accuracy are rapidly drawn as a process for the purpose of the precise design.

原稿受付　昭和 38 年 6 月 20 日

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In the shipyard where the authors work, studies that the initial design of a ship may be rapidly carried out by I.B.M. 7090 are now proceeding, the paper is a part of the studies.

2 Principles of the Method

The design procedure is as follows :-

(1) Calculation of prismatic curve

The ordinate of the prismatic curve at each station is calculated from the standard series of prismatic curves by given C_P, l_{CB} and sharpnesses of fore and after shoulders of prismatic curve. If the ordinates of the prismatic curve are given, this stage is omitted and calculation may be commenced from next stage.

(2) Calculation of the offsets of lines

The offsets of the lines are calculated from the standrd series of lines by the sectional areas and the shapes of sections at stations.

(3) Calculation of the profiles of stem and stern

The profile of stem is calculated from the offsets of each water line at fore three stations, on the other hand the profile of stern is interpolated from among the standard series of the profiles of sterns.

(4) Calculation of deck side line and flare above LWL

By giving the sheer at deck side, the offsets of the deck side line are calculated and if a wider deck area is required the flare above LWL is adjusted.

(5) Calculation of hydrostatic table

By the offsets calculated in stages from (1) to (4), the hydrostatic table is computed and in the near future other data required in the stage of initial design will become serially available.

3 Standard Series of Lines

The standard ship-lines are drawn for merchant ships of ordinary types. The authors have selected some ship forms of the best qualities in resistance and propulsion from many ships built in their shipyard and some series models in published reports[2)~7)] from which five standard ship lines are derived, C_BS ranging from 0.65 to 0.85 at intervals of 0.05.

The relations among C_B, C_M and l_{CB} of the five lines, shown in Table 1, seem to be reasonable, which are determined by the data of many actual ships.

Table 1. Relations among C_B C_M, l_{CB}, and particulars of midship section (unit length : draft=1)

C_B	0.65	0.70	0.75	0.80	0.85
l_{CB} (% of L_{pp})	1.25	0.0	−1.0	−1.6	−1.8
C_M	0.984	0.986	0.988	0.990	0.992
Half breadth of keel	0.08	0.08	0.08	0.08	0 08
Radius of bilge circle	0.2334	0.2195	0.2047	0.1887	0.1716
Rise of floor	0.014	0.012	0.010	0.008	0.006

3.1 Standard series of prismatic curves

The sharpness of the prismatic curves of the five lines is medium. Prismatic curves of sharp and round shoulders are derived by keeping the areas of the original prismatic curves unchanged. Some prismatic curves[1)2)8)] are referred for the determination of the sharpness.

Furthermore, four prismatic curves, C_Bs of which range from 0.675 to 0.825 at intervals of 0.05, are added to each sharpness, in order to interpolate more exactly a required prismatic curve. These prismatic curves are properly faired as to change smoothly from 0.65 in C_B to 0.85.

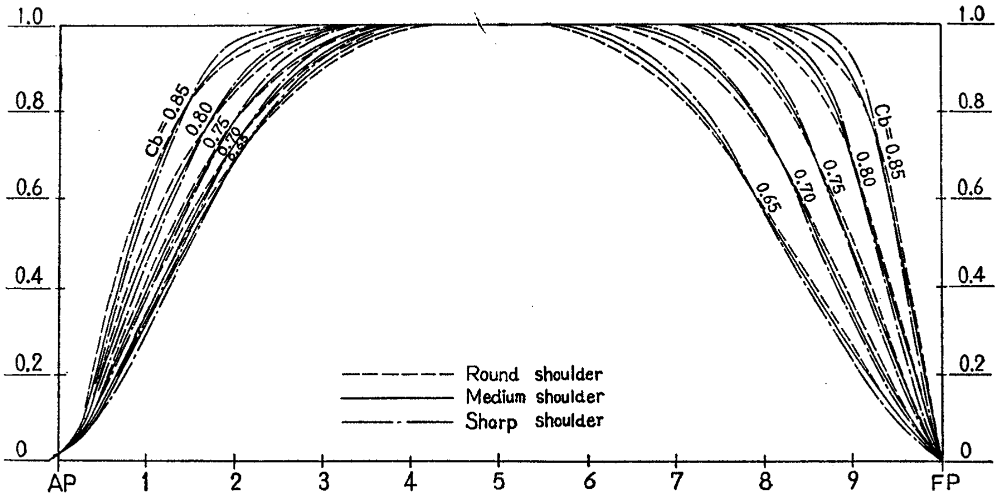

Fig. 1 Standard prismatic curves

3.2 Standard series of ship-lines

The above-mentioned five standard ship-lines have medium shapes of sections. In addition to these, two standard ship-lines which have *U* and *V* shapes of sections are drawn without changing the sectional area of each station of the original standard ship-lines. Consequently, the drawn lines amount to 15 in all, some of which are illustrated in Fig. 2. The shapes of sections are related to C_W as

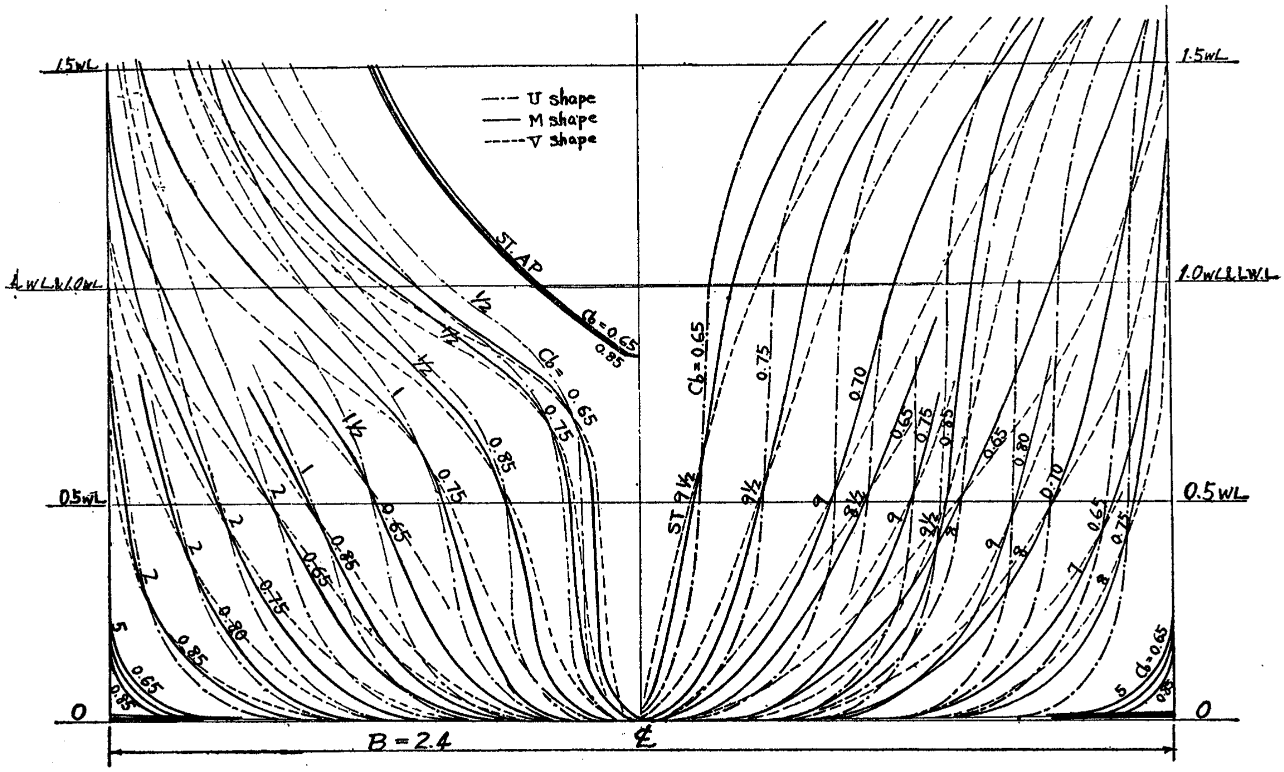

Fig. 2 Standard body plans

shown in Table 2.

The relation between C_W and C_B for the medium shape series is the mean line of many data of actual ships, such relations for the *U* and *V* shape series are respectively lower and upper limits of C_W against C_B.

The standard ship lines are drawn at 2.4 of B/d, which is in the middle of B/ds of many merchant ships.

The particulars of the midship sections, Table 1, and the profiles of the stems and sterns, Fig. 3, are changed systematically in accordance with the change of C_B.

Table 2. Relation between C_W and shape of section

	C_B	0.65	0.70	0.75	0.80	0.85
C_W	U-shape of section	0.738	0.778	0.818	0.858	0.898
	Medium shape of section	0.786	0.817	0.848	0.879	0.910
	V-shape of section	0.822	0.847	0.872	0.897	0.922

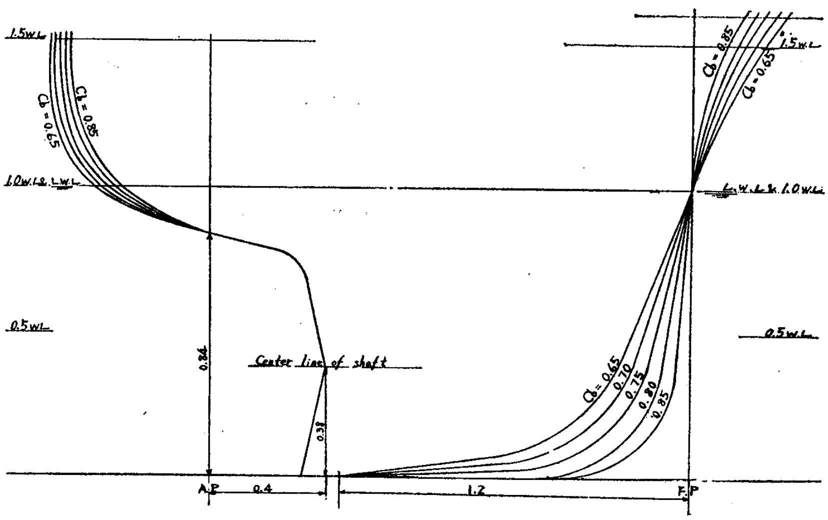

Fig. 3 Profiles of stems and sterns

4 Calculations of Lines

Input Data

(1) Basic Input Data: These input data are given in Section 3.

(2) Input Data of each actual ship: Principal dimensions, C_P, l_{CB}, C_M, s, f, sheer and a few data.

Calculations

The co-ordinates of ship are chosen as shown in Fig. 4, and the flow of these calculations which is so-called Flow Chart is simply shown in Fig. 5.

4.1 Calculation of prismatic curve

From among the prismatic curves given as basic data, illustrated in Fig. 1, the fore and after prismatic curves having required "s" are computed separately for each C_B in Table 1 by the linear interpolation, that is

$$P(Z) = P_M(Z) + (P_{S}/_{R}(Z) - P_M(Z)) \cdot |s| \qquad (1)$$

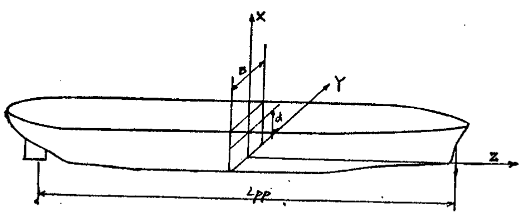

Fig. 4 Co-ordinates of a ship

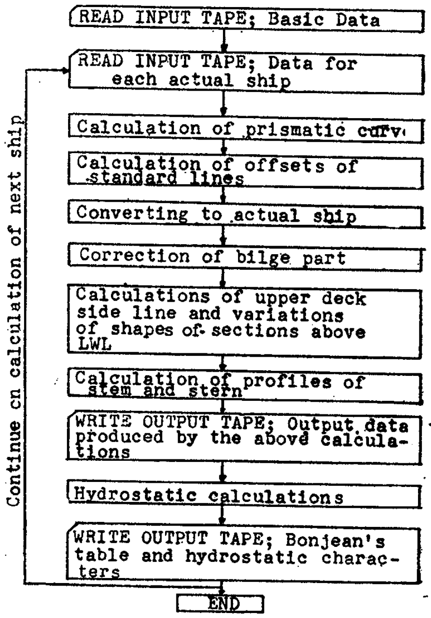

Fig. 5 Flow chart

Where $P(Z)=$(Sectional area below LWL at $Z)/AM$
and suffixes S, M and R show the sharp, medium
and round shoulders respectively.

After $C_{PF/A}$ and $l_{CBF/A}$ of these curves are calculated, the prismatic curve having given C_P and l_{CB} is computed by the following method.

$$C_P = C_{PA} + C_{PF} \qquad (2)$$

$$C_P \cdot l_{CB} = C_{PA} \cdot l_{CBA} + C_{PF} \cdot l_{CBF} \qquad (3)$$

The equations (2) and (3) are well-known relationship.

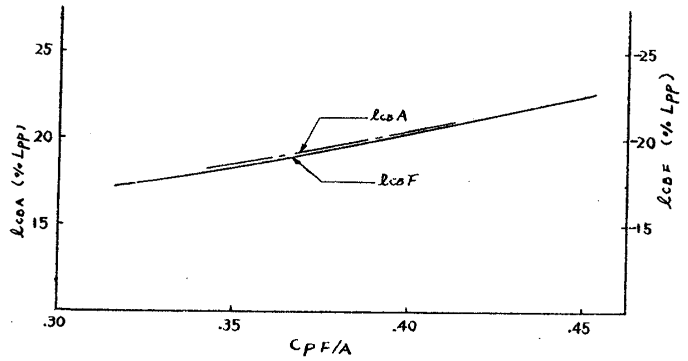

Fig. 6 Relationship between $C_{PF/A}$ and $l_{CBF/A}$ of prismatic curves having medium sharpness of shoulder

At this point, it is assumed that the following equations are available in the small range of $C_{PF/A}$.

$$l_{CBA} = F(C_{PA}) = A_1 C_{PA}^2 + B_1 C_{PA} + C_1 \qquad (4)$$

$$l_{CBF} = G(C_{PF}) = A_2 C_{PF}^2 + B_2 C_{PF} + C_2 \qquad (5)$$

From eqs. (3), (4) and (5), the following equation is obtained.

$$(A_1-A_2)C_{PA}^3+(B_1+3A_2C_p+B_2)C_{PA}^2+(C_1-3A_2\cdot C_P^2-2B_2\cdot C_P-C_2)\cdot C_{PA}+(C_P^3\cdot A_2+C_P^2\cdot B_2 +C_P\cdot C_2-C_P\cdot l_{CB})=0 \qquad (6)$$

The required C_{PA} is obtained as a root of this cubic equation and C_{PF} from eq. (2).

Finally the required prismatic curve having the value of $C_{P\,F/A}$ obtained in above relations is computed by the parabolic interpolation from among the series of the prismatic curves having required "s", which are obtained by the process of eq. (1), and at the same time l_{CB} and C_P of this curve are computed.

In a result of these calculations if the absolute errors are less than 10^{-4} corresponding to C_P and $5\times10^{-4}\times L_{PP}$ to l_{CB}, the authors consider that the obtained prismatic curve is quite satisfied with the given characteristics.

In case of the accuracy being insufficient, the result is modified by means of small correction on $C_{PF/A}$ using the derivative, $\dfrac{\partial P(Z)}{\partial C_{P\,F/A}}$ and keeping the relationships of eqs. (2) and (3), and this modification is continued until the conditions of the above mentioned allowances of the absolute errors are satisfied with.

4·2 Calculation of the offsets of lines

After the sectional area below LWL at Z is computed from the prismatic curve obtained by 4.1, three kinds *i.e.* U, M and V types of the primary offsets (refer to 4.3) having the required C_P and l_{CB} are computed by the linear interpolation from among the sectional areas of basic data by using the offsets of the standard lines given as basic data in Section 3. That is

$$Y(X,Z)=\frac{A(Z)-An\text{-}1\ (Z)}{An(Z)-An\text{-}1\ (Z)}\ (Yn(X,Z)-Yn\text{-}1(X,Z))+Yn\text{-}1(X,Z) \qquad (7)$$

Where $A(Z)=C_M\times B\times d\times$ (ordinate of the obtained prismatic curve)

$An(Z)=A(Z)$ given for each prismatic curves of basic data corresponding to C_B

Then the primary offsets having required f are obtained by the linear interpolation from among the above mentioned offsets having *U*, *M* and *V* shapes of sections. In this time, the sectional area will be kept constant by reason of the application of linear interpolation.

The shapes of sections above *LWL* are obtained similarly.

4.3 Converting to actual ship

The ratio of the principal dimensions of primary lines is as follows.

$L_{PP}:B:d=16:2.4:1$

Therefore, the ordinates of actual ship can be obtained as follows.

Y actual$=Y$ primary$\times(B/2.4)$, X actual$=X$ primary$\times(d/1)$, Z actual$=Z$ primary$\times(L_{PP}/16)$

4.4 Correction of bilge part

On converting primary offsets to actual ones the bilge part will not become circle. Therefore, the bilge part is corrected to circle without change of sectional area and also for keeping the fairness of water line the adjacent stations of both sides of parallel body are corrected.

4.5 Calculation of upper deck side line and modification on the shape of section above LWL

The following shapes of sheer are provided.

1) Standard sheer prescribed in rule
2) Parabolic sheer
3) Straight line sheer
4) No sheer

In calculation, by the parabolic interpolation from among the offsets of half breadth, the height and half breadth of upper deck side line at each station can be obtained by only indicating the shape of sheer when standard sheer or no sheer is applied and by additionaly giving the starting point of sheer and the sheers at *FP* and *AP* when parabolic or straight line sheer is applied.

On the other hand, for the purpose of getting some required deck area without change of the existing sectional area below *LWL*, the variated shape of upper deck side line and the shapes of sections above *LWL* can be calculated by the ratios of the expected half breadths at *AP* and 9 1/2 stations to the original ones which are gained in 4.2.

That is

a) equation of upper deck side line

$$yu(Z)=Yu(Z)+\alpha_{F/A}\ (1-Yu(Z)/B/2)\cdot Yu(Z) \qquad (8)$$

b) equation of the shape of section above *LWL*

$$y(X,Z)=(Y(X,Z)-Y(d,Z))\times\left\{1+\frac{y_u(Z)-Yu(Z)}{Yu(Z)-Y(d,Z)}\left(\frac{X-d}{Xu-d}\right)^{\frac{1}{2}}\right\}+Y(d,Z) \qquad (9)$$

Where $\alpha_{F/A}=$ (The increasing ratio of half breadth at *st.* $9^1/_2/AP)/(1-Yu(Z=st.\ 9^1/_2/AP)/B/_2)$

$y=$ variated half breadth

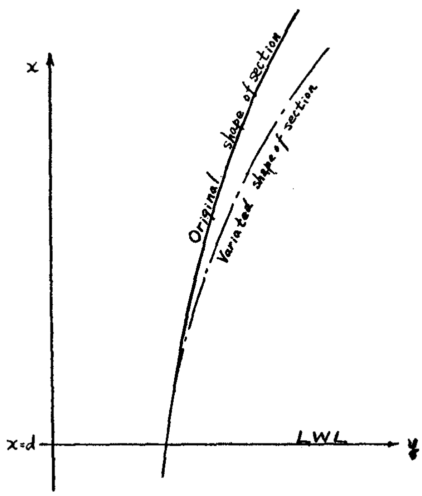

Fig. 7 Variating shape of section above *LWL*

Y=original half breadth

Suffix u shows upper deck side line

4.6 Calculation of the profiles of stem and stern

The stern profile is simply obtained by the linear interpolation from among basic data and then by multiplying the increasing ratio between the primary offsets and the final ones for the actual ship. On the other hand, the stem profile is obtained in a different way described as follows. The profile above LWL is obtained as a function of the inclination of raked line of stem and the cut up line is

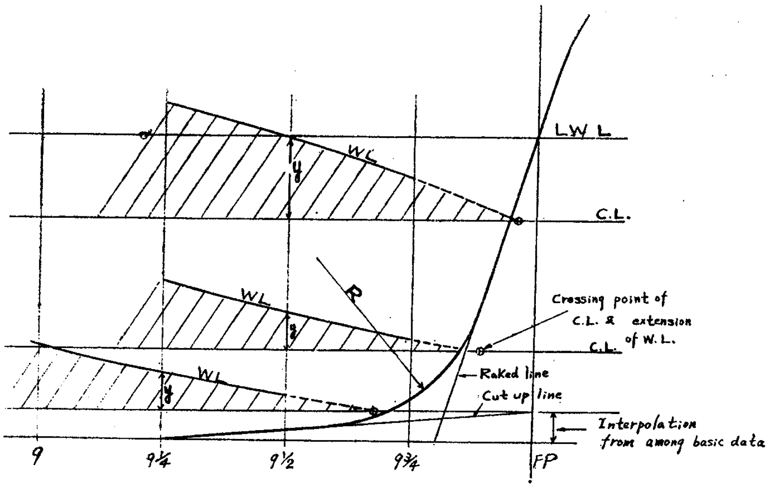

Fig. 8 Illustration of calculation of profile of stem

computed by the linear interpolation from among basic data using the kind of the shapes of sections at fore stations and given C_B as parameters, while the raked line under LWL and stem circle are calculated by weighed or/and simple least square approximation among the cross points of center plane of ship and the mathematically assumed extensions of water lines.

4.7 Hydrostatic calculations

By using the offsets of the ship calculated by the above mentioned method, bonjean's table and some hydrostatic characters are calculated serially.

5 Example

The input data and the results of an example by I.B.M. 7090 are shown in Table 3 and Figs. 9 at 11 inclusive.

Table 3. Input data except basic ones

L_{pp}	223,000 m	C_p	.8325	"s" of Fore body	Medium
B	32,150 m	l_{cb}	-1.8% L_{pp}	"s" of After body	〃
D	16,800 m	C_M	.9922	"f" of Fore body	Medium
d	12,345 m	sheer	no sheer	"f" of After body	〃

It is clear from these results that the lines calculated by the above mentioned method are considerably reasonable and applicable.

The absolute errors in this example are 5×10^{-5} to C_P and $5\times10^{-5}\times L_{PP}$ to l_{CB}, which errors are negligible in practical meaning.

The required computing time by I.B.M. 7090 is only about 0.5/100 hour per one ship.

(A part of output data, *i.e.*bonjean's table, hydrostatic characters and variations of shapes of sections is omitted from the example in this paper.)

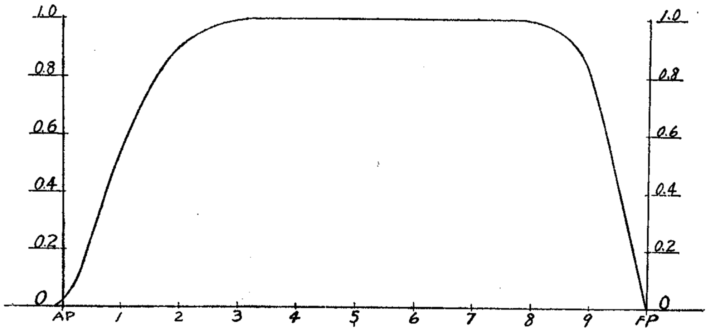

Fig. 9 Prismatic curve

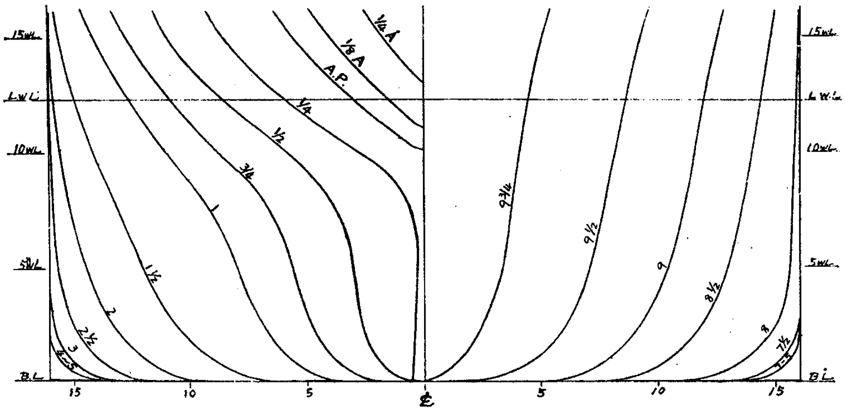

Fig. 10 Body plan

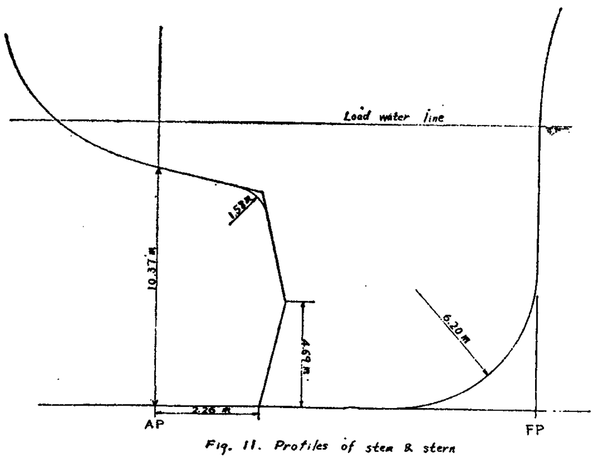

Fig. 11 Profiles of stem and stern

6 Conclusion

The standard series of prismatic curves and lines are drawn and a method which calculates preliminary lines having given hull form characteristics by means of interpolating the standard series using a digital computer is proposed.

Lines by the design procedure presented in the paper are sufficiently precise and quite rapidly produced as preliminary lines in the stage of the initial design of a ordinary merchant ship. If the standard series of prismatic curves and lines are expanded from ordinary type into special type, the design procedure may be applied to a special type ship.

It will not be so long in future that other data than the hydrostatic characters which are serially calculated from the offsets by a digital computer may be computed succeeding to those and that the initial design of a ship may be almost calculated only by writing necessary data in the input data sheets using a digital computer.

7 Acknowledgment

The authors wish to express their thanks to Mr. Akira Yamagata (Vice Manager of Hull Designing Department, Mitsubishi Yokohama Shipyard) and Mr. Nobuaki Akatsu (Assit. Chief of Planning Section) and Mr. Kenichi Terada (Head of Planning Branch) for their kind directions and suggestions.

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